UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

PROGRAMA DE DOCTORADO DE
SANIDAD ANIMAL Y SEGURIDAD ALIMENTARIA

Politraumatismo en la Paciente Embarazada: Descripción de los Cambios Fisiológicos y Anatómicos, Patofisiología de los Traumatismos y Violencia Interpersonal

Doctorando: Patrizio Petrone

Las Palmas de Gran Canaria - Febrero de 2019

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El Doctorando: Patrizio Petrone

El Director: José Ceballos Esparragón

Las Palmas de Gran Canaria - Febrero de 2019

JOSÉ CEBALLOS ESPARRAGÓN, DOCTOR EN MEDICINA POR LA UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA.

INFORMA:

Que la presente tesis doctoral titulada "Politraumatismo en la Paciente Embarazada: Descripción de los Cambios Fisiológicos y Anatómicos, Patofisiología de los Traumatismos y Violencia Interpersonal" ha sido realizada por D. Patrizio Petrone, licenciado en Medicina, bajo mi dirección y asesoramiento, por lo que considero que reúne las condiciones y calidad científica para optar al grado de Doctor.

Y para que conste a los efectos oportunos, firmo la presente en Las Palmas, a ocho de febrero de dos mil diecinueve.

Fdo.: JOSÉ CEBALLOS ESPARRAGÓN

Dedicatorias

A mis padres, Giovanni Petrone y Michelina Stella,
quienes me enseñaron el significado del espíritu de sacrificio.

A Marcela,
por su infinita paciencia y apoyo incondicional,
fuente de alegría y entereza en los momentos más difíciles.

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"La ciencia no está hecha para ensanchar el campo del conocimiento,

sino para estrechar el camino del error."

Galileo

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A. Tesis por Compendio de Publicaciones

La presente tesis doctoral, autorizada por el Director de Tesis, el Tutor y el Programa de Doctorado de la Universidad de Las Palmas de Gran Canaria (ULPGC), fue realizada por el Doctorando quien opta a la Mención de Doctorado Internacional y se presenta en la modalidad de Tesis por Compendio de Publicaciones. La normativa estipula *"un mínimo de tres publicaciones, con unidad temática, indexadas en el Journal Citation Reports, Arts and Humanities Citation Index o equivalentes, de las que el doctorando sea el primer autor o autor principal."* La tesis se encuentra basada en cuatro trabajos publicados en revistas científicas de reconocido prestigio que constituyen el cuerpo de la misma, cuyos nombres, abreviaturas y factor de impacto se encuentran detallados en el Apéndice 1. A continuación se encuentran las referencias completas de los artículos:

I. **Petrone P**, Asensio JA. (2006). Trauma in pregnancy: assessment and treatment. *Scandinavian Journal of Surgery.* 95, 4-10.

II. **Petrone P**, Talving P, Browder T, Teixeira PG, Fisher O, Lozornio A, Chan LS. (2011). Abdominal injuries in pregnancy: a 155-month study at two level 1 trauma centers. *Injury, International Journal of the Care of the Injured.* 42, 47-49.

III. **Petrone P**, Marini CP. (2015). Trauma in pregnant patients. *Current Problems in Surgery.* 52, 321-352.

IV. **Petrone P**, Jiménez-Morillas P, Axelrad A, Marini CP. (2017). Traumatic injuries to the pregnant patient: a critical literature review. *European Journal of Trauma and Emergency Surgery.* Sep 15. doi: 10.1007/s00068-017-0839-x.

La normativa indica también que si los trabajos se han *"redactado en una lengua diferente del Español, deberá incluirse un resumen en Español."* El Apéndice 2 muestra los títulos de los cuatro trabajos con sus respectivos resúmenes en Español.

De la misma manera se considera oportuno incluir en los Apéndices 3, 4 y 5 los siguientes trabajos que han contribuido en forma significativa con la base formativa del Doctorando, a saber:

V. Tillou A, **Petrone P**. Gynecologic injuries. *En:* Current Therapy of Trauma and Surgical Critical Care. Asensio JA, Trunkey D (Eds). 5ta edición, pp. 423-430. Mosby: Philadelphia, PA; 2008.

VI. **Petrone P**. (2014). Traumatismo en la mujer embarazada. *Revista Argentina de Cirugía.* 106, 46-52.

VII. **Petrone P**, Tillou A. Gynecologic injuries: trauma to gravid and nongravid uterus and female genitalia. *En:* Current Therapy of Trauma and Surgical Critical Care. Asensio JA, Trunkey D (Eds). 2da edición, pp. 401-417. Elsevier: Philadelphia, PA; 2016.

B. Abstract

Traumatic injuries, most commonly accidental, but also from interpersonal violence, are now considered the leading cause of death during pregnancy. Women between the ages of 10 and 50 years are considered of childbearing age; therefore, the possibility of pregnancy must be taken into consideration when a woman between these extremes of age is evaluated in the emergency department after having sustained a traumatic event. Pregnancy causes significant physiological and anatomical changes in every system of the female body that may play an important role in the response of the pregnant patient to traumatic events. The physician treating a pregnant trauma victim must remember that there are two patients, the treatment priorities are the same as for a non-pregnant trauma patient. The best initial treatment for the fetus is optimal resuscitation of the mother. The evaluation, interpretation of diagnostic tests, and management of the injured pregnant patient must take place within the context of all physiological alterations occurring during pregnancy.

A thorough examination should take place to discover the unique conditions that might be present specifically in the pregnant patient, such as blunt or penetrating injury to the uterus, placental abruption, amniotic fluid embolism, isoimmunization, and premature rupture of membranes.

Injuries to the gravid uterus have evolved from very primitive mechanisms, such as spears, sticks, and animal horns, to those typical of our time, including motor vehicle crushes, stab wounds, and gunshot wounds. The most frequent causes of maternal injury

and death include motor vehicle collision, violence and assault (gunshots, stabbing, and strangulation), falls, auto vs. pedestrian, suicide (drug overdose and poisoning), and burns.

Many studies have reported that young pregnant women with an average age of 25 years are a high risk for both blunt and penetrating trauma, including battering and suicide. Suicide remains the fourth leading cause of female mortality; however, pregnant women have a lower risk of successful suicide than that of women who are not pregnant.

The initial assessment and resuscitation of an injured pregnant patient are always the same for non-pregnant patients, although the anatomical and physiological changes during pregnancy may alter the response to the injury. An obstetrician should be present at all times and should be considered an integral member of the trauma team in the evaluation and treatment of a pregnant trauma patient.

Prehospital personnel must be aware of the physiological changes associated with pregnancy, in particular the importance of providing supplemental oxygen for preventing maternal and fetal hypoxia and infusing intravenous fluids liberally during the transport of these patients. Due to the increased intravascular volume, these patients can lose a significant amount of the circulating blood volume before the development of tachycardia, hypotension, and other signs of acute blood loss. To avoid the supine hypotension associated with the uterine aortocaval compression, patients after 20 weeks of gestation should be transported on a backboard tilted to the left by 15 degrees, with immobilization of the cervical spine. If lateral tilt is not feasible, manual uterine displacement to minimize inferior vena cava compression is indicated.

Fetal evaluation begins with checking the fetal heart rate and documenting the presence of fetal movement. The objective of the monitoring is to identify premature labor, placental abruption, and fetal distress. The combination of ultrasonography and cardiotocographic monitoring is the elective modality for diagnosis and follow-up.

The fetus is considered viable after 25 weeks of gestation, but when the gestational age is less than 24 weeks, emergency cesarean delivery is usually not indicated, because the fetus is too small to survive, and the removal of the fetus from the uterus is unlikely to provide a beneficial effect on maternal hemodynamics. After 32 weeks of gestation, when external cardiac massage is not effective, an emergency cesarean delivery must be performed immediately. Indications for perimortem cesarean delivery include maternal shock, threat to life from exsanguination, irreparable uterine injury, fetal distress in the viable fetus, and maternal death.

The predictive factors of outcome can be subdivided depending on whether they pertain to the fetus or to the mother. The predictive factors of fetal outcome include maternal death, maternal hypotension, maternal traumatic brain injury, high Injury Severity Score, pelvic fracture, ejection of the pregnant woman from a vehicle, and severe abdominal injury to the pregnant woman. The predictive factors of maternal outcome include amniotic fluid embolism, deep venous thrombosis and pulmonary embolism, and infections.

Injury prevention deserves specific attention during pregnancy, specifically related to the use of drugs and alcohol, and those actions involving domestic and interpersonal violence. All findings must be accurately documented for medical-legal purposes.

C. Introducción

C1: Objetivos de Investigación

Objetivo General:

Describir cómo los cambios anatómicos y fisiológicos que ocurren en las mujeres embarazadas durante el transcurso de su gestación normal, influyen en la evaluación y tratamiento de los traumatismos experimentados por estos pacientes.

Objetivos Específicos:

a) Identificar los factores de riesgo de morbilidad y mortalidad fetal y materna.

b) Desarrollar un algoritmo diagnóstico de evaluación inicial para la madre y el feto.

c) Diseñar un algoritmo para la cesárea de emergencia después de un traumatismo.

Justificación:

Los objetivos planteados motivaron la selección de la unidad temática de la tesis. Como parte de la realización de los trabajos de investigación se incluyó la epidemiología basada predominantemente en la edad de las pacientes y el mecanismo de lesión, abarcando desde el mecanismo contuso, siendo el más frecuente el relacionado con las colisiones automovilísticas, hasta el mecanismo penetrante, donde la lesión por arma de fuego es la más observada.

Una mención especial merece la violencia interpersonal, producida tanto por asaltos perpetrados por desconocidos en situaciones fortuitas, o bien como resultado de la violencia de género donde el agresor suele ser la pareja o alguien relacionado íntimamente

con la víctima, situación que siempre estuvo presente pero que en la actualidad ha tomado la importancia y la atención pertinente.

C2: Hipótesis de Trabajo

Se presenta como hipótesis general de trabajo conocer la real incidencia de los traumatismos en la mujer embarazada.

Hipótesis 1: El mecanismo contuso es la modalidad más frecuente de lesión.

Hipótesis 2: La mortalidad materna es de 5%.

Hipótesis 3: La mortalidad fetal excede el 50%.

Hipótesis 4: Mecanismo penetrante, elevado Índice de Severidad Lesional (*Injury Severity Score*, ISS) e hypotension materna son factores de riesgo de muerte fetal.

Hipótesis 5: La viabilidad fetal es mayor a las 24 semanas.

C3: Aportes del Doctorando

Como contribuciones del doctorando se destacan los diseños y metodologías de estudio de los diferentes artículos y capítulos, análisis estadísticos donde se justificará, obtención de las respectivas cartas de aprobación del Comité Institucional de Revisión (*Institutional Review Board*, IRB), búsquedas bibliográficas en las diferentes bases de datos (Pubmed, Medline, Scopus, Mendeley, Imbiomed, Scielo, Lilacs, entre otros), escritura de los manuscritos, revisión crítica de los mismos, envío y correspondencia con las diferentes revistas científicas y editoriales médicas de la especialidad, así como con los revisores designados, hasta la concreción final de su efectiva publicación.

D. Material y Métodos

REVIEW Scandinavian Journal of Surgery 95: 4–10, 2006

TRAUMA IN PREGNANCY: ASSESSMENT AND TREATMENT

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ABSTRACT

Women between the ages of 10 and 50 year-old have the potential for pregnancy; therefore this condition must be taken into consideration when a woman is examined in the Emergency Room after sustaining a traumatic event. Pregnancy produces significant physiologic and anatomic changes in every system of the female body. The evaluation of the traumatized pregnant patient, the approach, and the interpretation of the diagnostic tests results must be accompanied by the full knowledge of all changes that take place during pregnancy.

In the same context, although the physician treating a pregnant trauma victim must remember that there are two patients, the treatment priorities are the same as for the non-pregnant trauma patient. The best initial treatment for the fetus is the optimum resuscitation of the mother.

A thorough exam should take place to discover unique conditions that might be present in any pregnant patient such as blunt or penetrating injury to the uterus, placental abruption, amniotic fluid embolism, isoimmunization, and premature rupture of membranes.

The obstetrician should be present at all times and be considered a part of the trauma team in the evaluation and treatment of a pregnant trauma patient.

Key words: Trauma; pregnancy; diagnosis; treatment; surgery

I INTRODUCTION

In recent years trauma has been considered the leading cause of death during pregnancy. Fildes (1) reported nearly 30% of maternal deaths related to trauma. From 6% to 7% of all pregnancies are complicated by trauma, and 0.4% patients require hospitalization for the treatment of injuries (2). The actual number of injured pregnant women is underestimated as many of them are unreported, especially those due to domestic violence.

It is essential that all professionals specializing in treating trauma patients recognize and are aware of the anatomic and physiologic changes that occur to pregnant women and how these changes can impact the evaluation and treatment of this unique patient population. Complete evaluations of these patients include the assessment of the fetus in order to save the pregnancy.

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II HISTORICAL PERSPECTIVE

The oldest known cases of traumatic injury on pregnancy are referenced in the Code of Hammurabi (15th century BC) (3) and the Old Testament (Exodus 22:21). Penetrating injuries to the gravid uterus have been observed since antiquity when injuries with objects such as spears, sticks, and animal horns were described. The famous military surgeon Ambroise Paré, was the first to describe the treatment of penetrating injuries to the uterus. Paré wrote: "When the womb is wounded, the blood cometh out at the privites, and all other accidents appeared..." (4)

In medical literature of past centuries, the issue of trauma in pregnancy received more detailed interest. The earliest papers described cases related to falls, battering and assaults (5), but as the society become more industrialized the clinical reports focused on motor vehicle collisions and penetrating injuries.

III EPIDEMIOLOGY

The Center for Injury Research and Prevention in Pittsburgh, Pennsylvania, has published an excellent epidemiologic 1-year study which included all women who were of childbearing age, and required hospitalization for injuries. Of the total 16,722 women, 761 were identified (4.6%) as being pregnant (6). The most common causes of injury were motor vehicle collisions (33.6%), falls (26.4%), and poisonings (16%). Injured pregnant women had a mean age of 24.9 years. The same author reported a 3-year study in which 240 traumatic fetal injury deaths were identified (3.7 fetal deaths per 100,000 live births) (7). Motor vehicle collisions were the leading trauma mechanism (82% of cases), followed by firearm injuries (6% of cases), and falls (3% of cases). Traumatic injury-related fetal mortality was reported by Weiss (8) in a 2-year study with data from only one state, where he found 7,131 fetal deaths of which 31 traumatic injury cases were identified (6.5 fetal deaths per 100,000 live births). Motor vehicle collisions were the leading cause of injury (81%) and placental separation was the leading diagnosis (42%). Again, the younger pregnant women seemed to be at higher risk, with a mean maternal age of 25 years.

More recently Leggon et al (9) reported a very extensive literature review from 1932 through 2000, including 101 pelvic and acetabular fractures during pregnancy. They found that the average age of the women was 25 years, and associated maternal injuries were noted in 60% of the patients. The most common mechanism of injury was motor vehicle collisions (73%), followed by falls (14%), and automobile-pedestrian collisions (13%). The overall maternal mortality was 9% (9 of 101), and the overall fetal mortality was 35% (35 of 101). They stratified the mortality based on the mechanism of injury and found that the automobile-pedestrian collisions were associated with 27% (3 of 11) maternal mortality and 45% (5 of 11) fetal mortality. Motor vehicle collisions were associated with 6% (4 of 63) maternal and 37% (23 of 63) fetal mortality. Falls were associated with 0% (0 of 12) maternal and 8% (1 of 12) fetal mortality. They concluded that automobile-pedestrian collisions had a statistical trend for higher maternal mortality, and vehicular collisions had a higher statistical trend for higher fetal mortality.

Young pregnant women are also at high risk for battering. It has been reported that 10 to 30% of women are abused during pregnancy, and 5% of cases involving abuse result in fetal death (10). Physical abuse is suspected when the injuries are located proximal and in the midline rather than distal injuries. Abuse is suspected when trauma is evident to the neck, breast, face, upper arms and lateral thighs, as well as bizarre injuries like cigarette burns and bites (11). Because domestic violence is associated with a wide range of psychological, psychosomatic, and physical conditions, the diagnosis requires astute clinical skills. The most common symptoms associated with domestic violence are headache, chronic pain, gynecological symptoms, post-traumatic stress disorder, acute and chronic injuries like those described above, and substance abuse, among other conditions (12). An estimated 33% of abused women have anxiety and depression, and 26% of female suicide attempts are by women experiencing interpersonal violence, but this number is underestimated as these injuries are unreported, especially in the pregnant population.

IV ANATOMIC AND PHYSIOLOGIC CHANGES

The initial assessment and management for resuscitation of the injured pregnant patient are always the same as non-pregnant patients, although the anatomic and physiologic changes during pregnancy may alter the response to the injury. It is essential to understand all the changes that occur during this period in order to provide appropriate care to both mother and unborn child.

A) CARDIOVASCULAR SYSTEM

The plasma volume begins to expand at 10 weeks of gestation. The increases in estrogen, progesterone, renin and aldosterone contribute to expand the plasma volume up to 45% of pregravid levels, as the tubular resorption of sodium increases, about 950 meq of sodium and an additional 6 to 8 liters of total body water are retained (13). This hypervolemic state is protective for the mother during the potential bleeding from an injury, and prepares her for the blood loss during vaginal delivery (500 mL) or cesarean section (1,000 mL). This state is also known as "physiologic anemia of pregnancy," and in late pregnancy, a hematocrit of 31–35% is considered normal. Because of the increase in plasma volume, the pregnant patient may lose 35% of blood before exhibiting any sign or symptom of maternal shock, giving a false sense of security. The white blood cell increases as high as 25,000/mm³ during labor. The coagulation factors and fibrinogen are increased, and the fibrinolytic activity is reduced, which results in a hypercoagulable state which re-

sults in an increased risk for thromboembolic events.

The pulse rate also increases gradually 10 to 15 beats per minute throughout pregnancy, mainly because the diaphragm becomes more elevated secondary to the uterus and results in a lateral displacement of the cardiac apex, reaching the maximum by the third trimester. The mean blood pressure level by the first trimester is 105/60 mmHg, 102/55 mmHg for the second, and 108/67 mmHg by the end of the pregnancy. Any significant elevation may indicate pregnancy-induced hypertension.

By the end of the first trimester, cardiac output increases by 1.0 to 1.5 L/minute, which represents around 25% above the normal value due to an increase in plasma volume and decrease in vascular resistance of the uterus and placenta (14).

There is some point that will be worth emphasizing, and that is the maternal position during the second half of the pregnancy. When the patient is in supine position, the inferior vena cava (IVC) is partially obstructed by the enlarged uterus, thus there is a decrease in blood return to the right side of the heart, resulting in a decrease in cardiac output, causing the "supine hypotensive syndrome," which is characterized by dizziness, pallor, tachycardia, sweating, and hypotension. This condition is relieved when the patient is turned to the left lateral decubitus position.

B) RESPIRATORY SYSTEM

As aforementioned, the diaphragm rises approximately 4 cm and the diameter increases by 2 cm (15), secondary to hormonal effects and from mechanical pressure caused by the enlarged uterus. These changes should be taken into consideration when thoracic procedures are being performed.

The most notable changes in pulmonary volumes and capacities are the minute ventilation. It increases primarily because of an increase in tidal volume, as well as a decrease in functional residual capacity (FRC) due to a decline in expiratory reserve and residual volumes. The arterial partial pressure of oxygen (PaO_2) still unchanged, with a decrease in the partial pressure of carbon dioxide (PCO_2), with a compensatory decrease in plasma bicarbonate levels (16). Because of the reduced FCR, the pregnant patients do not tolerate apnea well, and the supplemental oxygen is always indicated.

C) GASTROINTESTINAL SYSTEM

Gastrointestinal motility, intestinal secretion, and absorption are inhibited because of increased levels of progesterone and estrogen during pregnancy. In addition, the lower esophageal sphincter is displaced into the thorax, and decreases its competency (17). Therefore, it should always be assumed that the stomach of a pregnant patient is full, and gastric tube decompression is indicated in order to avoid aspiration. As the uterus continues to grow the small bowel is displaced laterally and superiorly.

D) RENAL SYSTEM

The renal system also is affected during pregnancy. The earliest change is an increase of the glomerular filtration rate and the renal plasma blood flow by 30% (18). At the same time, there is an increase of the creatinine clearance as well as a marked fall of the serum levels of creatinine and blood urea nitrogen (BUN). As the uterus becomes larger, the ureters and bladder are compressed, resulting in hydronephrosis and hydroureter; thus, a dilated collecting system in a pregnant patient is normal.

E) ENDOCRINE SYSTEM

The pituitary gland increases approximately 135% its original size (19). Shock may cause necrosis of the anterior part of the gland, causing pituitary insufficiency or Sheehan's syndrome.

F) MUSCULOSKELETAL SYSTEM

The softening and relaxation of the interosseus ligaments during pregnancy increase the sacroiliac joint and make the symphysis pubis wider by 4 to 8 mm. Because of these changes, the maternal center of gravity is disrupted and the pregnant woman attempts to compensate with a lordotic posture, resulting in an increased risk of falls.

G) NEUROLOGIC SYSTEM

Intracerebral hemorrhage is the most common cause of death in patients with pregnancy-induced hypertension, and because it can produce seizures, it may mimic a head injury. It should be suspected when hypertension is associated with hyperreflexia, proteinuria, and peripheral edema.

V ASSESSMENT AND MANAGEMENT

Prehospital personnel must be aware of the physiologic changes of pregnancy. In particular, the importance of providing supplemental oxygen for preventing maternal and fetal hypoxia, and to give intravenous fluids liberally during transport of these patients. Because of the increased intravascular volume, these patients can lose a significant amount of blood volume before tachycardia, hypotension, and other signs of acute blood loss occur. In order to avoid supine hypotension associated with the uterine compression of the IVC (20), patients in the second or third trimester of pregnancy should be transported on a backboard tilted to the left, paying special attention to the immobilization of the cervical spine. If the patient is in a supine position, the right hip should be elevated 4 to 6 inches, and the uterus should be displaced manually to the left side (21).

The priority for treatment of an injured pregnant patient remains the same as that for the non-pregnant patient. The primary survey includes the airway, breathing, and circulation (ABC), including volume

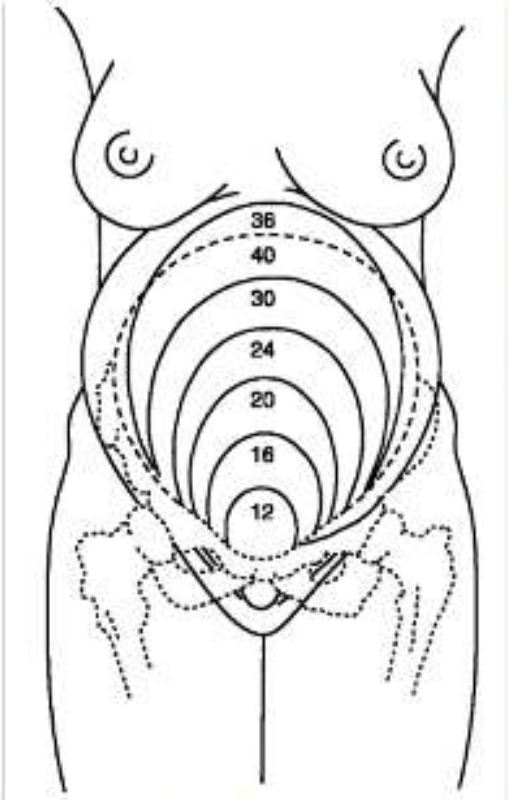

Fig. 1. Location and size of uterus during different stages of pregnancy. (Adapted from Kozycki GS, Champion HR, Deane M: Traumatic injuries in the pregnant patient. Hosp. Physician 1989; 25:20).

Fig. 2. Exploratory laparotomy in a pregnant patient with approximately 26 weeks of gestation. (From Dr Patrizio Petrone's archives)

replacement and hemorrhage control, being the mother who receives treatment first.

The secondary survey consists in obtaining the obstetrical history, a physical examination, and evaluation and monitoring of the fetus. All necessary films should be taken, regardless of the pregnancy. Comorbid factors such as pregnancy induced-hypertension, and diabetes mellitus, should be known in order to provide proper treatment. The obstetric history includes previous episodes of preterm labor, placental abruption, the date of the last menstrual cycle, expected date of delivery, and any problem or complications of the current and previous pregnancies.

The abdominal examination is critically important, as well as the determination of the uterine size, which provides an approximation of gestational age and fetal maturity (Figs 1 and 2). A discrepancy between dates and uterine size is suggestive of uterine rupture or uterine hemorrhage. Uterine rupture is suspected by findings of peritoneal signs but abdominal examination is sometimes difficult; other findings include abdominal palpation of fetal parts due to extrauterine location, and inability to palpate the uterine fundus.

There are six conditions that indicate the acute status of the pregnancy (22), and assessment of the pregnant patient must confirm or rule out the following:

1. Vaginal bleeding: it can suggest premature cervical dilation, early labor, placental abruption or placenta previa.
2. Ruptured membranes: prolapse of the umbilical cord can occur, resulting in compression of the umbilical vein and arteries.
3. Bulging perineum: caused by pressure from extrauterine located parts of the fetus.
4. Presence and patterns of contractions: their presence is important, so preparation for an eventual and early delivery can be made.
5. Abnormal fetal heart rate and rhythm.
6. Kleihauer-Betke (KB) test: is used after maternal injury to identify fetal blood in the maternal circulation (fetomaternal transfusion).

VI RADIOGRAPHIC EXAMINATION

Indicated radiographic studies should be performed as it is for non-pregnant patients (Fig. 3). Although there is an existing concern about radiation exposure during pregnancy, the benefits outweigh the risks. However, unnecessary duplication of films should be avoided.

There are three phases of radiation damage related to gestational age of the fetus (23). Before the three weeks of gestation, during preimplantation and early implantation, exposure to radiation can result in death of the embryo. Between 3 to 16 weeks of gestation, during organogenesis, radiation can damage the developing fetal tube, resulting in anomalies in the central nervous system. After 16 weeks, neurologic defects are the most common complication (23). Prenatal radiation exposure may be associated with some childhood cancers (24).

VII ABDOMINAL EVALUATION

Evaluation of the abdomen in the pregnant patient may be challenging. Special attention should be considered when there is a presence of one of the following: rib or pelvic fractures, unexplained hypotension, blood loss, hematuria, or altered sensorium due to drugs, alcohol, or brain injury.

A diagnostic peritoneal lavage (DPL) can be done safely and has the same sensitivity as in the non-pregnant patient. DPL should be performed above the umbilicus using an open technique. Abdominal computed tomography (CT) scanning can also be done safety with an evaluation of both mother and fetus, but the patient must be hemodinamically stable. Focused abdominal sonography for trauma (FAST) has a major role in the abdominal evaluation because it can rapidly detect intra-abdominal and pericardial fluid in the mother as well as the general fetal condition.

Fig. 3. Abdominal computed tomography (CT) scanning in a pregnant woman. [From Dr Patrizio Petrone's archives]

VIII MECHANISMS OF INJURY

Certain differences must be recognized in the gravid patients. Seventeen percent of the injured pregnant patients experience trauma as the result of another person, and 60% have repeated episodes of domestic violence (21).

A) BLUNT INJURY

Non-operative management of solid abdominal organs is performed successfully in the pregnant patient in stable conditions. On the other hand, unstable patients or those with intestinal injury likely benefit from early operative treatment, as hypotension and sepsis can be harmful or even lethal for the fetus.

The most challenging injury during pregnancy is the management of the pelvic fracture. Hemorrhage from dilated retroperitoneal veins can cause massive hemorrhagic shock and death (25). Pelvic fracture is the most common cause of fetal death with a fetal mortality of 25%. In non-pregnant patients, pelvic angioembolization is the usual treatment, but the dose of radiation exceeds which is considered safe during pregnancy.

The abdominal wall, uterine myometrium, and amniotic fluid act as a cushion to direct forces from blunt trauma. The most common cause of fetal death is a condition named placental abruption, due to anoxia, prematurity, or exsanguination. The manifestations include vaginal bleeding, abdominal pain, uterine tenderness, and contractions (26). One of the most serious complications associated with abruption is a condition of disseminated intravascular coagulation, caused when the thromboplastin from the placenta goes into the maternal circulation.

B) PENETRATING INJURY

As the uterus increases in size and expands out of the pelvis, it becomes the target much more easily (Figures 4-A through 4-C). Due to the thick density of the uterine musculature, it is able to absorb the energy from low-velocity penetrating injuries, which makes maternal death very uncommon, unless the injury is in the upper abdomen, which carries severe maternal damage. Up to 60–70% of the fetuses sustain injuries after abdominal gunshot wounds, and unfortunately, 40 to 65% of them die (Figure 5) (27). If the bullet has penetrated the uterus and the fetus is viable, cesarean section is indicated.

IX PERIMORTEM CESAREAN SECTION

Fetal viability is defined as 26 weeks of gestation, which corresponds to a fundal height halfway between the umbilicus and costal margin. The cesarean section at this stage is indicated after maternal death, as the fetus has 40–70% chance of survival (28, 29).

Another very important factor is the time between maternal death and delivery. If the C–section and delivery are done in five minutes or less, it has an excellent probability of survival. As the time increases, the chance of survival becomes more unlikely (28, 29).

One important technical approach during the C-section is to make a vertical midline incision through all the layers into the uterus as this is safer, faster, and avoids the high risk of adding more damage to the uterine vessels, as the trauma surgeons are not familiar with this kind of procedure.

X COMPLICATIONS

One of the most lethal complications associated with 80% maternal mortality is the condition known as amniotic fluid embolism, which together with pulmonary thromboembolism remains as the leading cause of maternal mortality in the United States (30). Besides the hemodynamic instability and pulmonary

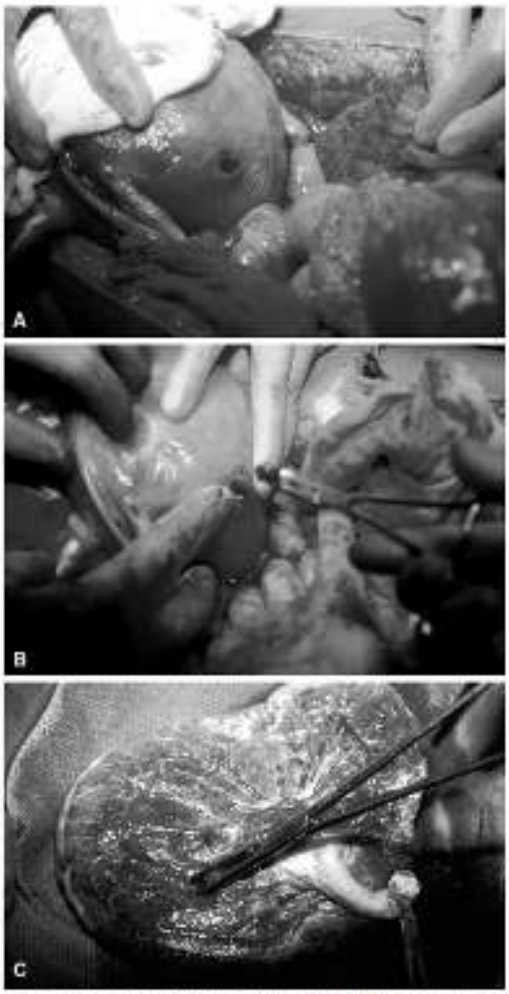

Fig. 4-A. Impact of the bullet in the posterior uterine wall after a gunshot wound to the abdomen. 4-B. Extraction of the bullet. 4-C. Same patient showing a perforation in the placenta. (From Dr Patrizio Petrone's archives)

compromise, these patients may develop minor alterations in the platelet count or disseminated intravascular coagulation.

Thromboembolic episodes remain as the most common cause of morbidity and mortality during this stage. The pregnancy is a hypercoagulable state due to the increased levels of fibrinogen and coagulation factors, and the decrease of fibrinolytic activity.

XI PREDICTING FACTORS OF OUTCOME

There are several factors associated with risk to the fetus (22). The most common factors are:

Fig. 5. Entrance of the bullet in the head of the fetus. Delivered by cesarean section. (From Dr Patrizio Petrone's archives)

1. Maternal death
2. Maternal hypotension
3. Maternal traumatic brain injury
4. High Injury Severity Score
5. Pelvic fracture
6. Ejection of pregnant woman from a vehicle
7. Severe abdominal injury to pregnant woman

XII INJURY PREVENTION DURING PREGNANCY

Injury prevention deserves specific attention during pregnancy. The first area of prevention is related to the use of drugs and alcohol. The use of these substances is not only harmful to the fetus, but also happen to be associated with high risk of injuries. In the same context, domestic violence is becoming a major cause of injury during pregnancy (10). One study noted a 17% prevalence of physical or sexual abuse during pregnancy, with 60% of women having two or more episodes of assault (11). Interpersonal violence is not dependent on race, age, marital status, or socioeconomic status; therefore all pregnant women are potential victims of abuse (31).

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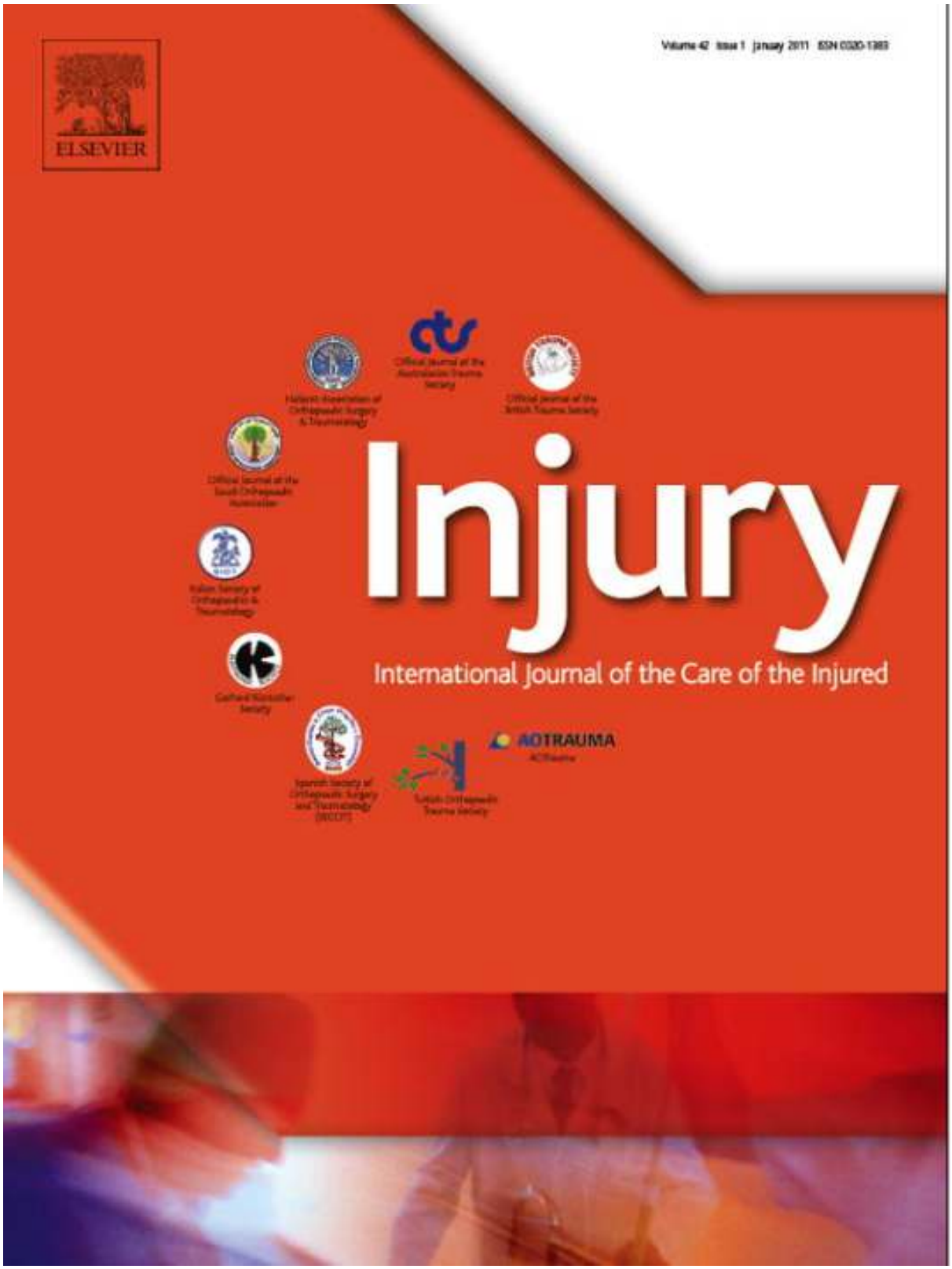
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Abdominal injuries in pregnancy: a 155-month study at two level 1 trauma centers

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ABSTRACT

Introduction: Trauma in pregnancy is the leading cause of non-obstetrical maternal death and remains a major cause of fetal demise. The objective of this study was to examine the outcomes of pregnant patients sustaining abdominal injury.

Patients and methods: This is a retrospective analysis of all pregnant trauma patients admitted to two level 1 trauma centers from February 1, 1996 to December 31, 2008. Patient data abstracted included mechanism of injury, physiologic parameters on admission, Injury Severity Score (ISS), abdominal Abbreviated Injury Scale (AIS), gestational age, diagnostic and surgical procedures performed, complications, and maternal and fetal mortality. Univariate analysis and logistic regression analysis were used.

Results: During the 155-month study period, 321 pregnant patients were included, of which 291 (91%) sustained a blunt injury, while 30 (9%) were victims of penetrating trauma. Of the penetrating injuries, 22 (73%) were gunshot wounds, 7 (23%) stab wounds, and 1 (4%) shotgun injury. The overall maternal and fetal mortality was 3% (n = 9) and 16% (n = 45), respectively. Mean age was 22 ± 6 year-old, and the mean ISS was 12 ± 16. The overall mean abdominal AIS was 2 ± 1.2. When adjusted for age, abdominal AIS, ISS, and diastolic blood pressure, the penetrating trauma group experienced higher maternal mortality [7% vs. 2% (adjusted OR: 7; 95% CI: 0.65–79), $p = 0.090$], significantly higher fetal mortality [73% vs. 10% (adjusted OR: 34; 95% CI: 11–124), $p < 0.0001$] and maternal morbidity [66% vs. 10% (adjusted OR: 25; 95% CI: 9–79) $p < 0.0001$].

Conclusions: Fetal mortality and overall maternal morbidity remains exceedingly high, at 73% and 66%, respectively, following penetrating abdominal injury. Penetrating injury mechanism, severity of abdominal injury and maternal hypotension on admission were independently associated with an increased risk for fetal demise following traumatic insult during pregnancy.

Introduction

Trauma in pregnancy is the leading non-obstetrical cause of maternal death and remains the most common cause of fetal demise. It has been reported that nearly 50% of maternal deaths are related to injury and almost 7% of all pregnancies are complicated by traumatic insults.[1]

The possibility of a pregnancy must be considered in all injured females between the ages of 10 and 50 years.[17] Pregnancy produces significant physiologic and anatomic changes in multiple organ systems[1,4,5,7,17] essential to be appreciated in order to provide appropriate care to both mother and unborn child. The evaluation, interpretation of diagnostic test results and management of the injured pregnant patient must be accompanied by the full comprehension of all physiologic alterations occurring during pregnancy.[17]

To our knowledge, only limited series[2,5–7,9,11] of pregnant patients sustaining blunt injury and only one multi-institutional study[18] including both blunt and penetrating trauma combined have been previously reported. However, studies focusing mainly on penetrating injuries during pregnancy are lacking. The objective of this study was to review the subgroup of pregnant trauma victims sustaining abdominal injury.

Patients and methods

After Institutional Review Board (IRB) approval by both participating trauma centers, a retrospective review of all trauma admissions to Los Angeles County + University of Southern California Medical Center and University Medical Center of Nevada

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from February 1, 1996 to December 31, 2008 was performed. Inclusion criteria consisted of all pregnant patients requiring hospital admission following injury. Data were extracted from the trauma registries at the two centers and included demographic characteristics, Injury Severity Score (ISS), Revised Trauma Score (RTS), abdominal Abbreviated Injury Scale (AIS), physiologic parameters at admission to the Emergency Department (ED), diagnostic and surgical interventions performed, in-hospital complications, maternal and fetal mortality, and Surgical Intensive Care Unit (SICU) and hospital lengths of stay.

The two-sided Fisher's exact test was used for testing the difference between proportions and the Mann–Whitney rank-sum test was utilised for testing the difference between means. Factors that were different between the two study groups at $p < 0.05$ were entered into a logistic regression model for adjustment. Adjusted odds ratio (OR) and its 95% confidence interval (CI) for the outcomes were derived. The SAS statistical program (SAS Institute Inc., Cary, NC) was used for all analysis.

Results

During the 155-month study period, 321 pregnant patients were included in the study. Overall, blunt and penetrating injuries occurred in 291 (91%) and 30 (9%) patients, respectively. Among these 30 victims of penetrating insult, 22 (73%) sustained gunshot wounds (GSW), 7 (23%) stab wounds (SW), and 1 (3%) shotgun injury. Mean age was 22 ± 6 year-old, and the mean ISS was 12 ± 16. Patient's demographics and physiologic characteristics are listed in Table 1. The overall mean abdominal AIS was 2 ± 1.2 and 2 ± 2 among patients sustaining penetrating insults. Forty-one percent of the patients (n = 12) sustained an abdominal injury, and 14% (n = 4) underwent cesarean section. The diagnostic procedures performed are listed in Table 2. The overall maternal mortality in the present series was 3% (n = 9), and the overall fetal mortality was 16% (n = 45). In the cohort of penetrating trauma patients, two women (7%) and 19 fetuses (73%) died. When adjusted for age, abdominal AIS, ISS, and diastolic blood pressure, no difference in maternal mortality was identified (7% vs. 2%; p = 0.090). Fetal mortality, however, was significantly higher in the penetrating injury cohort (73% vs. 10%; adjusted OR: 34; 95% CI: 11–124; $p < 0.0001$), in which the uterine injury occurred in the majority of the patients. The penetrating trauma cohort also had a significantly higher maternal morbidity rate (66% vs. 10%; adjusted OR: 25; 95% CI: 9–79; $p < 0.0001$) after adjustment (Table 3). The most common complication was ileus (57%) in the penetrating trauma group, followed by abortion (5%) in the blunt trauma group. The penetrating trauma group had a longer hospital length of stay (7 ± 9 vs. 4 ± 8; p = 0.058) as compared to the blunt trauma group.

Table 1
Demographic and physiologic characteristics of the study population.

	All patients (n = 321)	Penetrating trauma (n = 30)
Age (years)	25 ± 6	22 ± 6
Gestational age (weeks)	19 ± 10	17 ± 10
Vital signs of admission		
Fetal heart rate (beats/min)	73 ± 16	82 ± 22
Systolic blood pressure (mm Hg)	125 ± 22	129 ± 23
Heart rate (beats/min)	96 ± 20	101 ± 22
Respiratory rate (breaths/min)	20 ± 6	20 ± 3
Fetal heart rate (beats/min)	126 ± 48	114 ± 55
GCS	14 ± 1	14 ± 3
RTS	9 ± 2	8 ± 2
ISS	7 ± 11	12 ± 15
Abdominal AIS	2 ± 1.2	2 ± 2

GCS, Glasgow Coma Scale; RTS, Revised Trauma Score; ISS, Injury Severity Score; AIS, Abbreviated Injury Scale.

Table 2
Diagnostic modalities deployed.

	Penetrating trauma (n = 30)
Plain films	38%
CT abdomen	27%
Transabdominal pelvic ultrasound	15%
Tocodynamics	11%

CT, computed tomography.

Table 3
Adjusted* outcomes following penetrating and blunt trauma in during pregnancy.

Outcome	Penetrating trauma (n = 30)	Blunt trauma (n = 291)	Adjusted odds ratio (95% CI)	Adjusted p-value
Maternal mortality	7%	2%	7.29 (0.65–79)	0.090
Fetal mortality	73%	10%	34 (11–124)	<0.0001

* Adjusted for age, abdominal injury, ISS, and diastolic blood pressure.

Discussion

Penetrating injuries are exceedingly uncommon in pregnant population reflected by the lack of larger series on the topic. Nevertheless, Aniulene et al.[2] reported, in a Medline-based review of 13 years, that injury affects almost 8% of all pregnancies, however, only 16% of those victims sustain penetrating injury. Likewise, in our series a total of 9% of the cohort sustained a penetrating insult, predominantly GSW, in excess of 70% of cases.

All initial treatment priorities also in pregnant trauma victim follow ATLS principles.[1] Once life-threatening injuries have been addressed, the secondary survey of fertile female should include assessment of potential pregnancy, fetal age, and its possible extra-uterine survival prompting pertinent monitoring of fetal distress with cardiotocography.[11]

The incidence of uterine injury increases significantly after penetrating abdominal trauma, as the pregnant uterus expands beyond the pelvis by the 12th week of pregnancy. In the second half of pregnancy the vast majority of penetrating injuries to anterior abdomen are associated with uterine injury.[17,12] Nevertheless, by the middle of the second trimester, the uterine musculature is capable of absorbing most of the wounding energy resulting in a low maternal death-rate in these instances.[17,12] Stab wounds during pregnancy, in general, are less likely to cause maternal bowel injury. However, upper abdominal stab wounds may result in a complex bowel injury because of the cephalad bowel displacement. Gunshot wounds to the uterus cause frequently fetal injuries in 60–70% of cases. Such lesions are associated with fetal death in 40–65%.[17,12,19] In the current series, penetrating mechanisms of injury were significantly more frequently associated with abdominal insults at 41%. Likewise, penetrating mechanisms of injury resulted in significantly higher rate of fetal demise, overall morbidity, and in an obvious trend of maternal mortality in current series.

Emergency caesarian section may be indicated when fetal survival is noted following penetrating injury to the uterus.[22] Fetal viability is defined as 25 weeks of gestation, which corresponds to a fundal height halfway between the umbilicus and the costal margin,[10] and at this stage timing of the caesarian section is critical as the fetus has 40–70% chance of survival.[20] Indications for emergency caesarian section included maternal shock, threat to life from exsanguinations from any cause, irreparable uterine injury, fetal distress in a viable fetus,

unstable thoracolumbar spine injury, pregnancy near term, and maternal death.[22] Morris et al.[15] reported that the emergency caesarian section performed after 25 weeks of gestation for specific indications following trauma is associated with 45% fetal survival and 72% maternal survival. If the caesarian section and delivery are done within 5 min, there is an excellent probability of survival, but it is more unlikely as the time increases. Caesarian sections were performed in 8% of the penetrating trauma patients in our series, of which fetal mortality was significantly high.

It has been reported that 10–30% of women are abused during their pregnancy, and 5% of the cases involving abuse result in fetal death.[8,13] In our series, consistent with the literature, overall 11% of patients reported domestic assault. These insults may be highly unreported in the pregnant population in the present series in concordance with other reports.[17,18]

Although this study has some limitations, such as the retrospective design and the small number of subjects enrolled, this is to the best of our knowledge the largest series assembled from the two institutions focusing on penetrating abdominal injuries during pregnancy.

The penetrating trauma cohort of pregnant patients experienced higher maternal mortality [7% vs. 2% (adjusted OR: 7; 95% CI: 0.65–79), $p = 0.090$], significantly higher fetal mortality [73% vs. 10% (adjusted OR: 34; 95% CI: 11–124), $p < 0.0001$] and maternal morbidity [66% vs. 10% (adjusted OR: 25; 95% CI: 9–79) $p < 0.0001$] while adjusting for age, abdominal AIS, ISS, and diastolic blood pressure.

Conclusions

Assessment of a female trauma patient in the fertile age should always include the possibility of pregnancy. Fetal mortality and overall maternal morbidity remains exceedingly high, at 73% and 66%, respectively, following penetrating abdominal injury. Penetrating injury mechanism, severity of abdominal injury and maternal hypotension on admission were independently associated with an increased risk for fetal demise following traumatic insult during pregnancy.

Conflict of interest

None.

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Trauma in the Pregnant Patients

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Trauma in pregnant patients

Introduction

Over the past several decades, traumatic injuries have been identified as major contributors to maternal and fetal morbidity and mortality. Traumatic injuries, most commonly accidental, and occasionally the result of intentional violence, are now considered the leading cause of death during pregnancy. Fildes and colleagues[1] reported that nearly 50% of maternal deaths are caused by trauma. From 6%-7% of all pregnancies are complicated by trauma, and 0.4% of pregnant patients require hospitalization for the treatment of traumatic injuries.[2] The actual number of injured pregnant women is underestimated because many of them are unreported, especially those due to domestic violence.

Although major blunt and penetrating trauma is more likely to affect both a pregnant woman and her fetus, complications limited to the pregnancy itself, such as abruption placenta and fetal injuries, can occur after relatively minor trauma to the abdomen from falls, domestic abuse, and low-speed motor vehicle accidents.

The possibility of a pregnancy must be considered in all injured women between the ages of 10 and 50 years.[3] Pregnancy produces major physiological and anatomical changes in multiple organ systems that may affect the response of a pregnant woman to trauma. It is essential for a trauma surgeon or any practitioner taking care of a pregnant trauma patient to understand the effect of the physiological changes occurring during the early and late pregnancy on the symptoms and signs of the trauma victim to provide the appropriate care to both the mother and the unborn child. The evaluation, interpretation of diagnostic tests, and management of the injured pregnant patient must take place within the context of all the physiological alterations occurring during pregnancy.[3]

It is essential that all professionals responsible for the treatment of trauma patients recognize and be aware of the anatomical and physiological changes that occur to pregnant women and how these changes may affect the evaluation and treatment of this unique patient population.[3] Clearly, a comprehensive evaluation of these patients must include the assessment of the fetus to save the pregnancy.

Historical perspective

The oldest known cases of traumatic injury during pregnancy are referenced in the Code of Hammurabi (15th century BC)[4] and the Old Testament (Exodus 22:21). Penetrating injuries to the gravid uterus from spears, sticks, and animal horns have been observed from ancient times.

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The famous military surgeon Ambroise Paré, who was also an obstetrician, was the first to describe the treatment of penetrating injuries to the uterus.[5] He wrote, "When the womb is wounded, the blood cometh out at the privites, and all other accidents appeared."

Articles written in past centuries about trauma in pregnancy identified falls, battering, and assaults as the most common causes of traumatic injuries during pregnancy.[6] However, with the evolution from a less to a more industrialized society, the etiology of traumatic injuries has evolved from those previously reported to those typical of a more industrialized society, such as motor vehicle crashes and penetrating trauma from stab and gunshot wounds.

Epidemiology

The Center for Injury Research and Prevention in Pittsburgh, Pennsylvania, published in 1995 an excellent epidemiologic 1-year study[7] that included all women of childbearing age requiring hospitalization for injuries. Of the 16,722 women having traumatic injuries, 761 were identified (4.6%) as being pregnant. The most common causes of injury were motor vehicle collisions (33.6%), falls (26.4%), poisonings (16%), and "struck by or against" (11.4%). The mean age of injured pregnant women was 24.9 years. Weiss and colleagues[8] reported a 3-year study in which 240 traumatic fetal injury deaths were identified (3.7 fetal deaths per 100,000 live births). Motor vehicle collisions were the leading trauma mechanism (82% of cases), followed by firearm injuries (6% of cases) and fall-related injuries (3% of cases).

Traumatic injury–related fetal mortality was reported by the same author[9] in a 2-year study, with data from only 1 state: 31 of 7131 (0.4%) fetal deaths were ascribed to trauma, whereas the fetal death rate was 6.5 per 100,000 live births. Motor vehicle collisions were the leading cause of injury (81%) and placental separation was the most common diagnosis (42%).

More recently, Leggon and colleagues[10] reported a very extensive literature review from 1932 through 2000, including 101 pelvic and acetabular fractures during pregnancy. They found that the average age of the women was 25 years, and associated maternal injuries were noted in 60% of the patients. The most common mechanism of injury was motor vehicle collisions (73%), followed by falls (14%) and automobile-pedestrian collisions (13%). The overall maternal mortality rate was 9%, and the fetal mortality rate was 35%. The mortality stratified by the mechanism of injury led to the following observations. Firstly, automobile-pedestrian collisions were responsible for 7% (3 of 11) of maternal mortality and 45% (5 of 11) of fetal mortality. Secondly, motor vehicle collisions were associated with 6% (4 of 63) of maternal mortality and 37% (23 of 63) of fetal mortality. Lastly, falls did not cause maternal deaths (0 of 12) but were associated with an 8% (1 of 12) fetal mortality. These authors concluded that automobile-pedestrian collisions have a statistical trend for higher maternal mortality, whereas vehicular collisions tend to cause more fetal deaths.

Young pregnant women are also at high risk for battering. It has been reported that 10%-30% of women are abused during pregnancy, and 5% of cases involving abuse result in fetal death.[11] Physical abuse should be suspected based on the pattern of injuries. Although motor vehicle collisions and pedestrian struck type of injuries tend to affect more commonly the distal extremities, pelvis, and abdomen, the injuries caused by physical abuse tend to be more proximal and more commonly in the midline. Pregnant women subjected to physical abuse typically present with injuries to the neck, breast, face, upper arms, and lateral thighs, as well as with bizarre injuries such as cigarette burns and bites.[12] Because domestic violence is associated with a wide range of psychological, psychosomatic, and physical conditions, the diagnosis requires a high degree of suspicion and astute clinical skills. The most common symptoms associated with domestic violence include headache, chronic pain, gynecologic symptoms, posttraumatic stress disorder, acute and chronic injuries such as those described earlier, and substance abuse, among other conditions.[13]

An estimated 33% of abused women have anxiety and depression, and 26% of female suicide attempts are by women experiencing interpersonal violence, but this number is underestimated, as these injuries are unreported, especially in the pregnant population. Identified risk factors for

trauma during pregnancy include younger age,[7] drug and alcohol use, and domestic violence.[12,14,15] Berenson and collegues[16] found that battered women were more likely to use alcohol and tobacco. Holland and colleagues[17] reported a 21% incidence of preterm birth when pregnant women tested positive for drugs.

Although in general the physical abuse to a pregnant woman is aimed at injuring the person herself, occasionally the physical abuse is directed specifically to the gravid abdomen, with the intent of causing fetal injury.[18] Battering can initiate or escalate during pregnancy; however, pregnancy can be a protective hiatus for some women. It is estimated that between 10% and 30% of women are abused during pregnancy, with a fetal mortality of 5%.[19] In a review of domestic violence, intimate partner violence and battering was reported to occur in 1 of every 12 pregnancies in the inner city.[15] Intimate partner violence contributed to 20% of all nonfatal violent crimes experienced by women.[20] Homicide rates for African American women were 3 times higher than those for white women.[21] According to Chang and colleagues,[22] homicide is the third leading cause of injury-related death for all women of childbearing age, independent of pregnancy status. They reported a homicide rate of 1.7 per 100,000 live births. Risk factors for homicide during pregnancy included age younger than 20 years, belonging to the African American ethnic group, and later or no prenatal care. The most common mechanisms of injury were gunshots (58%), stabbing (18%), strangulation (14%), and battering (8%).[22]

Ikossi and colleagues[23] identified factors predictive of injury in a group of pregnant women. Based on the National Trauma Data Bank (NTDB) of the American College of Surgeons, among the 77,321 women of childbearing age hospitalized for traumatic injuries, 1.5% (1195) were pregnant. The most common mechanisms of injury in this review article were motor vehicle crash (70%), interpersonal violence (11.6%), and falls (9.3%). Young age at the time of the pregnancy, African American or Hispanic heritage, and lack of insurance or underinsurance status were the highest risk factors for injury during pregnancy.

Depression during pregnancy and postpartum has contributed to a higher suicide-related maternal mortality rate.[22,24,25] All pregnant and postpartum women have to be screened for depression to prevent the possibility of suicidal ideation and the possibility of attempts to suicide. Suicide remains the fourth leading cause of female mortality[26]; however, pregnant women have a lower risk of successful suicide than that of women who are not pregnant.[27,28] The attempted suicide rate during pregnancy has been estimated to be 0.4 per 1000 pregnancies.[29] Common methods of attempted suicide include drug overdose and poisoning with a corrosive substance.[1,29]

Table 1
Changes in maternal physiology during pregnancy.

Change	Consequence
Cardiac output and blood volume increase	Shock after more than 40% of blood loss
Expansion of plasma volume	Physiological anemia
Decline in arterial and venous pressure	Vital signs are not reflective of hemodynamic status
Increase of resting pulse	
Chest enlargement	Change in anatomical landmarks
Diaphragm rise	Caution during thoracic procedures (eg, thoracostomy)
Substernal angle increase	
Decrease in functional residual capacity	Rapid decline in PO_2 during apnea or airway obstruction
Increase in oxygen consumption	
Airway closure when supine	
Increase in tidal volume and minute ventilation	Reduction in PCO_2 and bicarbonate levels
Decrease in anesthetic requirements	Need for adjustment of sedative doses
Decreased gastric motility	Risk of aspiration
Relaxation of gastroesophageal sphincter	

Adapted with permission from Tillou and Petrone.[40]

Anatomical and physiological changes

The initial assessment and management for resuscitation of an injured pregnant patient are always the same as in nonpregnant patients, although the anatomical and physiological changes during pregnancy may alter the response to the injury. It is essential to understand all the changes that occur during this period to provide appropriate care to both the mother and the unborn child (Table 1).[1]

Cardiovascular System

The plasma volume begins to expand at 10 weeks of gestation. The increases in estrogen, progesterone, renin, and aldosterone levels contribute to expand the plasma volume by up to 45% of pregravid levels. In particular, the enhanced activity of aldosterone is responsible for an additional resorption of approximately 950 mEq of sodium each day, which in turn leads to retention of approximately 6-8 L of total body water by the third trimester of the pregnancy.[30]

This hypervolemic state, which is teleologically meant to compensate for the blood loss of approximately 500 mL that occurs at the time of vaginal delivery and which can also protect the mother from the blood loss of approximately 1000 mL associated with a cesarean delivery, is protective of the mother in the case of hemorrhage from trauma.

Because of increased plasma volume in relation to the red cell mass, the pregnant woman develops a "physiological anemia" with a hematocrit of 31%-35% in the late pregnancy.

Because of the increase in plasma volume, the pregnant patient may lose 35% of the circulating blood volume before exhibiting any sign or symptom of maternal shock, giving a false sense of security to the caregiver. The white blood cell count increases, reaching values as high as 25,000 per mm^3 during labor. The levels of coagulation factors and fibrinogen are increased, and the fibrinolytic activity is reduced; this results in a hypercoagulable state that accounts for the increased risk of venous thromboembolism during the pregnancy.

The pulse rate also increases gradually 10-15 beats per minute throughout pregnancy, mainly because the diaphragm becomes more elevated secondary to the enlarged uterus that causes a lateral displacement of the cardiac apex, reaching the maximum by the third trimester. The mean blood pressure averages 105/60, 102/55, and 108/67 mm Hg, by the first, second, and third trimester, respectively. Levels of blood pressures more than these mean values should alert the physician to the possibility of pregnancy-induced hypertension.

By the end of the first trimester, cardiac output increases by 1.0-1.5 L/min, which represents approximately 25% more than the normal value because of an increase in plasma volume and the decrease in vascular resistance of the uterus and placenta.[31]

A point worth emphasizing is the maternal position during the second half of the pregnancy. When the patient is in supine position, the inferior vena cava is partially obstructed by the enlarged uterus; thus, there is a decrease in blood return to the right side of the heart, resulting in a decrease in cardiac output, causing the "supine hypotensive syndrome," which is characterized by dizziness, pallor, tachycardia, sweating, and hypotension. This condition is relieved when the patient is turned to the left lateral decubitus position.

Respiratory System

As previously mentioned, the diaphragm rises approximately 4 cm and the chest diameter increases by 2 cm, increasing the substernal angle by approximately 50°.[32] These changes occur secondary to hormonal effects and from the mechanical pressure imposed by the enlarged uterus. To avoid iatrogenic complications, these anatomical changes should be taken into consideration when thoracic procedures such as tube thoracostomy, placement of pigtail catheters, and thoracentesis are being performed.

The most notable changes in respiratory physiology and oxygen use include increased minute ventilation and vital capacity with decreased residual volume and functional residual capacity,

as well as an increase in oxygen consumption by approximately 20%. The rise in minute ventilation is caused primarily by the increase in tidal volume, which averages 200 mL. The respiratory rate does not alter significantly throughout pregnancy. The arterial partial pressure of oxygen remains unchanged, whereas the partial pressure of carbon dioxide decreases because of the augmented minute ventilation. The pH does not change because of the compensatory decrease in the plasma bicarbonate level; therefore, the pregnant woman develops a state of compensated respiratory alkalosis.[33] Because of the reduced functional residual capacity, pregnant patients do not tolerate apnea well, and supplemental oxygen is always indicated.

Gastrointestinal system

Gastrointestinal motility, intestinal secretion, and absorption are reduced because of increased levels of progesterone and estrogen during pregnancy. In addition, because of the partial displacement of the lower esophageal sphincter into the thorax and the decreased tone of the lower esophageal sphincter from the action of progesterone, which is associated with decreased gastric emptying, a pregnant woman is at a higher risk of aspiration following a traumatic event.

As the uterus continues to grow, the small bowel is displaced laterally and superiorly, making it more vulnerable to penetrating trauma to the upper abdomen. Biliary secretion is also altered, as shown by the increase of the alkaline phosphatase levels to nearly twice its normal value.[34] Because of the decreased flow-dependent biliary secretion and the decreased cholecystokinin-induced gall bladder emptying, both caused by the increased level of progesterone, a pregnant woman is prone to bile stasis and to the formation of gall bladder sludge and gallstones, which can be documented by the end of the second trimester in 31% and 3% of pregnant women, respectively.[35–37] There is also a decrease in the level of plasma albumin to an average of 3.0 g/dL, but this is probably dilutional and not due to compromised synthetic activity.[38]

Renal system

The renal system also is affected during pregnancy. The earliest change is an increase of the renal blood flow by approximately 30% that increases the creatinine clearance. Therefore, the serum levels of creatinine and blood urea nitrogen are markedly decreased during pregnancy. By 26 weeks of gestation, renal plasma blood flow and glomerular filtration rate are 80% and 50% more than the normal baseline values, respectively.[39,40] Because of these increases, more plasma is filtered, diminishing the protein levels and therefore the oncotic pressure, which places the pregnant patient at a higher risk of pulmonary edema. As the uterus becomes larger, the ureters and bladder are compressed, resulting in hydronephrosis and hydroureter; thus, a dilated collecting system in a pregnant patient is normal. Because of the anterior and superior displacement of the bladder, it becomes more susceptible to lower abdominal injuries.

Endocrine system

The pituitary gland enlarges by 0.08 mm/wk, reaching a maximum height of 10-12 mm immediately postpartum; this represents an increase of approximately 135% from its original size.[41] Owing to the more dominant enlargement of the anterior lobe of the gland and its increased blood requirement, this portion of the gland is more prone to ischemia and necrosis particularly in pregnant women with type 1 diabetes mellitus. Traumatic shock may cause antepartum necrosis of the anterior part of the gland, causing pituitary insufficiency, as opposed to the Sheehan syndrome, which is a postpartum pituitary necrosis caused typically by massive bleeding during or after delivery.

The placenta produces human chorionic gonadotropin, human placental lactogen, progesterone, estrogen, thyroid-stimulating hormone, and adrenocorticotropic hormone.[41] Because

estriol production depends on the appropriate function of the fetal-placenta system, it can be used as a marker of fetal and placental well-being.[42]

Musculoskeletal system

The softening and relaxation of the interosseus ligaments during pregnancy widens the sacroiliac joint and the pubic symphysis from 4-8 mm. Because of these changes, the maternal center of gravity is disrupted, and a pregnant woman attempts to compensate assuming a more lordotic posture, resulting in an increased risk of falls.

Neurologic system

Intracerebral hemorrhage is the most common cause of death in patients with pregnancy-induced hypertension, and because it can produce seizures, it may mimic a head injury. It should be suspected when hypertension is associated with hyperreflexia, proteinuria, and peripheral edema.

Reproductive system

The weight of the uterus increases 60 times, ranging from 60 -1000 g by the end of the gestation. After the third month, the uterus is outside the pelvis, and by the third trimester, it is at a level above the umbilicus, displacing the hollow viscous viscera upward and laterally.

Uterine blood flow increases by approximately 500 mL/min; this represents an increase of approximately 17% of the cardiac output.[43] Simultaneously, uterine veins may enlarge up to 60 times their size when compared with the prepregnant state. The increased vascularity of the uterus and the pelvis resulting from the increased inflow caused by the expanded runoff provided by the gravid uterus places a pregnant woman at a higher risk of massive bleeding in the case of pelvic fracture or uterine injury.

Assessment and management

Prehospital care

Prehospital personnel must be aware of the physiological changes associated with pregnancy, in particular, the importance of providing supplemental oxygen for preventing maternal and fetal hypoxia and of infusing intravenous fluids liberally during the transport of these patients. Because of the increased intravascular volume, these patients can lose a significant amount of circulating blood volume before the development of tachycardia, hypotension, and other signs of acute blood loss.

Military antishock trousers (MAST), also known as a pneumatic antishock garment, are a 1-piece inflatable device that has been used to support blood pressure in hypotensive patients during transport to the trauma center. The current indications include the presence of severe hypotension in patients with suspected or documented pelvic fractures and temporary support of blood pressure in patients with hemorrhage from abdominal trauma who are on route to the operating room or to another facility.[44] The MAST are potentially harmful to pregnant women in the second and third trimester of pregnancy and are relatively contraindicated in pregnancy other than for a ruptured ectopic pregnancy.[45] The emergency department team must be aware to limit the inflation of the MAST only to the leg compartments and to avoid inflation of the abdominal section if used while transporting a pregnant woman whose pregnancy has progressed beyond midterm gestation, because inflation of the abdominal compartment of the MAST can compromise uteroplacental blood flow.[45] Deflation should occur in the hospital only

after intravenous lines are secured and after appropriate volume loading with crystalloids, blood products, and control of the bleeding source.[44]

To avoid the supine hypotension associated with the uterine aortocaval compression (Fig 1), patients after 20 weeks of gestation should be transported on a backboard tilted to the left by 15°, paying special attention to the immobilization of the cervical spine.[3,45] The aortocaval compression by the uterus decreases the venous return to the right heart, causing supine hypotension because of the reduced stroke volume and cardiac output. It is noteworthy that aortocaval compression from the enlarged uterus can compromise the effectiveness of chest compressions during cardiopulmonary resuscitation (CPR) in the third trimester of pregnancy. If the patient is in a supine position, the right hip should be elevated 4-6 in (15-30°), placing a firm wedge under the right hip to achieve tilt. In cases of major trauma, the wedge should be placed under the spinal board. If lateral tilt is not feasible, manual uterine displacement to minimize inferior vena cava compression is indicated: standing on the woman's left, the physician places both the hands around the uterus and gently pulls the uterus toward himself or herself.[47]

Primary survey

The priorities for treatment of an injured pregnant patient remain the same as those for the treatment of a nonpregnant patient. The primary survey includes establishing the patency of the airway, maintaining the breathing, and providing adequate support of the circulation with volume replacement and hemorrhage control, if necessary, with the understanding that the treatment of the mother takes precedence over the treatment of the fetus.[48]

Severe trauma induces the release of maternal catecholamines that cause uteroplacental vasoconstriction, compromising the fetal circulation. Therefore, supplemental oxygen is always indicated to prevent maternal and fetal hypoxia. Because of the increased cardiac output present in pregnant patients, the increase in oxygen in solution provided by the administration of supplemental oxygen may increase oxygen delivery to the fetus.

Hypovolemia should be suspected in all pregnant victims of trauma before it becomes clinically apparent, because the pregnancy-induced hypervolemia may mask significant blood losses, and the occurrence of shock may be delayed. Vigorous volume resuscitation is encouraged even for patients who appear normotensive after major trauma.

Fig. 1. Compression of the inferior vena cava (within the oval) in advanced pregnancy. (From Dr Patrizio Petrone's personal archives.) (Color version of figure is available online.)

Secondary survey

The secondary survey consists of obtaining the obstetrical history, a physical examination, and evaluation and monitoring of the fetus. All necessary radiological investigations should be performed regardless of the pregnancy. Comorbid factors such as pregnancy-induced hypertension and diabetes mellitus should be known to provide proper treatment. The obstetrical history of preterm labor or placental abruption places the patient at increased risk for the recurrence of this condition. The obstetric history includes previous episodes of preterm labor, placental abruption, the date of the last menstrual cycle, expected date of delivery, and any problem or complications of the current and previous pregnancies.

The abdominal examination is critically important, as well as the determination of the uterine size, which provides an approximation of gestational age and fetal maturity (Figs 2 and 3). It is important to stratify the pregnant patient into 1 of the categories shown in Table 2.[47] The fetus is usually considered viable when it has a 50% chance of extrauterine survival. With the use

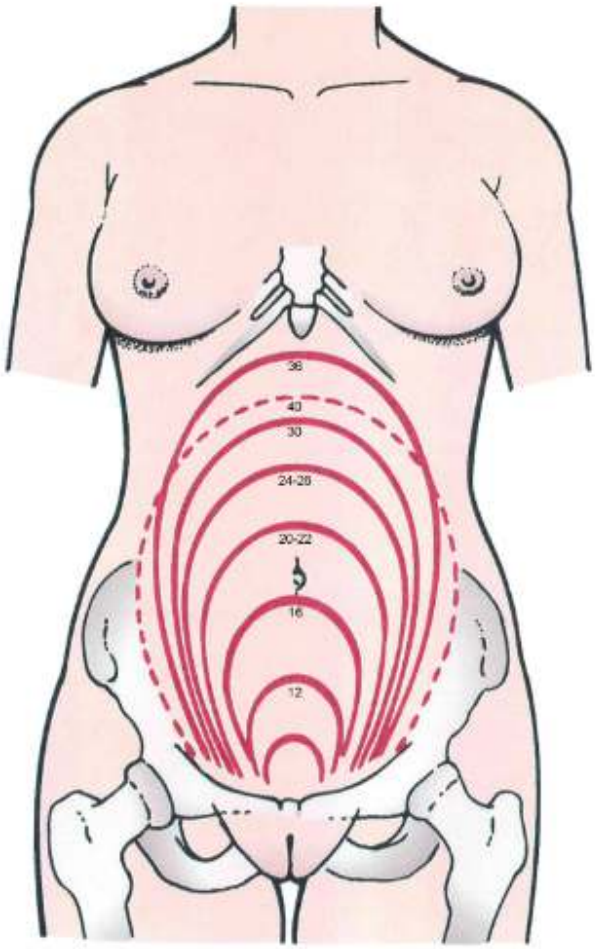

Fig. 2. Location and size of uterus during different stages of pregnancy. The numbers indicate weeks of gestation. (Modified with permission from Wilson SF ed. Assessment of the Pregnant Patient. *Health Assessment for Nursing Practice*. 4th ed. Mosby; 2009.) (Color version of figure is available online.)

Fig. 3. Exploratory laparotomy in a pregnant patient at approximately 26 weeks of gestation. (From Dr Patrizio Petrone's personal archives.) (Color version of figure is available online.)

of advanced neonatal supportive capabilities, newborns weighing 500-600 g can be supported in appropriate neonatal intensive care units with 20%-30% chance of meaningful survival. Decisions regarding fetal viability are based on the assessed gestational age by ultrasonography; however, it must be mentioned that even with the use of the most advanced technology, gestational age is subject to an error of 1-2 weeks. A rule of thumb assessment of gestational age in the trauma bay uses the umbilicus as the landmark of potential fetal viability. If the fundus of the uterus extends above the umbilicus, the fetus is considered potentially viable. A discrepancy between gestational dates and uterine size is suggestive of uterine rupture or uterine hemorrhage. Uterine rupture is suspected by the presence of peritonitis, findings of extrauterine fetal parts on abdominal palpation, as well as the inability to palpate the fundus of the uterus. However, the abdominal examination may be unreliable and cannot be relied upon as the sole diagnostic modality. An algorithm for initial maternal and fetal assessment is presented in Figure 4.[49]

There are 6 conditions suggesting potential harm to the pregnancy itself in a patient who has experienced a traumatic event that must be assessed at the time of the evaluation of the pregnant patient.[48] They include one or more of the following conditions:

1. Vaginal bleeding: it can suggest premature cervical dilation, early labor, placental abruption or placenta previa.

Table 2
Patient stratification by category.

Category	Considerations
Potentially pregnant	History alone is unreliable in excluding pregnancy Perform a pregnancy test on all women of childbearing age who sustained trauma Where pregnancy is confirmed after a trauma event, provide counseling on the implications (ie, radiographic studies)
Previable gestation (< 24 wk)	Dates and estimations of gestational age may be inaccurate or unreliable Where in doubt, presume viability Document presence or absence of fetal heart rate
Viable gestation	Gestation greater than 24 wk Start cardiotocograph monitoring
Perimortem	Evaluate to perform cesarean delivery

Adapted with permission from Queensland Clinical Guidelines.[47]

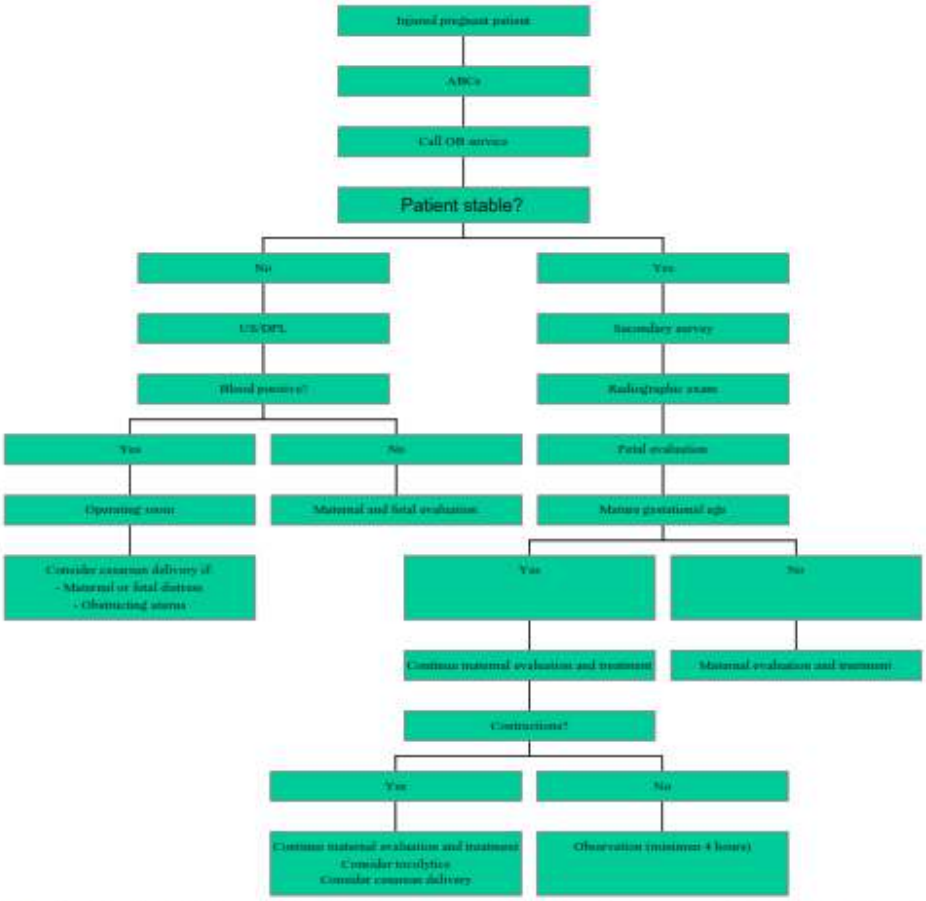

Fig. 4. Algorithm for initial maternal and fetal assessment. OB, obstetrics; US, ultrasound. (Color version of figure is available online.)

2. Ruptured membranes: prolapse of the umbilical cord can occur, resulting in compression of the umbilical vein and arteries.
3. Bulging perineum: caused by pressure from extrauterine located parts of the fetus.
4. Presence and patterns of contractions: their presence is important, so preparation for an eventual and early delivery can be made.
5. Abnormal fetal heart rate and rhythm.
6. Kleihauer-Betke test: is used after maternal injury to identify fetal blood in the maternal circulation (fetomaternal hemorrhage).

Fetomaternal hemorrhage

FMH, the transplacental hemorrhage of fetal blood into the normally separate maternal circulation, is a unique complication of trauma during pregnancy.[51] The reported incidence of FMH after trauma is approximately 10%-30%.[52] There is no proven correlation between the severity of trauma, gestational age, and frequency and volume of FMH. Complications of FMH include Rh sensitization in the mother, fetal anemia, fetal paroxystic atrial tachycardia, fetal hypoxia, intrauterine death from exsanguination, or neonatal neurologic damage.[53]

Theoretically, FMH is possible by the fourth week of gestation; some authors suggest that FMH becomes a concern only after 12 weeks of gestation when the uterus rises above the pelvis and becomes an organ susceptible to direct trauma. FMH is detected by the KB test, an acid elution technique on maternal blood. On examination, adult cells remain colorless, whereas fetal red blood cells turn bright purple-pink. The ratio of fetal cells to maternal cells is recorded, enabling calculation of the volume of fetal blood leaked into the maternal circulation.

The management of the FMH includes continuous electronic fetal monitoring of the viable fetus, abdominal ultrasound to detect fetal heart activity, placental location, amniotic fluid index, and excluding intraperitoneal bleeding. Elevated peak systolic velocity of the fetal middle cerebral artery correlates with fetal anemia.[54,55] Occasionally, emergency cesarean delivery may be indicated.[47]

Most clinical laboratories screen 1000 red blood cells taken from the mother. A maternal blood volume of 5 L is commonly assumed in the laboratory formulas used; therefore, the presence of 1 fetal cell per 1000 cells counted corresponds to a FMH of 5 mL. However, the amount of FMH sufficient to sensitize most Rh-negative women is well less than the 5-mL sensitivity level of the standard laboratory's KB test. As little as 1 mL of Rh-positive blood can sensitize 70% of Rh-negative women. Currently, several commercial kits expedite and simplify the test process. Unfortunately, the sensitivity of the KB test remains low. Therefore, all Rh-negative mothers who present with a history of abdominal trauma should receive 1 prophylactic dose of 300 μg of Rho(D) immune globulin (RHOgam) within 72 hours of the traumatic event. Although controversial, the KB test should be reserved for Rh-negative women who are at risk for massive FMH that would exceed the efficacy of 1 dose of immune globulin (ie, more than 30 mL). According to some studies, less than 1% of all trauma cases and only 3.1% of major trauma cases exceed the coverage provided by 1 dose of 300 μg Rh immune globulin. As a general rule, 300 μg of Rh immune globulin should be given for every 30 mL of fetal blood found in the maternal circulation. The KB test should be performed in all pregnant patients with gestational age more than 12 weeks.[56–58] For cases of documented FMH, some studies recommend repeating the KB test in 24 hours to check for ongoing bleeding.

Radiographic examination

Indicated radiographic studies should be performed independent of the status of the pregnancy (Fig 5). The effect of radiation on the pregnancy is completely dependent on the gestational age of the fetus.[59] Before the third week of gestation, during preimplantation and early implantation, exposure to radiation can result in death of the embryo. Between 3 and 16 weeks of gestation, during organogenesis, radiation can damage the developing fetal tube, resulting in anomalies in the central nervous system. After 16 weeks, neurologic defects are the most common complications.[60] Prenatal radiation exposure may be associated with some childhood cancers.[61]

Most of the human data on exposure to radiation are not based on doses applied during normal diagnostic studies. Although there is existing concern about radiation exposure during pregnancy, in general, the benefits of the radiological investigations outweigh the risks associated with it. However, unnecessary duplication of films should be avoided. It is generally believed that exposure of the fetus to less than 5-10 rad causes no increase in the risk of congenital malformations, intrauterine growth retardation, or miscarriage. Radiation doses from common imaging studies are shown in Table 3.[61–63] The American College of Obstetricians and Gynecologists (ACOG) has published a consensus statement[64] with the following recommendations: (a) Women should be counseled that x-ray exposure from a single diagnostic procedure does not result in harm to the fetus or the pregnancy; (b) Concern about possible effects of high-dose ionizing radiation should not prevent medically indicated diagnostic x-ray procedures from being performed during pregnancy; (c) Consultation with an expert in dosimetry calculation may be helpful when several diagnostic x-rays are required. Specifically, exposure to less than 5 rad has not been associated with an increase in fetal anomalies or pregnancy loss.[64]

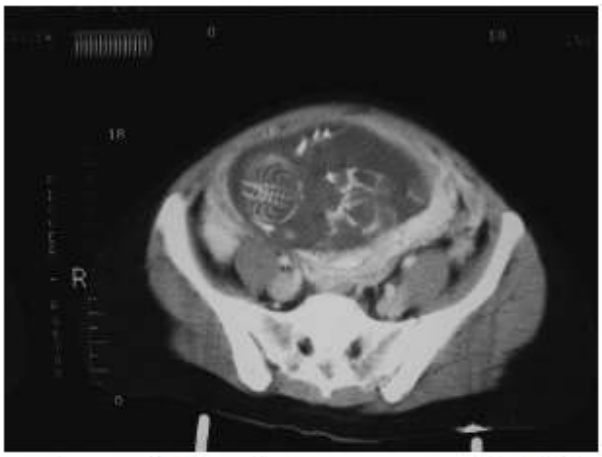

Fig. 5. Abdominal computed tomography (CT) scanning in a pregnant woman. (From Dr Patrizio Petrone's personal archives.)

Important statements on radiographic studies were also made by the American College of Radiology and the National Council on Radiation Protection, including that no single diagnostic procedure results in a radiation dose that threatens the well-being of the developing embryo and fetus.[63] Furthermore, fetal risk is considered negligible at 5 rad or less when compared with the other risks of pregnancy, and the risk of malformations is significantly increased only when levels of radiation exposure exceed 15 rads.[66]

Although there have been no documented adverse effects reported, the National Radiological Protection Board arbitrarily advises against the use of magnetic resonance imaging in the first trimester.[64] There have been no reports of documented adverse fetal effects from diagnostic ultrasound procedures, including duplex Doppler imaging, and there are no contraindications to ultrasound procedures during pregnancy. Ultrasonography has largely replaced x-ray as the primary method of fetal imaging during pregnancy.[64]

In summary, the following guidelines are suggested: First, limit the number of radiographic studies to the minimum necessary to establish the diagnosis, avoiding unnecessary duplications. Second, shield the abdomen with a lead apron when a radiological study does not involve

Table 3
Estimated fetal exposure.

Procedure	Fetal exposure (rad)	Number of studies required for a cumulative 5-rad dose
Chest x-ray (2 views)	0.00007	71,429
Abdominal film (multiple view)	0.245	20
Cervical spine	0.002	2500
Upper or lower extremity	0.001	5000
Thoracic spine	0.009	555
Lumbosacral spine	0.359	13
Pelvis	0.040	125
Hip (single view)	0.213	23
Head CT (10 slices/10 mm)	< 0.050	> 100
Chest CT (10 slices/10 mm)	< 0.100	> 50
Abdomen/lumbar spine CT	3.5	1

CT, computed tomography. (Modified with permission from Queensland Clinical Guidelines[47] and Tillou and Petrone.[49])

investigation of the abdomen. Third, limit the number of radiographs required over a protracted intensive care unit stay in critically ill patients.

Fetal assessment

Fetal evaluation begins with checking the fetal heart rate and documenting the presence of fetal movement. Currently, the most valuable information regarding fetal viability can be obtained by a combination of monitoring of the fetal heart rate and ultrasound imaging. Fetal heart tones can be detected by auscultation or Doppler probe. This should be accomplished early in the secondary survey and repeated frequently. The normal range for the fetal heart rate is 120-160 beats per minute. Continuous electronic fetal heart rate monitoring remains the most widely used modality for evaluation of the fetus and is an adjunct to the monitoring of the maternal condition. The use of electronic fetal heart rate monitoring permits prompt identification of fetal distress including the possibility of asphyxia and fetal death. Any viable fetus of 24 or more weeks of gestation requires monitoring after a trauma event. This includes patients with no obvious signs of external abdominal injury, because direct impact is not necessary for fetoplacental pathology to occur.[50,51]

The objective of the monitoring is to identify premature labor, placental abruption, and fetal distress. The combination of high-resolution real-time ultrasonography and cardiotocographic monitoring (CTM) appears to have the highest sensitivity and specificity. They should both be instituted as soon as feasible without interfering with maternal resuscitative efforts.[51]

The most common obstetrical problem caused by trauma is the occurrence of premature uterine contractions. Myometrial and decidual cells, damaged by contusion or placental separation, release prostaglandins that stimulate uterine contractions. Progression from uterine contractions to actual labor depends on the size of uterine damage, the amount of prostaglandins released, and the gestational age of the pregnancy. Some studies question the routine use of tocolytics for the prevention of premature labor after trauma, because most of the contractions (90%) stop spontaneously, and persistent contractions are often pathologic in origin, thus, in itself, a contraindication to tocolytic therapy.[51]

Blunt trauma to the abdomen can result in uterine rupture, but this event is uncommon and usually rapidly fatal for the fetus. A much more common event is placental separation from the uterus because of the shearing forces following blunt injury. This separation is called placental abruption.[67] Although placental abruption involving more than 50% separation of the placenta from uterus is uniformly fatal for the fetus, minor cases may initially go undetected. Placental abruption after trauma occurs in 2%-4% of minor accidents and in up to 50% of major injuries. Separation results as the inelastic placenta shears away from the elastic uterus during sudden deformation of the uterus. Abruption can occur with little or no external signs of injury to the abdominal wall. Maternal mortality from abruption is less than 1%, but fetal death rates range from 20%-35%. Clinical findings suggestive of abruption include vaginal bleeding, abdominal cramps, uterine tenderness, amniotic fluid leakage, maternal hypovolemia, a uterus larger than normal for the gestational age, or a change in the fetal heart rate. When present after trauma, vaginal bleeding is an ominous sign often indicative of placental separation. The first test to confirm the presence of abruption is the transabdominal ultrasound (less than 50% accurate). CTM is more sensitive in detecting placental abruption by fetal distress than ultrasound by visualization. CTM should be started in the resuscitation room and continued for a minimum of 6 hours. A minimum of 24 hours of CTM is recommended for patients with frequent uterine activity (more than 6 contractions per hour), abdominal or uterine tenderness, ruptured membranes, vaginal bleeding, or hypotension. Fetal distress is associated with placental abruption 60% of the time.[50,51]

Table 4
The American Association for the Surgery of Trauma-Organ Injury Scale (AAST-OIS) for gravid uterus.

Grade	Injury description	AIS-90 score
I	Hematoma or contusion without placental abruption	2
II	Superficial laceration < 1 cm in depth or partial placental abruption 25%	3
III	Deep laceration 1 cm in depth in second trimester or placental abruption 25% but < 50%; deep laceration in third trimester	3-4
IV	Laceration extending to the uterine artery; deep laceration 1 cm with 50% placental abruption	4
V	Uterine rupture in second or third trimester; complete placental abruption	4-5

AIS, abbreviated injury scale. (Adapted with permission from Tillou and Petrone.[49])

Abdominal evaluation

Accurate evaluation of the abdomen in a pregnant patient may be challenging. Special attention should be given to the evaluation of pregnant women who have 1 or more of the following: rib or pelvic fractures; unexplained hypotension; vaginal blood loss; hematuria; or altered sensorium due to drugs, alcohol, or brain injury.

A diagnostic peritoneal lavage (DPL) can be performed safely and has the same sensitivity as in nonpregnant patients. DPL should be performed superior to the umbilicus using an open technique. Abdominal computed tomography scanning can also be performed safely with an evaluation of both the mother and the fetus, but the patient must be hemodynamically stable. Focused abdominal sonography for trauma has a major role in the abdominal evaluation because it can rapidly detect intra-abdominal and pericardial fluid in the mother as well as assess the general fetal condition. The American Association for the Surgery of Trauma-Organ Injury Scale (AAST-OIS) for gravid uterus is shown in Table 4.[08]

Mechanisms of injury

Differences regarding the mechanisms of injury in pregnancy must be recognized in gravid patients. Overall, 17% of injured pregnant patients experience trauma because of assaults, and 60% of pregnant women have been exposed to repeated episodes of domestic violence.[48] Table 5 shows the leading causes of maternal traumatic injury and death.[3,44]

Blunt injury

The most frequent blunt mechanism of injury is motor vehicle collision, followed by assault and falls. Nonoperative management of hemodynamically stable patients with solid abdominal organ injury can be accomplished successfully in most pregnant patients. In contrast, unstable

Table 5
Causes of maternal traumatic injury and death.

Motor vehicle collision
Violence and assault
Gunshots
Stabbing
Strangulation
Falls
Auto vs pedestrian
Suicide
Drug overdose
Poisoning
Burns

patients or stable patients with suspected intestinal injury benefit from early operative treatment, as hypotension and sepsis can be harmful or even lethal for the fetus.

In the first and early second trimester, the pregnant uterus is an endopelvic rather than an abdominal organ. At 13-14 weeks of gestation, the uterus is just above the pubic symphysis and therefore is unlikely to be subjected to direct trauma because it is protected by the bony pelvis. Fetal loss in the first trimester is rarely attributable to direct uterine trauma but usually is due to maternal hypotension and the consequent hypoperfusion of the uterus and the developing fetus, or to the mother's death.

The management of pelvic fractures can be particularly challenging in pregnant patients. Leggon and colleagues[10] reported on 101 cases of pelvic or acetabular fractures in pregnant women from 1932-2000. This report identified 3 mechanisms of injury: motor vehicle collisions (73%), falls (14%), and pedestrian struck by a car (13%). The mortality rate correlated with mechanism of injury and the injury severity score. The overall fetal mortality rate in patients with pelvic and acetabular fractures was 35%, compared with a 9% maternal mortality.[10] Hemorrhage from dilated retroperitoneal veins can cause hemorrhagic shock and death.[61]

In nonpregnant patients, bleeding from complex pelvic fractures is usually controlled with angioembolization; however, the dose of radiation necessary to achieve control of bleeding with angioembolization in pregnant patients exceeds the upper limit of what is considered safe during pregnancy.

The abdominal wall, uterine myometrium, and amniotic fluid act as a cushion to direct forces from blunt trauma, but in some instances, blunt trauma can be so severe that it may cause uterine rupture (Fig 6). Uterine rupture occurs in less than 1% of pregnant trauma victims but has an obvious grave prognosis for the fetus and the mother.[69–71] As the uterus becomes an

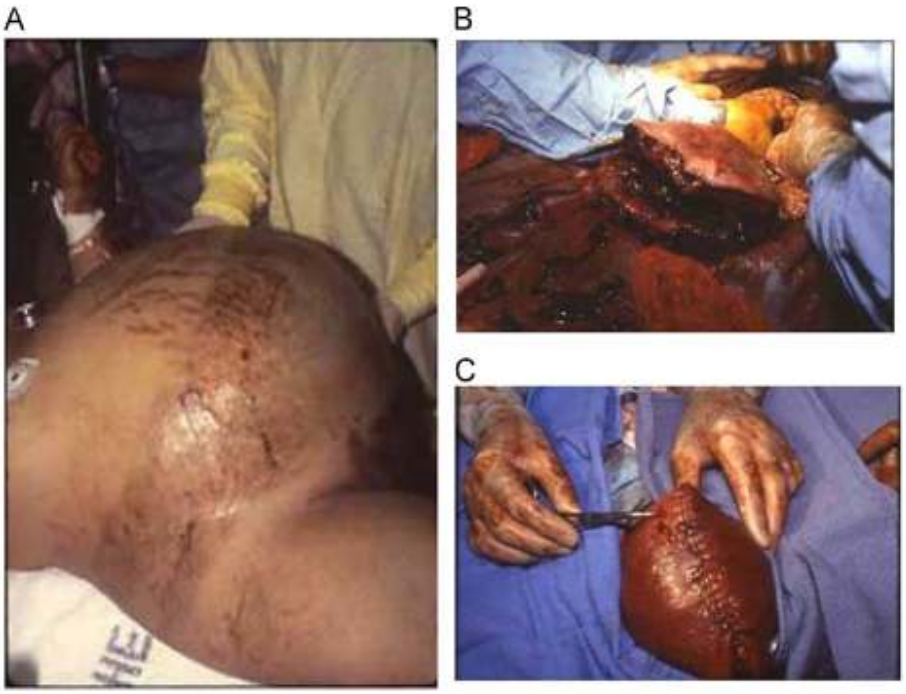

Fig. 6. (A) Pregnant patient unrestrained ejected through the windshield and rollover by a car. The tire mark on the abdomen is shown. (B) Rupture of the uterus of the same patient. She was pregnant with triplets; all of them died. (C) Reconstruction of the uterus was accomplished. (From Dr Patrizio Petrone's personal archives.) (Color version of figure is available online.)

abdominal organ, the risk of direct uterine trauma and rupture increases. The enhanced uterine vascularity and blood flow associated with the advancing pregnancy increase the possibility of massive hemorrhage if the uterus is injured and the uterine vasculature is disrupted.[72,73] The extent of uterine damage and injury to adjacent organs cannot be predicted on clinical presentation and is typically not apparent until exploratory surgery is performed. However, surgeons must be prepared to act quickly to avoid the consequences of severe hemorrhage and to prevent the development of the deadly triad of hypothermia, acidosis, and coagulopathy. If the uterus is severely damaged and cannot be repaired expeditiously, then hysterectomy is appropriate to prevent further deterioration in the woman's condition and the associated maternal morbidity and mortality.

The most common causes of fetal death include placental abruption due to anoxia, prematurity, and exsanguination. The manifestations include vaginal bleeding, abdominal pain, uterine tenderness, and contractions.[67] One of the most serious complications associated with abruption is the occurrence of disseminated intravascular coagulation, activated by the migration of thromboplastin from the placenta into the maternal circulation. In this setting, cesarean delivery should be avoided because it is associated with a very high risk of hemorrhage, hysterectomy, and subsequent death.

Because of evidence that the use of car restraint reduces both maternal and fetal morbidity and mortality, the ACOG recommends seat belt use in pregnant women to reduce both maternal and fetal morbidity and mortality.[64,74] Education on the proper use of restraints should be a standard component of all prenatal care programs. The use of 3-point seat belt restraints during pregnancy is highly recommended. The National Highway Transportation Safety Administration (NHTSA) recommends that pregnant women wear their seatbelts between the breasts, and the lap belt portion under the pregnant abdomen as low as possible on the hips and across the upper thighs, and not above or over the abdomen.

Penetrating injury

As the uterus increases in size and expands out of the pelvis, it becomes more vulnerable to penetrating trauma. Penetrating injuries are exceedingly uncommon in the pregnant population; this is reflected by the absence of larger series on the topic. Nevertheless, Aniulene and colleagues[75] reported, in a MEDLINE-based review encompassing 13 years, that 16% of injuries in pregnant women were caused by penetrating injury. Likewise, in the series by Petrone and colleagues[76] of abdominal injuries in pregnancy, 9% of the cohort reported in the review sustained a penetrating insult, with more than 70% of penetrating injuries caused from gunshot wounds.

Because of the thickness of the uterine musculature, the uterus can absorb the energy from low-velocity penetrating injuries; therefore, maternal death is relatively uncommon with injuries limited to the uterus. In contrast, because of the upward displacement of the intestine from the enlarged gravid uterus, penetrating injuries to the upper abdomen tend to be more frequently associated with massive bowel injury that may cause maternal death.

However, the extent of injury from single gunshot wounds depends on the type of firearm, the size and muzzle velocity of the bullet, the distance from perpetrator to the victim, and the anatomical region penetrated by the bullet and on the subsequent secondary missiles created by the impact of the bullet. Although maternal deaths are relatively rare with penetrating injuries limited to the uterus, fetal injury and fetal mortality rates are very high if the uterus is the main organ affected by either stabbing or gunshot wounds.[64] Fetal death is dependent on the amount of placental or umbilical cord disruption. Up to 60%-70% of the fetuses sustain injuries after abdominal gunshot wounds, with a fetal death rate reported to be as high as 71% with gunshot injuries[77] (Fig 7) and 42% with stabbings.[78] Gunshot wounds to the uterus carry a maternal mortality rate of 7%-9%.[77]

Pregnant women with gunshot wounds to the abdomen should undergo exploratory surgery with debridement of damaged tissues. Stab wounds to the abdomen should be managed in a

Fig. 7. Entrance of the bullet in the head of fetus. Delivered by cesarean section. (From Dr Patrizio Petrone's personal archives.) (Color version of figure is available online.)

manner similar to the management in nonpregnant patients if intra-abdominal injury is suspected. In cases of gunshot wounds, if the bullet has penetrated the uterus and the fetus is viable, cesarean delivery is indicated.

If a surgical procedure other than a nonobstetric procedure is required, it is extremely important to maintain adequate maternal oxygenation, circulating blood volume, and uterine perfusion. DPL can be performed safely in all trimesters using an open direct visualization technique through a supraumbilical incision[78] or under ultrasound guidance at a point above the umbilicus. Tube thoracostomy should be performed 1 or 2 interspaces higher than usual because of elevation of the diaphragm. The surgical team should never allow the enlarged uterus to compromise surgical exploration. However, the performance of an exploratory laparotomy is not in itself a justification for the delivery of the fetus. If there is significant potential for coagulopathy such as from a placental abruption, it may be beneficial to proceed with evacuation of the uterus whether the fetus is viable. Coagulopathy further complicates the hemorrhagic picture and leads to a more complicated perioperative management and the possibility of the development of the adult respiratory distress syndrome. Fetal heart monitoring should be performed throughout surgery. Hysterectomy is required if the uterus is injured beyond repair from penetrating trauma.

Perimortem cesarean delivery

The fetus is considered viable after 25 weeks of gestation, which corresponds to a fundal height halfway between the umbilicus and the costal margin. Cesarean delivery at this stage of gestation is indicated after maternal death, as the fetus has a 40%-70% chance of survival.[80,81] An important variable affecting the survival and functional outcome of the fetus is the time interval between maternal death and the cesarean delivery. If the cesarean delivery is accomplished within 5 minutes or less of maternal death, the fetus has an excellent probability of survival.[49] As the time increases, the chance of meaningful survival decreases dramatically.[80,81] The indications for perimortem cesarean delivery are shown in Table 6.[82] In the rare case in which the mother is declared brain dead but remains stable from the respiratory and hemodynamic standpoints, the fetus can be allowed to grow and mature before delivery.

An important technical aspect of a perimortem cesarean delivery is to make a vertical midline incision through all the layers into the uterus because this is safer, faster, and avoids the high risk of adding more damage to the uterine vessels. Clearly, this approach facilitates the delivery of a fetus by trauma surgeons who are less familiar with the transverse incision on the lower

Table 6
Indications for cesarean delivery during trauma.[49]

Maternal shock
Threat to life from exsanguination from any cause
Mechanical limitation for maternal repair
Irreparable uterine injury
Fetal distress in viable fetus
Unstable thoracolumbar spine injury
Instability in a potentially viable fetus
Maternal death

Adapted with permission from Tillou and Petrone.[49]

segment of the uterus, typically used by obstetricians. An algorithm for emergency cesarean delivery is shown in Figure 8.

During maternal resuscitation, adequate oxygenation, fluid loading, and left lateral decubitus positioning should be tried to see if maternal circulation can be improved. If there is no response to advanced cardiac life support within 2-3 minutes, maternal CPR must be continued, anterior thoracotomy with open-chest cardiac massage (OCM) but without aortic cross-clamping should be considered, and emergency cesarean delivery for a viable fetus should be performed. It is known that conventional external cardiac massage (ECM) is less effective as the patient approaches term because of mechanical factors. The only method of assessing adequacy of fetal oxygenation during CPR is to monitor the fetal heart rate. Carotid pulse and end-tidal CO_2 monitoring should be used to monitor adequacy of maternal vital organ perfusion during CPR.[51]

When the gestational age is less than 24 weeks, emergency cesarean delivery is usually not indicated because the fetus is too small to survive and the birth is unlikely to have much effect on

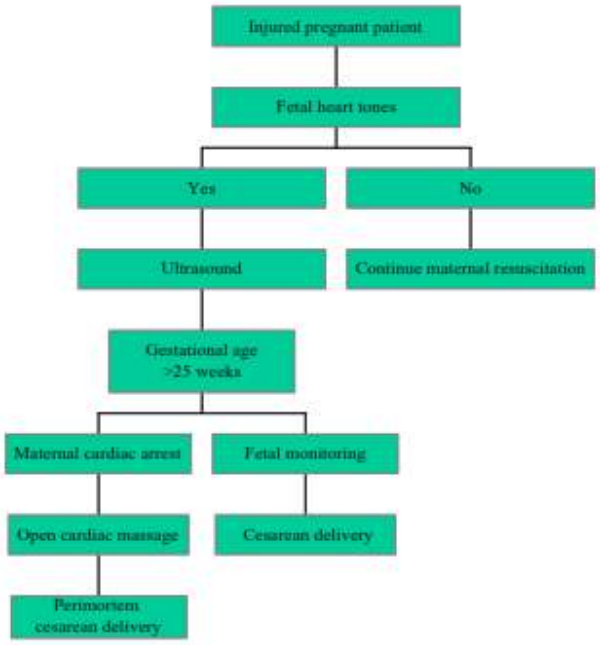

Fig. 8. Algorithm for emergency cesarean section after trauma. (Color version of figure is available online.)

maternal hemodynamics. However, when gestational age is greater than 24 weeks, emergency cesarean delivery favorably affects maternal or fetal outcome. At a gestational age of 26-32 weeks, when ECM is not effective, as indicated by failure to generate a carotid pulse, inadequate end-tidal CO_2 levels, or fetal bradycardia, OCM should be seriously considered before an emergency cesarean delivery is performed. If OCM proves successful, the delivery may be delayed so that chances of postnatal survival improve. Even slight prolongation of fetal intrauterine life probably improves the chances of fetal survival, especially when gestational age is less than 28 weeks. However, if OCM proves to be ineffective, the fetus must be delivered immediately.[51]

After 32 weeks of gestation, when ECM is not effective, an emergency cesarean delivery must be performed immediately. Delivering the infant improves maternal cardiac filling, thereby improving the success of CPR. The longer the delay between the onset of cardiac arrest and delivery, the less are the chances of fetal and maternal survival. In contrast, if the ECM appears to be effective, it may be continued for 5 minutes. If a spontaneous circulation is not restored within 5 minutes, an emergency cesarean delivery must be performed. If this fails to revive the mother, OCM may be considered.[51]

Complications

One of the most lethal complications, associated with 80% maternal mortality, is the occurrence of amniotic fluid embolism, which together with pulmonary thromboembolism remains the leading cause of maternal mortality in the United States.[83] In addition to complications involving hemodynamic instability and pulmonary compromise, pregnant women with traumatic injuries may develop minor alterations in the platelet count or the more serious complication of disseminated intravascular coagulation.

Although thromboembolic events remain the most common cause of morbidity and mortality during normal pregnancy, they may become even more frequent after traumatic injuries owing to the added hypercoagulability associated with trauma and are a frequent cause of maternal morbidity and death. The pregnancy is a hypercoagulable state due to the increased levels of fibrinogen and factors V, VII, VIII, IX, X, and XII, and placental inhibitor of fibrinolysis. There is also a release of tissue thromboplastin into the circulation at placental separation, venous stasis of the lower extremities, and an endothelial damage associated with parturition. Conversely, there is a decrease of fibrinolytic activity.[50]

Another important complication during pregnancy is the development of pregnancy-induced hypertension, occasionally with systolic blood pressure of 160 mm Hg and diastolic blood pressure of 110 mm Hg, which must be taken into account when treating a pregnant woman with traumatic injuries.

Predictive factors of outcome

The predictive factors can be subdivided depending if they pertain to the fetus or to the mother. There are several factors associated with risk to the fetus.[3,49,50] The most common factors are (1) maternal death, (2) maternal hypotension, (3) maternal traumatic brain injury, (4) high injury severity score, (5) pelvic fracture, (6) ejection of pregnant woman from a vehicle, and (7) severe abdominal injury to pregnant women. The predictive factors associated with maternal mortality include[3] (1) amniotic fluid embolism, (2) deep venous thrombosis and pulmonary embolism, and (3) infections.

Medico-legal implications

Depending on the outcome of the mother and the fetus after a motor vehicle collision or assault, physicians treating pregnant patients subjected to trauma are at risk of being involved in

legal and medico-legal actions that may require the treating physician to testify about the care rendered to the mother and the fetus. Therefore, it is imperative that all findings identified on serial examinations and by diagnostic studies, in addition to the degree of monitoring of the mother and the fetus, be accurately documented. Therefore, the evaluation and the recommendation for monitoring of the mother and the fetus for up to 4 hours after an accident or injury is not only necessary for maternal and fetal treatment but also to have complete documentation of maternal and fetal status during the stay at the trauma center while they received treatment.[44]

Injury prevention during pregnancy

Injury prevention deserves specific attention during pregnancy. The first area of prevention is related to the use of drugs and alcohol. The use of these substances is not only harmful to the fetus, but it is also associated with a high risk of injuries. In the same context, domestic violence is becoming a major cause of injury during pregnancy.[11] A study noted a 17% prevalence of physical or sexual abuse during pregnancy, with 60% of women having 2 or more episodes of assault.[84] Interpersonal violence is not dependent on race, age, marital status, or socioeconomic status; therefore, all pregnant women are potential victims of abuse.[84]

Conclusions

Injuries to the gravid uterus are rare and should be suspected in all assault victims and all patients with direct perineal trauma,[85] pelvic fractures, or penetrating injury to the pelvis. Thorough physical examination, preferably in the operating room, with prompt surgical treatment improves the outcome of these potentially challenging injuries. An obstetrician is an essential member of the multidisciplinary team for the initial assessment, stabilization, and subsequent management of a pregnant trauma victim. Pregnant women must be educated on the proper use of restraints, and screening for domestic abuse and depression are essential components of quality care of this unique population.

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Traumatic injuries to the pregnant patient: a critical literature review

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REVIEW ARTICLE

Traumatic injuries to the pregnant patient: a critical literature review

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Abstract
Introduction Trauma during pregnancy is the leading non-obstetrical cause of maternal death and a significant public health burden. This study reviews the most common causes of trauma during pregnancy, morbidity, and mortality, and the impact upon perinatal outcomes associated with trauma, providing a management approach to pregnant trauma patients.
Materials and methods A systematic review of the current literature from January 2006 to July 2016 was performed.
Results Fifty-one articles were identified, including a total of 95,949 patients. Motor vehicle crash was the most frequent cause of blunt trauma, followed by falls, assault both domestic and interpersonal violence, and penetrating injuries (gunshot and stab wounds).
Conclusions Trauma in pregnant women is associated with high rates of adverse maternal and neonatal outcomes. Knowledge of the mechanism of injury is important to identify the potential injuries and the complexity of the management of these patients. As in all traumatic events, prevention is of paramount importance.

Keywords Trauma · Pregnancy · Fetal injuries · Blunt · Penetrating

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Introduction

Trauma is the leading non-obstetrical cause of maternal death during pregnancy. However, it may be an underestimation of the true incidence of trauma during pregnancy due to the under-reporting of trauma, especially trauma from interpersonal violence [1]. The aim of this article is to review the literature regarding trauma during pregnancy focusing on the most common mechanisms of injury, and maternal and fetal outcomes.

Materials and methods

Articles in the English language between January 2006 and July 2016 on trauma during pregnancy were identified using the following key words: trauma and pregnancy, blunt trauma, penetrating wound, injury during pregnancy, motor vehicle accident/crash, falls, assault, interpersonal violence, fetal monitoring, perimortem cesarean section, obstetrical patient, pregnant trauma patient, and mortality and pregnancy.

Results

Of the 200 articles identified, 51 were included in this study for a total of 95,949 patients.

Blunt trauma is the most common mechanism of trauma among pregnant women accounting for 69% of the total number of traumas, whereas penetrating trauma accounts for only 1.5% of episodes of trauma during pregnancy. In 37 articles reviewed herein, MVC is not only the most common but also the most life-threatening of mechanisms on injury. Mortality occurred in 100 of 728 (13.7%) mothers

and 78/728 (10.7%) fetuses. The frequency of use of seat belts by pregnant women was available in 8 of the 37 articles in which MVC was reported mechanism of injury, which ranged from a low of 21% to high value of 98%.

The second most common cause of trauma during pregnancy, especially during the second and third trimester due primarily, amongst other reasons, to weight gain, and changes in the center of gravity. The reported prevalence of interpersonal violence ranges between 1 and 20% of all pregnant women. During pregnancy, there is a spatial redistribution of the viscera inside the abdominal cavity due to the progressive increase in the size of the uterus.

The impact of abdominal trauma on the fetus depends to high degree on the gestational age at the time of the trauma. Direct injury to the uterus and fetus is unlikely during the first 12 weeks of gestation due to the protective effect of the bony pelvis, unless the traumatic event has caused complex pelvic fractures.

Table 1 includes the total number of patients stratified by the mechanism of injury, whereas Table 2 reports prevalence rates based on the causes of trauma. Maternal and fetal mortality rates have been derived from 28 of the 51 articles that included maternal and fetal mortality data (Table 3).

Table 1 Mechanisms of injury

Author (year)	Total *n*	Blunt *n*	Penetrating *n*
Metz (2006) [2]	30	30	0
El Kady (2006) [3]	3292	3292	0
Barré (2006) [4]	95	95	0
Amiliene (2006) [5]	372	312	60
Weintraub (2006) [6]	54	54	0
Sperry (2006) [7]	151	NS	8
Hitosugi (2006) [8]	135	135	0
Kuo (2007) [9]	16,982	7100	335
Aboutanos (2007) [10]	294	259	NS
Greene (2007) [11]	352	NR	NR
Patteson (2007) [12]	188	NR	4
Kvarnstrand (2008) [13]	2270	2270	0
Weiss (2008) [14]	7350	3939	739
Cahill (2008) [15]	317	NR	NR
Klinich (2008) [16]	57	57	0
Aboutanos (2008) [17]	148	148	0
Schiff (2008) [18]	693	693	0
Nannini (2008) [19]	1468	1468	0
Dunning (2010) [20]	1070	1070	0
Cannada (2010) [21]	65	65	0
Tinker (2010) [22]	490	NR	NR
Vlahutin (2010) [23]	34	34	0
Schiff (2010) [24]	3348	3348	0
Petrone (2011) [1]	321	292	29
Preeti (2011) [25]	3763	NR	121
Vivian-Taylor (2012) [26]	2147	2147	0
Fischer (2011) [27]	5352	NR	NR
Lin (2011) [28]	27	NR	18
Meuleners (2011) [29]	468	468	0
Melamed (2012) [30]	411	411	0
Karadas (2012) [31]	139	NR	NR
Mesdaghinia (2012) [32]	32	32	0
Njoku (2013) [33]	63	56	5
Lailey (2013) [34]	126	126	0
Vlahutin (2013) [35]	25,168	25,168	0
Periyanayagam (2014) [36]	635	NR	NR
Brookfield (2013) [37]	351	284	67
Zangene (2014) [38]	102	69	33
Wall (2014) [39]	42	24	9
Okeke (2014) [40]	108	108	0
Harland (2014) [41]	1488	372	NR
Ibrahim (2015) [42]	819	819	0
Chibber (2015) [43]	728	728	0
Jackson (2015) [44]	36	36	0
Azar (2015) [45]	5936	5936	0
Van der Knoop (2015) [46]	16	16	0
Shakerian (2015) [47]	74	74	0
Weiner (2016) [48]	946	946	0
Miller (2016) [49]	3794	3794	0
Battaloglu (2016) [50]	173	164	9

Epidemiology

Trauma is the leading cause of death in pregnant women, and it is responsible for a high rate of maternal and fetal morbidity. While the reported rate of complications of pregnancy due to trauma appears low, this rate is likely underestimated due to under-reporting particularly in cases of domestic violence [1].

Based on our review, blunt trauma is the most common mechanism of trauma among pregnant women accounting for 69% of the total number of traumas, whereas penetrating trauma accounts for only 1.5% of episodes of trauma during pregnancy (Table 1). Among the causes of blunt trauma, MVC is the most frequent cause of injury followed by falls, assault, gunshot, and stab wounds (Table 2). The severity of gravid uterus injuries is graded using the Organ Injury Scale of the American Association for the Surgery of Trauma (AAST-OIS) [54] (Table 4).

In a review of 102 trauma pregnant patients by Zangene et al. [38], blunt trauma was found to be the cause of trauma in 68% of pregnant women compared to 32% who had penetrating trauma. The most common mechanism of injury was MVC followed by domestic violence. The traumatic event caused maternal injuries, mostly lower extremity injuries, in 67% of patients, and it was associated with a 13% incidence of fetal complications [placental abruption (PA) and preterm]. Wall and others [39] have reported blunt trauma as a MOI in 57% of all cases compared to 21% where the MOI was penetrating

Table 1 (continued)

Author (year)	Total *n*	Blunt *n*	Penetrating *n*
Distelhorst (2016) [51]	3429	NR	NR
Total	95,949	66,439 (69%)	1437 (1.5%)

NR not recorded, *NS* not specified

trauma. Of note, in this study, interpersonal violence was the most common cause of injury followed by MVC, 52 and 26%, respectively. Fetal deaths occurred in 90% of patients with severe injuries (ISS > 15) and urgent laparotomy was required in 86% of women presenting with direct trauma to the abdomen.

In 37 articles reviewed herein, MVC is not only the most common but also the most life-threatening of mechanisms on injury [12]. Chibber et al. [43] have reported that 647 of 728 (89%) pregnant women involved in MVC presented with maternal and fetal complications (placental and preterm labor, 59 and 40% respectively). Mortality occurred in 100 of 728 (13.7%) mothers and 78/728 (10.7%) fetuses. Ninety-one perimortem cesareans sections were performed with a maternal mortality of 66% (60/91) and a much lower fetal mortality rate, 18.6% (17/91).

Vivian-Taylor et al. [26] have reported a series of 2147 pregnant women involved in MVC. In 72 of 2147 (3.3%) patients, the traumatic event caused delivery during the trauma hospitalization, five (7%) of whom suffered pelvic fractures, six (8%) presented intra-abdominal injuries, and seven (10%) were admitted to the ICU, three of whom subsequently died. They concluded that the injuries from an MVC during pregnancy are independent risk factors for induced delivery with poor perinatal outcomes.

The association of maternal fractures and perinatal outcomes has been investigated in a retrospective cohort study of 3292 pregnant women by El Kady et al. [3]. In their cohort study, fractures were identified in 44% of pregnant patients involved in an MVC. Pelvic fractures increased the morbidity and mortality not only of mothers, but also of fetuses. Aboutanos [17] reported a 48-fold increase in fetal death in patients with pelvic and acetabular fractures from MVC. However, due to the absence of specific information regarding the type of pelvic and acetabular fractures in the study population, these authors were unable to establish a causal relationship between the fractures themselves and fetal mortality. It is likely that the presence of either pelvic or acetabular fractures is a marker of the severity of the transfer of energy to the pregnant uterus and that the type and/or complexity of the fractures itself is less important from the standpoint of the risk of fetal mortality. One finding of interest in this study is that the presence of pelvic fractures is an independent risk factor for stillbirth regardless of gestational age. Similar conclusions were reported in a study by Cannada et al. [21] in which pelvic fractures and acetabular fractures were shown to be associated with a 30% rate of fetal death.

The severity of the injuries sustained during MVC depends not only on the characteristics of the accident itself, but also on the appropriate use of safety devices such as airbags and seat belts on the part of the pregnant woman. The frequency of use of seat belts by pregnant women was available in 8 of the 37 articles in which MVC was the reported mechanism of injury, which ranged from a low of 21% to high value of 98%. The type and the severity of maternal and fetal injury in MVC accidents are related to the appropriate use of seat belts and/or the presence of frontal and lateral airbags. Five of the six deaths reported in a series of 160 pregnant women involved in MVC were unrestrained women, two drivers, and three passengers [12]. There is a high correlation between the absence of use of seat belts and the revised trauma score (RTS) severity of injury suffered by pregnant women involved in MVC. Additional supportive evidence of the value of seat belt use by pregnant women in MVC is provided by Luley et al. [34]. These authors have shown that women who do not wear seat belts suffer more severe injuries; furthermore, they require more frequently non-obstetric surgery, primarily orthopedic procedures, as a result of the injuries sustained when compared to pregnant women wearing seat belts, 25% as opposed to 7%, respectively. While airbag deployment was more frequent in patients who had abruption placenta and fetal loss, there was no statistically significant correlation between the both. It is very likely that the abruption placenta and fetal loss are the result of the force of the impact and the transfer of the kinetic energy to the pregnant uterus from the MVC rather than the abdominal trauma caused by the deployed airbag. The absence of causal relationship between airbag deployment and placental abruption was investigated by Metz and his collaborators [2] in a retrospective study of 30 pregnant women (20 or more weeks' gestation) who were involved in a MVC with a reported median speed of 35 mph. Among the 30 women, one experienced PA with subsequent intrauterine fetal demise. This study suggests that PA occurs with a low frequency with airbag deployment. Based on computer modeling in crash tests dummies, airbag deployment may be a risk factor for PA and fetal loss in unbelted pregnant women, but it does not increase the risk of PA and fetal loss in properly restrained pregnant women [53].

Klinich et al. [16] investigated how restraint conditions and crash characteristics affected the fetal outcome in 57 pregnant women. Fetal loss occurred in 12 of 41 properly restrained occupants (29%), in contrast to three of the six (50%) improperly restrained women. Eight of the ten (80%) unrestrained women had adverse fetal outcomes. The rate of fetal death in unbelted women was 62%, while 79% of properly restrained women had only minor complications.

Table 2 Prevalence of the causes of trauma

Author (year)	MVC (%)	Fall (%)	Assault (%)	GSW (%)	SW (%)	Others (%)
Metz (2006) [2]	100	0	0	0	0	–
El Kady (2006) [3]	44	25	10	0	0	–
Barré (2006) [4]	51	41	0	0	0	8
Aniulione (2006) [5]	NS	NS	NS	NS	NS	–
Weintraub (2006) [6]	NS	NS	NS	0	0	–
Sperry (2006) [7]	25	46	23	NR	NR	–
Hirasugi (2006) [8]	100	0	0	0	0	–
Kuo (2007) [9]	48	52	NS	1	NR	85
Abouzanos (2007) [10]	NS	NS	NS	NS	NS	–
Greene (2007) [11]	95	3	NR	NR	NR	–
Patterson (2007) [12]	85	6	2	1	NR	2
Kvarnstrand (2008) [13]	100	0	0	0	0	–
Weiss (2008) [14]	25	18	NS	0.1	NR	36
Cahill (2008) [15]	29	48	19	NR	NR	–
Klinich (2008) [16]	100	0	0	0	0	–
Abouzanos (2008) [17]	100	0	0	0	0	–
Schiff (2008) [18]	0	100	0	0	0	–
Nannini (2008) [19]	0	0	100	0	0	–
Dunning (2010) [20]	0	100	0	0	0	–
Canada (2010) [21]	40	41	8	0	0	6
Tinker (2010) [22]	34	52	NR	NR	NR	15
Vladutiu (2010) [23]	0	64	0	0	0	–
Schiff (2010) [24]	100	0	0	0	0	–
Petrone (2011) [1]	NR	NR	11	73	25	–
Peetti (2011) [25]	NR	NR	NR	NR	NR	–
Vivian-Taylor (2012) [26]	100	0	0	0	0	–
Fischer (2011) [27]	20	20	9	NR	NR	–
Lin (2011) [28]	0	0	34	48	18	–
Meeuwers (2011) [29]	0	0	100	NR	NR	–
Melamed (2012) [30]	39	50	3	0	0	–
Karadas (2012) [31]	21	56	NR	NR	NR	23
Mesdaghinia (2012) [32]	13	28	47	0	0	–
Njoku (2013) [33]	30	14	46	6	NR	–
Luley (2013) [34]	100	0	0	0	0	–
Vladutiu (2013) [35]	100	0	0	0	0	–
Periyanayagam (2014) [36]	75	NR	9	NR	NR	11
Brookfield (2013) [37]	72	4	4	10	9	–
Zangene (2014) [38]	47	26	25	NR	2	–
Wall (2014) [39]	26	7	52	10	7	–
Okeke (2014) [40]	0	100	0	0	0	–
Harland (2014) [41]	30	46	NR	NR	NR	–
Ibrahim (2015) [42]	0	0	100	0	0	–
Clubber (2015) [43]	100	0	0	0	0	–
Jackson (2015) [44]	0	0	100	0	0	–
Azar (2015) [45]	100	0	0	0	0	–
Van der Knoop (2015) [46]	50	44	6	0	0	–
Shakerian (2015) [47]	81	7	8	0	0	–
Weiner (2016) [48]	26	58	9	0	0	–
Miller (2016) [49]	100	0	0	0	0	–
Battaloglu (2016) [50]	56	32	11	NR	NR	–
Distelhorst (2016) [51]	33	32	5	NR	NR	–

NR not recorded, *NS* not specified, *MVC* motor vehicle collision, *GSW* gunshot wound, *SW* stab wound

Table 3 Maternal and fetal mortality

Author (year)	Maternal mortality (%)	Fetal mortality (%)
Metz (2006) [2]	NR	3
El Kady (2006) [3]	0.39	1
Barré (2006) [4]	NR	1
Aniniliene (2006) [5]	4	9
Hitosugi (2006) [8]	NR	55
Aboutanos (2007) [10]	0	4
Greene (2007) [11]	0	1
Patteson (2007) [12]	3	8
Kvarnstrand (2008) [13]	29	2
Weiss (2008) [14]	NR	1
Klinich (2008) [16]	NR	21
Aboutanos (2008) [17]	NR	5
Schiff (2008) [18]	NR	1
Schiff (2010) [24]	NR	0.4
Petrone (2011) [1]	9	83
Vivian-Taylor (2012) [26]	NR	31
Lin (2011) [28]	100	100
Meuleners (2011) [29]	NR	1
Melamed (2012) [30]	NR	1
Mesdaghinia (2012) [32]	0	1
Njoku (2013) [33]	2	8
Luley (2013) [34]	NR	4
Periyanayagam (2014) [36]	8	NR
Wall (2014) [39]	2	36
Chibber (2015) [43]	14	11
Shakerian (2015) [47]	NR	1
Miller (2016) [49]	NR	0.2
Distelhorst (2016) [51]	1	2

NR not recorded

Based on the results of their study, these authors conclude that women restrained by three-point seat belts are less likely to suffer severe injuries, with an 84% estimated reduction of the risk of fetal complications, potentially preventing an estimated 192 fetal losses.

Falls are the second most common cause of trauma during pregnancy, especially during the second and third trimester due primarily, amongst other reasons, to weight gain, and changes in the center of gravity. Most falls in pregnant women tend to be from a standing height. Schiff et al. [18] studied 693 women who fell during pregnancy, 79% of whom fell during the third trimester. The hospitalization rate was twice higher than in non-pregnant women, and resulted in a twofold increase in the risk of stillbirth. Although 54% of the patients had an ISS between one and eight, 90% required induction of labor, and 30% an emergency cesarean section. Okeke [40] has reported a 32.5% incidence of falls in a cross-sectional study of 332 pregnant women presenting in labor for delivery at the University of Nigeria Teaching Hospital Enugu, in Nigeria. This is similar to the 27% reported incidence of falls among pregnant women in the US [54].

Interpersonal violence during pregnancy poses also a high risk to both the mother and fetus. In the majority of cases, the injuries are limited to the soft tissues, head, neck, and torso sparing the abdomen. When the physical aggression is directed to the abdomen, there is an increased incidence of antepartum hemorrhage (AP) with subsequent perinatal complications. The reported prevalence of interpersonal violence ranges between 1 and 20% of all pregnant women, with the domestic partner identified as the aggressor in the majority of the cases [22]. However, the prevalence of interpersonal violence is affected by several factors, including socioeconomic factors, cultural upbringing, the status of women in the specific society, and the normative use of violence in conflict situations as it relates to different countries. Mesdaghinia et al. [32] have reported a 47% of incidence of domestic violence in Iran, especially during the second trimester of pregnancy. Ibrahim and others [42] have reviewed a series of 1857 Egyptian pregnant women to study the incidence of intimate partner abuse. In their study, 44% of pregnant women were found to have experienced some form of interpersonal violence, including physical violence (16%) and sexual assault (10%). According to the study of Meuleners et al. [29] that included 465 pregnant women exposed to interpersonal violence, injury associated with interpersonal violence resulted in a 1.7-fold risk in maternal

Table 4 AAST-OIS for gravid uterus [52]

Grade	Injury description
I	Hematoma or contusion without placental abruption
II	Superficial laceration < 1 cm in depth or placental abruption < 25%
III	Deep laceration 1 cm in depth in second trimester or placental abruption 25% but < 50%. Deep laceration in third trimester
IV	Laceration extending to the uterine artery. Deep laceration 1 cm with 50% placental abruption
V	Uterine rupture in second or third trimesters. Complete placental abruption

AAST-OIS American Association for the Surgery of Trauma Organ Injury Scale

complications (abortions, preterm, AP), and twofold risk in fetal adverse outcomes (low weight at birth, fetal distress, and fetal death). The risk of fetal death is directly correlated to the severity of maternal injuries. In the study by Njoku et al. [33] with a 50% reported incidence of domestic violence in pregnant women, 80% of fetal deaths occurred in women who had suffered severe maternal injuries, compared to a fetal loss rate of 20% in pregnant women with less severe injuries.

Pathophysiology

During pregnancy, there is a spatial redistribution of the viscera inside the abdominal cavity due to the progressive increase in the size of the uterus. The abdominal viscera are displaced cephalad as the uterus reaches the central region of the abdomen. That is the reason why penetrating abdominal injuries during the third trimester of pregnancy are associated not only with high maternal morbidity, but also with a significant increased incidence of uterine and fetal injury (60–70%), including a very high fetal death rate (40–65%). As reported by Shakerian et al. [47], the fetal death rate from stab and gunshot wounds is 42 and 71%, respectively. In a study by Petrone et al. [1], penetrating injuries, mostly gunshot wounds (73%) accounted for 9% of the mechanism of trauma in 321 pregnant women with abdominal trauma. The cohort of women suffering penetrating injuries had a significantly higher maternal morbidity (66 vs. 10%), as well as fetal mortality (73 vs. 10%) when compared to pregnant women who had blunt abdominal trauma.

The impact of abdominal trauma on the fetus depends to high degree on the gestational age at the time of the trauma. Direct injury to the uterus and fetus is unlikely during the first 12 weeks of gestation due to the protective effect of the bony pelvis, unless the traumatic event has caused complex pelvic fractures [55]. Miscarriage is uncommon following abdominal trauma during the first trimester unless the pregnant woman has suffered sustained hypotension leading to uterine hypoperfusion from extracavitary blood loss. Trauma during pregnancy can cause immediate fetal compromise; however, it can also be associated with delayed complications, such as delayed placenta abruption, which has been reported to occur up to 6 days after the traumatic event [56]. It is for this reason that prolonged fetal heart monitoring is required in pregnancies that have reached viability. Abdominal trauma may cause a subclinical chronic PA that may evolve into an acute episode of PA, preterm labor, premature membrane rupture, and placental insufficiency that may, in turn, cause fetal growth retardation, oligohydramnios, and low birth weight. The short- and long-term complications of blunt trauma during pregnancy were investigated by Melamed et al. [30] in a retrospective cohort study of 411 pregnant women. Thirteen women who had immediate complications were compared to 398 women who did not suffer any complications. In addition, 303 pregnant women who did not deliver at the time of the traumatic event were compared to a normal cohort of 909 matched by maternal age and parity to assess the impact of trauma on the outcome of the pregnancy. Immediate complications in the form of preterm labor and AP occurred in 3.2% of women. Independent risk factors for immediate complications included high severity of trauma, multiple gestations, vaginal bleeding, and the development of uterine contractions. Late-term complications, including preterm labor, PA, and perinatal morbidity, were also associated with a high ISS and the requirement for laparotomy at the time of the trauma.

Primary treatment

After the 10th week of pregnancy, there is an increase in plasma volume by up to 50% with a dilutional anemia secondary to a lesser increase in the red blood cell mass (15–30%) relative to the expansion of the plasma volume. These changes can provide some maternal tolerance to hemorrhagic shock. Therefore, symptoms such as tachycardia or hypotension may not occur until there is a blood loss, as high as 35% [57]. Blood pressure less than 80/40 mmHg, a pulse greater than 140 or less than 50 beats per minute, a respiratory rate less than 10 or greater than 24, and a fetal heart rate less than 110 or greater than 160 beats per minute are associated with the presence of shock. If used, the abdominal portion of the military anti-shock trousers (MAST) should be deflated en route, since compression can reduce blood flow to the placenta [57, 58]. The presence of any of the above reflects the severity of trauma and should alert the trauma surgeon to a high risk of maternal and fetal morbidity and mortality. In addition, during the second and third trimesters of pregnancy, the compression of the inferior vena cava in the supine position by the gravid uterus can contribute to a state of hypotension because of the decreased venous return. To avoid this, the patient must be placed in the 15°–30° left tilt position by placing a firm wedge underneath the right buttock/hip, manually displacing the uterus if necessary, always ensuring the immobilization of the cervical spine [57, 59].

The use of vasopressors, such as norepinephrine or phenylephrine, is not recommended, since they reduce placental perfusion, unless the patient does not respond to appropriate volume loading with crystalloids. Both the mother and the fetus are extremely vulnerable to hypoxia due to the respiratory changes associated with pregnancy, namely, a shallow breathing pattern, decreased functional residual capacity, and the increased oxygen consumption by 20%; therefore, the administration of supplemental oxygen is always required. The elevation of the diaphragm up to 4 cm compared to its normal anatomical position must be taken

into account when undertaking any thoracic procedure such as the performance of tube thoracostomy [56]. If necessary, the chest tube should be placed one or two intercostal spaces above the fifth intercostal space to avoid abdominal injuries. Due to the increased uterine size, there is a displacement of the lower esophageal sphincter that reduces its competence. In addition, the physiological inhibition of gastric motility and the increased relaxation of the lower esophageal sphincter predispose the pregnant woman to the risk of aspiration. To avoid aspiration, placement of a decompressive nasogastric tube is warranted [57, 59].

Definitive treatment

After the initial assessment is performed (Fig. 1) [60], and once maternal hemodynamic stability is reached, fetal monitoring should be initiated immediately. Information about the obstetric history such as gestational age, fetal maturity, date of delivery, and any other complication during pregnancy

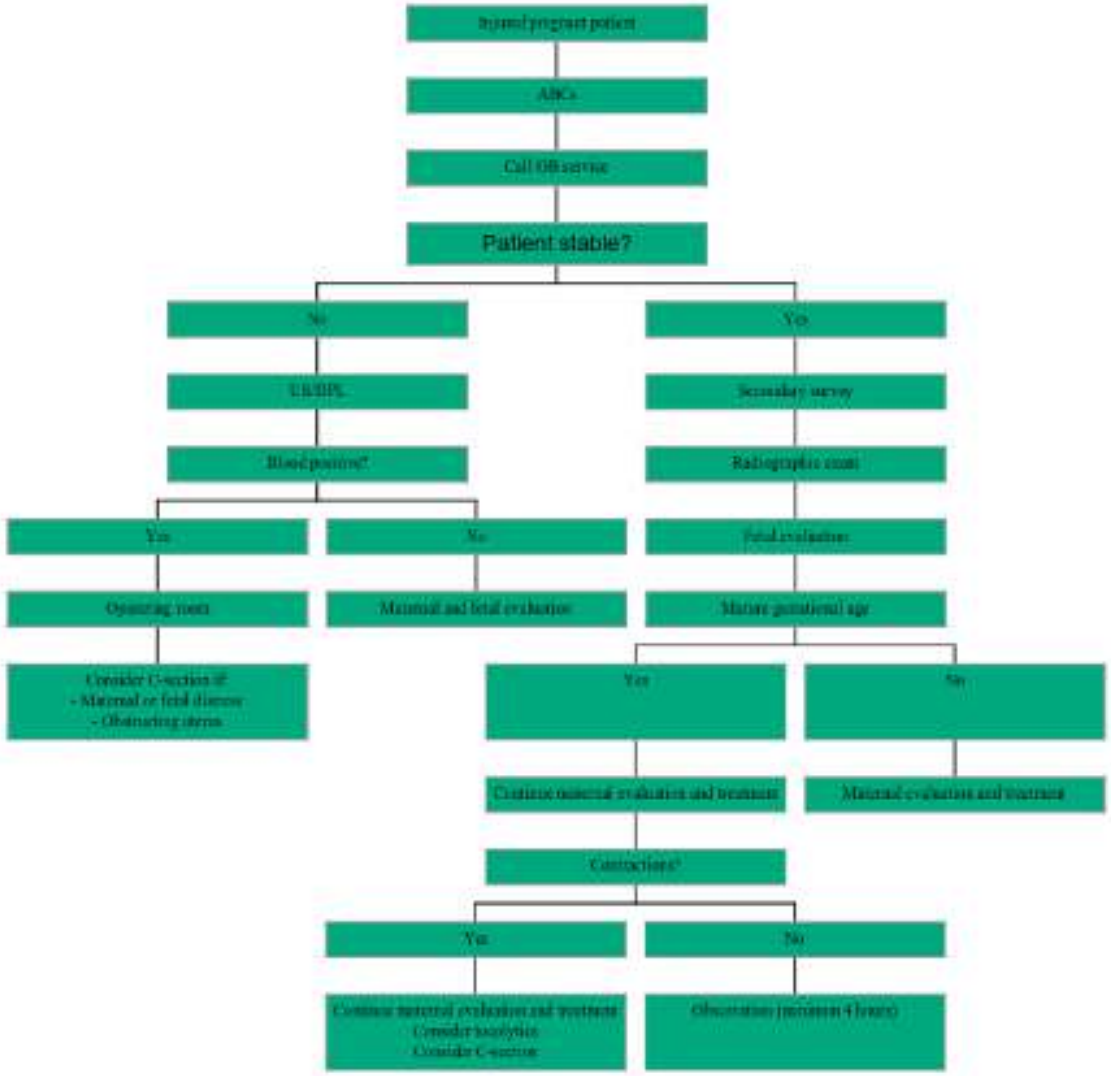

Fig. 1 Algorithm for initial maternal and fetal assessment [60]. *OB* Obstetrics, *US* ultrasound, *DPL* diagnostic peritoneal lavage, *C-section* cesarean section. Modified from Petrone P, Tillou A. Gynecologic injuries: trauma to gravid and nongravid uterus and female genitalia. In: Current therapy of trauma and surgical critical care. (Elsevier, Philadelphia, 2016), pp 401–407

must be obtained [59]. During the physical examination, particular attention should be paid to signs of trauma such as vaginal bleeding, spontaneous rupture of membranes, presence, intensity and frequency of uterine contractions, and abnormal fetal heart rate [58]. The possibility of bleeding and fetal-placental transfusion must be evaluated using the Kleihauer–Betke test, with appropriate administration of AntiD immunoglobulin in Rh negative mothers. A multidisciplinary assessment that includes evaluation by the obstetrician is recommended [60].

Imaging during pregnancy and the negative impact that radiation may have on fetal development remain controversial. However, if these tests are clinically justified, the indications for imaging are the same as for any other non-pregnant trauma patient, and do not have to be delayed as the benefits outweigh the risks. Fetal harm due to radiation depends on the gestational age of exposure, with the most vulnerable time being within the first 16 weeks of gestation [57]. Computed tomography (CT) scans can identify maternal and fetal injuries, but should be only performed when the patient is hemodynamically stable. Despite the high sensitivity and specificity of CT, focused abdominal sonography for trauma (FAST) is considered the gold standard due to its safety and a non-invasive nature. FAST can identify solid organs injuries, the presence of free fluid, fetal well-being, gestational age, amniotic fluid volume, and location of the placenta. Other diagnostic techniques, such as diagnostic peritoneal lavage (DPL) can be safely done, if performed above the umbilicus.

Maternal pelvic fractures are the most common cause of fetal death amongst traumatic injuries. When taken in isolation, pelvic fractures do not represent an indication for emergency cesarean section, since vaginal delivery can be performed safely, even in the third trimester of pregnancy in most cases [3, 21, 59]. Angioembolization is the ideal treatment for pelvic or retroperitoneal hemorrhage, although the radiation dose is considered excessive and it is not exempted of fetal complications [57].

When the fetus is viable (more than 24 weeks' gestation) continued fetal monitoring must be provided. A minimum of 2–6 h and up to 48 h of monitoring is recommended, as some cases of placental abruption have been reported more than 24 h after the initial injury. Fetal arrhythmia may be the first sign of maternal hemodynamic compromise. As placental perfusion and oxygenation depend directly on maternal cardiorespiratory condition, continuous fetal monitoring is recommended in cases of maternal acute respiratory distress syndrome, severe lung damage, or abnormal heart rhythm. In low-risk patients with minor trauma and once any maternal injury are excluded, fetal monitoring for 4 h appears to be a sufficient period of monitoring.

Perimortem cesarean section in viable fetuses can be successful if performed no later than 4 min following maternal cardiac arrest. Fetal survival rates are excellent with a reported fetal survival rate of 70%. A vertical uterine midline section is recommended to avoid injury to the uterine vessels. The recommendations [60, 61] for emergency cesarean section are listed in Table 5.

Table 5 Indications for emergency cesarean section [60, 61]

Viable pregnancies (> 24 weeks) or near term
Maternal death
Trauma patients with cardiac arrest
No later than 4 min of properly performed cardiopulmonary resuscitation that has failed
Loss of fetal well-being in viable fetus
Irreparable uterine rupture
Massive hemorrhage/shock
Threat to life from exsanguination from any cause
Mechanical limitation for maternal repair
Unstable thoracolumbar spine injury

Conclusion

Trauma in pregnant women represents a significant public health burden and a clinical challenge for the trauma surgeon given the complexity of the pregnant woman. The priority should always lie with the mother. While injuries to the gravid uterus are uncommon, they should be suspected in all assault victims and all patients with direct perineal trauma, pelvic fractures, or penetrating injury to the pelvis. An obstetrician is an essential member of the multidisciplinary team for the initial assessment, stabilization, and subsequent management of a pregnant trauma victim. Pregnant women must be educated on the proper use of restraints, and screening for domestic abuse and depression are essential components of quality care of this unique population. It is of a great importance that all professionals specializing in treating trauma patients recognize and are aware of the anatomic and physiologic changes that occur to pregnant women and how these changes can impact the evaluation and treatment of this unique patient population.

Compliance with ethical standards

Conflict of interest Patrizio Petrone, Patricia Jiménez Morillas, Alexander Axelrad, and Corrado P. Marini declare that they have no conflict of interest.

Informed consent This research consisted of literature review only, and, therefore, did not involve human participants or animals.

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E. Resultados

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Abdominal injuries in pregnancy: a 155-month study at two level 1 trauma centers

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ABSTRACT

Introduction: Trauma in pregnancy is the leading cause of non-obstetrical maternal death and remains a major cause of fetal demise. The objective of this study was to examine the outcomes of pregnant patients sustaining abdominal injury.

Patients and methods: This is a retrospective analysis of all pregnant trauma patients admitted to two level 1 trauma centres from February 1, 1996 to December 31, 2008. Patient data abstracted included mechanism of injury, physiologic parameters on admission, Injury Severity Score (ISS), abdominal Abbreviated Injury Scale (AIS), gestational age, diagnostic and surgical procedures performed, complications, and maternal and fetal mortality. Univariate analysis and logistic regression analysis were used.

Results: During the 155-month study period, 321 pregnant patients were included, of which 291 (91%) sustained a blunt injury, while 30 (9%) were victims of penetrating trauma. Of the penetrating injuries, 22 (73%) were gunshot wounds, 7 (23%) stab wounds, and 1 (4%) shotgun injury. The overall maternal and fetal mortality was 3% (n = 9) and 16% (n = 45), respectively. Mean age was 22 ± 6 year-old, and the mean ISS was 12 ± 16. The overall mean abdominal AIS was 2 ± 1.2. When adjusted for age, abdominal AIS, ISS, and diastolic blood pressure, the penetrating trauma group experienced higher maternal mortality [7% vs. 2% (adjusted OR: 7; 95% CI: 0.65–79), p = 0.098], significantly higher fetal mortality [73% vs. 10% (adjusted OR: 34; 95% CI: 11–124), p < 0.0001] and maternal morbidity [66% vs. 10% (adjusted OR: 25; 95% CI: 9–79) p < 0.0001].

Conclusions: Fetal mortality and overall maternal morbidity remains exceedingly high, at 73% and 66%, respectively, following penetrating abdominal injury. Penetrating injury mechanism, severity of abdominal injury and maternal hypotension on admission were independently associated with an increased risk for fetal demise following traumatic insult during pregnancy.

Introduction

Trauma in pregnancy is the leading non-obstetrical cause of maternal death and remains the most common cause of fetal demise. It has been reported that nearly 50% of maternal deaths are related to injury and almost 7% of all pregnancies are complicated by traumatic insults.[1]

The possibility of a pregnancy must be considered in all injured females between the ages of 10 and 50 years.[2,3] Pregnancy produces significant physiologic and anatomic changes in multiple organ systems[4,5,6,7] essential to be appreciated in order to provide appropriate care to both mother and unborn child. The evaluation, interpretation of diagnostic test results and management of the injured pregnant patient must be accompanied by the full comprehension of all physiologic alterations occurring during pregnancy.[3]

To our knowledge, only limited series[2,3,8,9,11] of pregnant patients sustaining blunt injury and only one multi-institutional study[10] including both blunt and penetrating trauma combined have been previously reported. However, studies focusing mainly on penetrating injuries during pregnancy are lacking. The objective of this study was to review the subgroup of pregnant trauma victims sustaining abdominal injury.

Patients and methods

After Institutional Review Board (IRB) approval by both participating trauma centers, a retrospective review of all trauma admissions to Los Angeles County + University of Southern California Medical Center and University Medical Center of Nevada

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from February 1, 1996 to December 31, 2008 was performed. Inclusion criteria consisted of all pregnant patients requiring hospital admission following injury. Data were extracted from the trauma registries at the two centers and included demographic characteristics, Injury Severity Score (ISS), Revised Trauma Score (RTS), abdominal Abbreviated Injury Scale (AIS), physiologic parameters at admission to the Emergency Department (ED), diagnostic and surgical interventions performed, in-hospital complications, maternal and fetal mortality, and Surgical Intensive Care Unit (SICU) and hospital lengths of stay.

The two-sided Fisher's exact test was used for testing the difference between proportions and the Mann–Whitney rank-sum test was utilised for testing the difference between means. Factors that were different between the two study groups at $p < 0.05$ were entered into a logistic regression model for adjustment. Adjusted odds ratio (OR) and its 95% confidence interval (CI) for the outcomes were derived. The SAS statistical program (SAS Institute Inc., Cary, NC) was used for all analysis.

Results

During the 155-month study period, 321 pregnant patients were included in the study. Overall, blunt and penetrating injuries occurred in 291 (91%) and 30 (9%) patients, respectively. Among these 30 victims of penetrating insult, 22 (73%) sustained gunshot wounds (GSW), 7 (23%) stab wounds (SW), and 1 (3%) shotgun injury. Mean age was 22 ± 6 year-old, and the mean ISS was 12 ± 16. Patient's demographics and physiologic characteristics are listed in Table 1. The overall mean abdominal AIS was 2 ± 1.2 and 2 ± 2 among patients sustaining penetrating insults. Forty-one percent of the patients (n = 12) sustained an abdominal injury, and 14% (n = 4) underwent cesarean section. The diagnostic procedures performed are listed in Table 2. The overall maternal mortality in the present series was 3% (n = 9), and the overall fetal mortality was 16% (n = 45). In the cohort of penetrating trauma patients, two women (7%) and 19 fetuses (73%) died. When adjusted for age, abdominal AIS, ISS, and diastolic blood pressure, no difference in maternal mortality was identified (7% vs. 2%; p = 0.090). Fetal mortality, however, was significantly higher in the penetrating injury cohort (73% vs. 10%; adjusted OR: 34; 95% CI: 11–124; $p < 0.0001$), in which the uterine injury occurred in the majority of the patients. The penetrating trauma cohort also had a significantly higher maternal morbidity rate (66% vs. 10%; adjusted OR: 25; 95% CI: 9–79; $p < 0.0001$) after adjustment (Table 3). The most common complication was ileus (57%) in the penetrating trauma group, followed by abortion (5%) in the blunt trauma group. The penetrating trauma group had a longer hospital length of stay (7 ± 9 vs. 4 ± 8; p = 0.058) as compared to the blunt trauma group.

Table 1
Demographic and physiologic characteristics of the study population.

	All patients (n = 321)	Penetrating trauma (n = 30)
Age (years)	25 ± 6	22 ± 6
Gestational age (weeks)	19 ± 10	17 ± 10
Vital signs of admission		
Fetal heart rate (beats/min)	73 ± 16	82 ± 22
Systolic blood pressure (mm Hg)	125 ± 22	129 ± 23
Heart rate (beats/min)	96 ± 20	101 ± 22
Respiratory rate (breaths/min)	20 ± 6	20 ± 3
Fetal heart rate (beats/min)	126 ± 48	114 ± 55
GCS	14 ± 1	14 ± 3
RTS	9 ± 2	8 ± 2
ISS	7 ± 11	12 ± 15
Abdominal AIS	2 ± 1.2	2 ± 2

GCS, Glasgow Coma Scale; RTS, Revised Trauma Score; ISS, Injury Severity Score; AIS, Abbreviated Injury Scale.

Table 2
Diagnostic modalities deployed.

	Penetrating trauma (n = 30)
Plain films	38%
CT abdomen	27%
Transabdominal pelvic ultrasound	15%
Tocodynamics	11%

CT, computed tomography.

Table 3
Adjusted* outcomes following penetrating and blunt trauma in during pregnancy.

Outcome	Penetrating trauma (n = 30)	Blunt trauma (n = 291)	Adjusted odds ratio (95% CI)	Adjusted p-value
Maternal mortality	7%	2%	7.28 (0.65–79)	0.090
Fetal mortality	73%	10%	34 (11–124)	<0.0001

* Adjusted for age, abdominal injury, ISS, and diastolic blood pressure.

Discussion

Penetrating injuries are exceedingly uncommon in pregnant population reflected by the lack of larger series on the topic. Nevertheless, Aniulene et al.[2] reported, in a Medline-based review of 13 years, that injury affects almost 8% of all pregnancies, however, only 16% of those victims sustain penetrating injury. Likewise, in our series a total of 9% of the cohort sustained a penetrating insult, predominantly GSW, in excess of 70% of cases.

All initial treatment priorities also in pregnant trauma victim follow ATLS principles.[1] Once life-threatening injuries have been addressed, the secondary survey of fertile female should include assessment of potential pregnancy, fetal age, and its possible extra-uterine survival prompting pertinent monitoring of fetal distress with cardiotocography.[21]

The incidence of uterine injury increases significantly after penetrating abdominal trauma, as the pregnant uterus expands beyond the pelvis by the 12th week of pregnancy. In the second half of pregnancy the vast majority of penetrating injuries to anterior abdomen are associated with uterine injury.[17,12] Nevertheless, by the middle of the second trimester, the uterine musculature is capable of absorbing most of the wounding energy resulting in a low maternal death-rate in these instances.[17,12] Stab wounds during pregnancy, in general, are less likely to cause maternal bowel injury. However, upper abdominal stab wounds may result in a complex bowel injury because of the cephalad bowel displacement. Gunshot wounds to the uterus cause frequently fetal injuries in 60–70% of cases. Such lesions are associated with fetal death in 40–65%.[17,12,19] In the current series, penetrating mechanisms of injury were significantly more frequently associated with abdominal insults at 41%. Likewise, penetrating mechanisms of injury resulted in significantly higher rate of fetal demise, overall morbidity, and in an obvious trend of maternal mortality in current series.

Emergency caesarian section may be indicated when fetal survival is noted following penetrating injury to the uterus.[22] Fetal viability is defined as 25 weeks of gestation, which corresponds to a fundal height halfway between the umbilicus and the costal margin,[10] and at this stage timing of the caesarian section is critical as the fetus has 40–70% chance of survival.[20] Indications for emergency caesarian section included maternal shock, threat to life from exsanguinations from any cause, irreparable uterine injury, fetal distress in a viable fetus,

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unstable thoracolumbar spine injury, pregnancy near term, and maternal death.[22] Morris et al.[15] reported that the emergency caesarian section performed after 25 weeks of gestation for specific indications following trauma is associated with 45% fetal survival and 72% maternal survival. If the caesarian section and delivery are done within 5 min, there is an excellent probability of survival, but it is more unlikely as the time increases. Caesarian sections were performed in 8% of the penetrating trauma patients in our series, of which fetal mortality was significantly high.

It has been reported that 10–30% of women are abused during their pregnancy, and 5% of the cases involving abuse result in fetal death.[8,13] In our series, consistent with the literature, overall 11% of patients reported domestic assault. These insults may be highly unreported in the pregnant population in the present series in concordance with other reports.[17,18]

Although this study has some limitations, such as the retrospective design and the small number of subjects enrolled, this is to the best of our knowledge the largest series assembled from the two institutions focusing on penetrating abdominal injuries during pregnancy.

The penetrating trauma cohort of pregnant patients experienced higher maternal mortality [7% vs. 2% (adjusted OR: 7; 95% CI: 0.65–79), $p = 0.090$], significantly higher fetal mortality [73% vs. 10% (adjusted OR: 34; 95% CI: 11–124), $p < 0.0001$] and maternal morbidity [66% vs. 10% (adjusted OR: 25; 95% CI: 9–79) $p < 0.0001$] while adjusting for age, abdominal AIS, ISS, and diastolic blood pressure.

Conclusions

Assessment of a female trauma patient in the fertile age should always include the possibility of pregnancy. Fetal mortality and overall maternal morbidity remains exceedingly high, at 73% and 66%, respectively, following penetrating abdominal injury. Penetrating injury mechanism, severity of abdominal injury and maternal hypotension on admission were independently associated with an increased risk for fetal demise following traumatic insult during pregnancy.

Conflict of interest

None.

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Trauma in pregnant patients

Introduction

Over the past several decades, traumatic injuries have been identified as major contributors to maternal and fetal morbidity and mortality. Traumatic injuries, most commonly accidental, and occasionally the result of intentional violence, are now considered the leading cause of death during pregnancy. Fildes and colleagues[1] reported that nearly 50% of maternal deaths are caused by trauma. From 6%-7% of all pregnancies are complicated by trauma, and 0.4% of pregnant patients require hospitalization for the treatment of traumatic injuries.[2] The actual number of injured pregnant women is underestimated because many of them are unreported, especially those due to domestic violence.

Although major blunt and penetrating trauma is more likely to affect both a pregnant woman and her fetus, complications limited to the pregnancy itself, such as abruption placenta and fetal injuries, can occur after relatively minor trauma to the abdomen from falls, domestic abuse, and low-speed motor vehicle accidents.

The possibility of a pregnancy must be considered in all injured women between the ages of 10 and 50 years.[3] Pregnancy produces major physiological and anatomical changes in multiple organ systems that may affect the response of a pregnant woman to trauma. It is essential for a trauma surgeon or any practitioner taking care of a pregnant trauma patient to understand the effect of the physiological changes occurring during the early and late pregnancy on the symptoms and signs of the trauma victim to provide the appropriate care to both the mother and the unborn child. The evaluation, interpretation of diagnostic tests, and management of the injured pregnant patient must take place within the context of all the physiological alterations occurring during pregnancy.[3]

It is essential that all professionals responsible for the treatment of trauma patients recognize and be aware of the anatomical and physiological changes that occur to pregnant women and how these changes may affect the evaluation and treatment of this unique patient population.[3] Clearly, a comprehensive evaluation of these patients must include the assessment of the fetus to save the pregnancy.

Historical perspective

The oldest known cases of traumatic injury during pregnancy are referenced in the Code of Hammurabi (15th century BC)[4] and the Old Testament (Exodus 22:21). Penetrating injuries to the gravid uterus from spears, sticks, and animal horns have been observed from ancient times.

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The famous military surgeon Ambroise Paré, who was also an obstetrician, was the first to describe the treatment of penetrating injuries to the uterus.[5] He wrote, "When the womb is wounded, the blood cometh out at the privites, and all other accidents appeared."

Articles written in past centuries about trauma in pregnancy identified falls, battering, and assaults as the most common causes of traumatic injuries during pregnancy.[6] However, with the evolution from a less to a more industrialized society, the etiology of traumatic injuries has evolved from those previously reported to those typical of a more industrialized society, such as motor vehicle crashes and penetrating trauma from stab and gunshot wounds.

Epidemiology

The Center for Injury Research and Prevention in Pittsburgh, Pennsylvania, published in 1995 an excellent epidemiologic 1-year study[7] that included all women of childbearing age requiring hospitalization for injuries. Of the 16,722 women having traumatic injuries, 761 were identified (4.6%) as being pregnant. The most common causes of injury were motor vehicle collisions (33.6%), falls (26.4%), poisonings (16%), and "struck by or against" (11.4%). The mean age of injured pregnant women was 24.9 years. Weiss and colleagues[8] reported a 3-year study in which 240 traumatic fetal injury deaths were identified (3.7 fetal deaths per 100,000 live births). Motor vehicle collisions were the leading trauma mechanism (82% of cases), followed by firearm injuries (6% of cases) and fall-related injuries (3% of cases).

Traumatic injury–related fetal mortality was reported by the same author[9] in a 2-year study, with data from only 1 state: 31 of 7131 (0.4%) fetal deaths were ascribed to trauma, whereas the fetal death rate was 6.5 per 100,000 live births. Motor vehicle collisions were the leading cause of injury (81%) and placental separation was the most common diagnosis (42%).

More recently, Leggon and colleagues[10] reported a very extensive literature review from 1932 through 2000, including 101 pelvic and acetabular fractures during pregnancy. They found that the average age of the women was 25 years, and associated maternal injuries were noted in 60% of the patients. The most common mechanism of injury was motor vehicle collisions (73%), followed by falls (14%) and automobile-pedestrian collisions (13%). The overall maternal mortality rate was 9%, and the fetal mortality rate was 35%. The mortality stratified by the mechanism of injury led to the following observations. Firstly, automobile-pedestrian collisions were responsible for 7% (3 of 11) of maternal mortality and 45% (5 of 11) of fetal mortality. Secondly, motor vehicle collisions were associated with 6% (4 of 63) of maternal mortality and 37% (23 of 63) of fetal mortality. Lastly, falls did not cause maternal deaths (0 of 12) but were associated with an 8% (1 of 12) fetal mortality. These authors concluded that automobile-pedestrian collisions have a statistical trend for higher maternal mortality, whereas vehicular collisions tend to cause more fetal deaths.

Young pregnant women are also at high risk for battering. It has been reported that 10%-30% of women are abused during pregnancy, and 5% of cases involving abuse result in fetal death.[11] Physical abuse should be suspected based on the pattern of injuries. Although motor vehicle collisions and pedestrian struck type of injuries tend to affect more commonly the distal extremities, pelvis, and abdomen, the injuries caused by physical abuse tend to be more proximal and more commonly in the midline. Pregnant women subjected to physical abuse typically present with injuries to the neck, breast, face, upper arms, and lateral thighs, as well as with bizarre injuries such as cigarette burns and bites.[12] Because domestic violence is associated with a wide range of psychological, psychosomatic, and physical conditions, the diagnosis requires a high degree of suspicion and astute clinical skills. The most common symptoms associated with domestic violence include headache, chronic pain, gynecologic symptoms, posttraumatic stress disorder, acute and chronic injuries such as those described earlier, and substance abuse, among other conditions.[13]

An estimated 33% of abused women have anxiety and depression, and 26% of female suicide attempts are by women experiencing interpersonal violence, but this number is underestimated, as these injuries are unreported, especially in the pregnant population. Identified risk factors for

trauma during pregnancy include younger age,[7] drug and alcohol use, and domestic violence.[12,14,15] Berenson and collegues[16] found that battered women were more likely to use alcohol and tobacco. Holland and colleagues[17] reported a 21% incidence of preterm birth when pregnant women tested positive for drugs.

Although in general the physical abuse to a pregnant woman is aimed at injuring the person herself, occasionally the physical abuse is directed specifically to the gravid abdomen, with the intent of causing fetal injury.[18] Battering can initiate or escalate during pregnancy; however, pregnancy can be a protective hiatus for some women. It is estimated that between 10% and 30% of women are abused during pregnancy, with a fetal mortality of 5%.[19] In a review of domestic violence, intimate partner violence and battering was reported to occur in 1 of every 12 pregnancies in the inner city.[15] Intimate partner violence contributed to 20% of all nonfatal violent crimes experienced by women.[20] Homicide rates for African American women were 3 times higher than those for white women.[21] According to Chang and colleagues,[22] homicide is the third leading cause of injury-related death for all women of childbearing age, independent of pregnancy status. They reported a homicide rate of 1.7 per 100,000 live births. Risk factors for homicide during pregnancy included age younger than 20 years, belonging to the African American ethnic group, and later or no prenatal care. The most common mechanisms of injury were gunshots (58%), stabbing (18%), strangulation (14%), and battering (8%).[22]

Ikossi and colleagues[23] identified factors predictive of injury in a group of pregnant women. Based on the National Trauma Data Bank (NTDB) of the American College of Surgeons, among the 77,321 women of childbearing age hospitalized for traumatic injuries, 1.5% (1195) were pregnant. The most common mechanisms of injury in this review article were motor vehicle crash (70%), interpersonal violence (11.6%), and falls (9.3%). Young age at the time of the pregnancy, African American or Hispanic heritage, and lack of insurance or underinsurance status were the highest risk factors for injury during pregnancy.

Depression during pregnancy and postpartum has contributed to a higher suicide-related maternal mortality rate.[22,24,25] All pregnant and postpartum women have to be screened for depression to prevent the possibility of suicidal ideation and the possibility of attempts to suicide. Suicide remains the fourth leading cause of female mortality[26]; however, pregnant women have a lower risk of successful suicide than that of women who are not pregnant.[27,28] The attempted suicide rate during pregnancy has been estimated to be 0.4 per 1000 pregnancies.[29] Common methods of attempted suicide include drug overdose and poisoning with a corrosive substance.[1,29]

Table 1
Changes in maternal physiology during pregnancy.

Change	Consequence
Cardiac output and blood volume increase	Shock after more than 40% of blood loss
Expansion of plasma volume	Physiological anemia
Decline in arterial and venous pressure	Vital signs are not reflective of hemodynamic status
Increase of resting pulse	
Chest enlargement	Change in anatomical landmarks
Diaphragm rise	Caution during thoracic procedures (eg, thoracostomy)
Substernal angle increase	
Decrease in functional residual capacity	Rapid decline in PO_2 during apnea or airway obstruction
Increase in oxygen consumption	
Airway closure when supine	
Increase in tidal volume and minute ventilation	Reduction in PCO_2 and bicarbonate levels
Decrease in anesthetic requirements	Need for adjustment of sedative doses
Decreased gastric motility	Risk of aspiration
Relaxation of gastroesophageal sphincter	

Adapted with permission from Tillou and Petrone.[40]

Anatomical and physiological changes

The initial assessment and management for resuscitation of an injured pregnant patient are always the same as in nonpregnant patients, although the anatomical and physiological changes during pregnancy may alter the response to the injury. It is essential to understand all the changes that occur during this period to provide appropriate care to both the mother and the unborn child (Table 1).[1]

Cardiovascular System

The plasma volume begins to expand at 10 weeks of gestation. The increases in estrogen, progesterone, renin, and aldosterone levels contribute to expand the plasma volume by up to 45% of pregravid levels. In particular, the enhanced activity of aldosterone is responsible for an additional resorption of approximately 950 mEq of sodium each day, which in turn leads to retention of approximately 6-8 L of total body water by the third trimester of the pregnancy.[30]

This hypervolemic state, which is teleologically meant to compensate for the blood loss of approximately 500 mL that occurs at the time of vaginal delivery and which can also protect the mother from the blood loss of approximately 1000 mL associated with a cesarean delivery, is protective of the mother in the case of hemorrhage from trauma.

Because of increased plasma volume in relation to the red cell mass, the pregnant woman develops a "physiological anemia" with a hematocrit of 31%-35% in the late pregnancy.

Because of the increase in plasma volume, the pregnant patient may lose 35% of the circulating blood volume before exhibiting any sign or symptom of maternal shock, giving a false sense of security to the caregiver. The white blood cell count increases, reaching values as high as 25,000 per mm^3 during labor. The levels of coagulation factors and fibrinogen are increased, and the fibrinolytic activity is reduced; this results in a hypercoagulable state that accounts for the increased risk of venous thromboembolism during the pregnancy.

The pulse rate also increases gradually 10-15 beats per minute throughout pregnancy, mainly because the diaphragm becomes more elevated secondary to the enlarged uterus that causes a lateral displacement of the cardiac apex, reaching the maximum by the third trimester. The mean blood pressure averages 105/60, 102/55, and 108/67 mm Hg, by the first, second, and third trimester, respectively. Levels of blood pressures more than these mean values should alert the physician to the possibility of pregnancy-induced hypertension.

By the end of the first trimester, cardiac output increases by 1.0-1.5 L/min, which represents approximately 25% more than the normal value because of an increase in plasma volume and the decrease in vascular resistance of the uterus and placenta.[31]

A point worth emphasizing is the maternal position during the second half of the pregnancy. When the patient is in supine position, the inferior vena cava is partially obstructed by the enlarged uterus; thus, there is a decrease in blood return to the right side of the heart, resulting in a decrease in cardiac output, causing the "supine hypotensive syndrome," which is characterized by dizziness, pallor, tachycardia, sweating, and hypotension. This condition is relieved when the patient is turned to the left lateral decubitus position.

Respiratory System

As previously mentioned, the diaphragm rises approximately 4 cm and the chest diameter increases by 2 cm, increasing the substernal angle by approximately 50°.[32] These changes occur secondary to hormonal effects and from the mechanical pressure imposed by the enlarged uterus. To avoid iatrogenic complications, these anatomical changes should be taken into consideration when thoracic procedures such as tube thoracostomy, placement of pigtail catheters, and thoracentesis are being performed.

The most notable changes in respiratory physiology and oxygen use include increased minute ventilation and vital capacity with decreased residual volume and functional residual capacity,

as well as an increase in oxygen consumption by approximately 20%. The rise in minute ventilation is caused primarily by the increase in tidal volume, which averages 200 mL. The respiratory rate does not alter significantly throughout pregnancy. The arterial partial pressure of oxygen remains unchanged, whereas the partial pressure of carbon dioxide decreases because of the augmented minute ventilation. The pH does not change because of the compensatory decrease in the plasma bicarbonate level; therefore, the pregnant woman develops a state of compensated respiratory alkalosis.[33] Because of the reduced functional residual capacity, pregnant patients do not tolerate apnea well, and supplemental oxygen is always indicated.

Gastrointestinal system

Gastrointestinal motility, intestinal secretion, and absorption are reduced because of increased levels of progesterone and estrogen during pregnancy. In addition, because of the partial displacement of the lower esophageal sphincter into the thorax and the decreased tone of the lower esophageal sphincter from the action of progesterone, which is associated with decreased gastric emptying, a pregnant woman is at a higher risk of aspiration following a traumatic event.

As the uterus continues to grow, the small bowel is displaced laterally and superiorly, making it more vulnerable to penetrating trauma to the upper abdomen. Biliary secretion is also altered, as shown by the increase of the alkaline phosphatase levels to nearly twice its normal value.[34] Because of the decreased flow-dependent biliary secretion and the decreased cholecystokinin-induced gall bladder emptying, both caused by the increased level of progesterone, a pregnant woman is prone to bile stasis and to the formation of gall bladder sludge and gallstones, which can be documented by the end of the second trimester in 31% and 3% of pregnant women, respectively.[35–37] There is also a decrease in the level of plasma albumin to an average of 3.0 g/dL, but this is probably dilutional and not due to compromised synthetic activity.[38]

Renal system

The renal system also is affected during pregnancy. The earliest change is an increase of the renal blood flow by approximately 30% that increases the creatinine clearance. Therefore, the serum levels of creatinine and blood urea nitrogen are markedly decreased during pregnancy. By 26 weeks of gestation, renal plasma blood flow and glomerular filtration rate are 80% and 50% more than the normal baseline values, respectively.[39,40] Because of these increases, more plasma is filtered, diminishing the protein levels and therefore the oncotic pressure, which places the pregnant patient at a higher risk of pulmonary edema. As the uterus becomes larger, the ureters and bladder are compressed, resulting in hydronephrosis and hydroureter; thus, a dilated collecting system in a pregnant patient is normal. Because of the anterior and superior displacement of the bladder, it becomes more susceptible to lower abdominal injuries.

Endocrine system

The pituitary gland enlarges by 0.08 mm/wk, reaching a maximum height of 10-12 mm immediately postpartum; this represents an increase of approximately 135% from its original size.[41] Owing to the more dominant enlargement of the anterior lobe of the gland and its increased blood requirement, this portion of the gland is more prone to ischemia and necrosis particularly in pregnant women with type 1 diabetes mellitus. Traumatic shock may cause antepartum necrosis of the anterior part of the gland, causing pituitary insufficiency, as opposed to the Sheehan syndrome, which is a postpartum pituitary necrosis caused typically by massive bleeding during or after delivery.

The placenta produces human chorionic gonadotropin, human placental lactogen, progesterone, estrogen, thyroid-stimulating hormone, and adrenocorticotropic hormone.[41] Because

estriol production depends on the appropriate function of the fetal-placenta system, it can be used as a marker of fetal and placental well-being.[42]

Musculoskeletal system

The softening and relaxation of the interosseus ligaments during pregnancy widens the sacroiliac joint and the pubic symphysis from 4-8 mm. Because of these changes, the maternal center of gravity is disrupted, and a pregnant woman attempts to compensate assuming a more lordotic posture, resulting in an increased risk of falls.

Neurologic system

Intracerebral hemorrhage is the most common cause of death in patients with pregnancy-induced hypertension, and because it can produce seizures, it may mimic a head injury. It should be suspected when hypertension is associated with hyperreflexia, proteinuria, and peripheral edema.

Reproductive system

The weight of the uterus increases 60 times, ranging from 60 -1000 g by the end of the gestation. After the third month, the uterus is outside the pelvis, and by the third trimester, it is at a level above the umbilicus, displacing the hollow viscous viscera upward and laterally.

Uterine blood flow increases by approximately 500 mL/min; this represents an increase of approximately 17% of the cardiac output.[43] Simultaneously, uterine veins may enlarge up to 60 times their size when compared with the prepregnant state. The increased vascularity of the uterus and the pelvis resulting from the increased inflow caused by the expanded runoff provided by the gravid uterus places a pregnant woman at a higher risk of massive bleeding in the case of pelvic fracture or uterine injury.

Assessment and management

Prehospital care

Prehospital personnel must be aware of the physiological changes associated with pregnancy, in particular, the importance of providing supplemental oxygen for preventing maternal and fetal hypoxia and of infusing intravenous fluids liberally during the transport of these patients. Because of the increased intravascular volume, these patients can lose a significant amount of circulating blood volume before the development of tachycardia, hypotension, and other signs of acute blood loss.

Military antishock trousers (MAST), also known as a pneumatic antishock garment, are a 1-piece inflatable device that has been used to support blood pressure in hypotensive patients during transport to the trauma center. The current indications include the presence of severe hypotension in patients with suspected or documented pelvic fractures and temporary support of blood pressure in patients with hemorrhage from abdominal trauma who are on route to the operating room or to another facility.[44] The MAST are potentially harmful to pregnant women in the second and third trimester of pregnancy and are relatively contraindicated in pregnancy other than for a ruptured ectopic pregnancy.[45] The emergency department team must be aware to limit the inflation of the MAST only to the leg compartments and to avoid inflation of the abdominal section if used while transporting a pregnant woman whose pregnancy has progressed beyond midterm gestation, because inflation of the abdominal compartment of the MAST can compromise uteroplacental blood flow.[45] Deflation should occur in the hospital only

after intravenous lines are secured and after appropriate volume loading with crystalloids, blood products, and control of the bleeding source.[44]

To avoid the supine hypotension associated with the uterine aortocaval compression (Fig 1), patients after 20 weeks of gestation should be transported on a backboard tilted to the left by 15°, paying special attention to the immobilization of the cervical spine.[3,45] The aortocaval compression by the uterus decreases the venous return to the right heart, causing supine hypotension because of the reduced stroke volume and cardiac output. It is noteworthy that aortocaval compression from the enlarged uterus can compromise the effectiveness of chest compressions during cardiopulmonary resuscitation (CPR) in the third trimester of pregnancy. If the patient is in a supine position, the right hip should be elevated 4-6 in (15-30°), placing a firm wedge under the right hip to achieve tilt. In cases of major trauma, the wedge should be placed under the spinal board. If lateral tilt is not feasible, manual uterine displacement to minimize inferior vena cava compression is indicated: standing on the woman's left, the physician places both the hands around the uterus and gently pulls the uterus toward himself or herself.[47]

Primary survey

The priorities for treatment of an injured pregnant patient remain the same as those for the treatment of a nonpregnant patient. The primary survey includes establishing the patency of the airway, maintaining the breathing, and providing adequate support of the circulation with volume replacement and hemorrhage control, if necessary, with the understanding that the treatment of the mother takes precedence over the treatment of the fetus.[48]

Severe trauma induces the release of maternal catecholamines that cause uteroplacental vasoconstriction, compromising the fetal circulation. Therefore, supplemental oxygen is always indicated to prevent maternal and fetal hypoxia. Because of the increased cardiac output present in pregnant patients, the increase in oxygen in solution provided by the administration of supplemental oxygen may increase oxygen delivery to the fetus.

Hypovolemia should be suspected in all pregnant victims of trauma before it becomes clinically apparent, because the pregnancy-induced hypervolemia may mask significant blood losses, and the occurrence of shock may be delayed. Vigorous volume resuscitation is encouraged even for patients who appear normotensive after major trauma.

Fig. 1. Compression of the inferior vena cava (within the oval) in advanced pregnancy. (From Dr Patrizio Petrone's personal archives.) (Color version of figure is available online.)

Secondary survey

The secondary survey consists of obtaining the obstetrical history, a physical examination, and evaluation and monitoring of the fetus. All necessary radiological investigations should be performed regardless of the pregnancy. Comorbid factors such as pregnancy-induced hypertension and diabetes mellitus should be known to provide proper treatment. The obstetrical history of preterm labor or placental abruption places the patient at increased risk for the recurrence of this condition. The obstetric history includes previous episodes of preterm labor, placental abruption, the date of the last menstrual cycle, expected date of delivery, and any problem or complications of the current and previous pregnancies.

The abdominal examination is critically important, as well as the determination of the uterine size, which provides an approximation of gestational age and fetal maturity (Figs 2 and 3). It is important to stratify the pregnant patient into 1 of the categories shown in Table 2.[47] The fetus is usually considered viable when it has a 50% chance of extrauterine survival. With the use

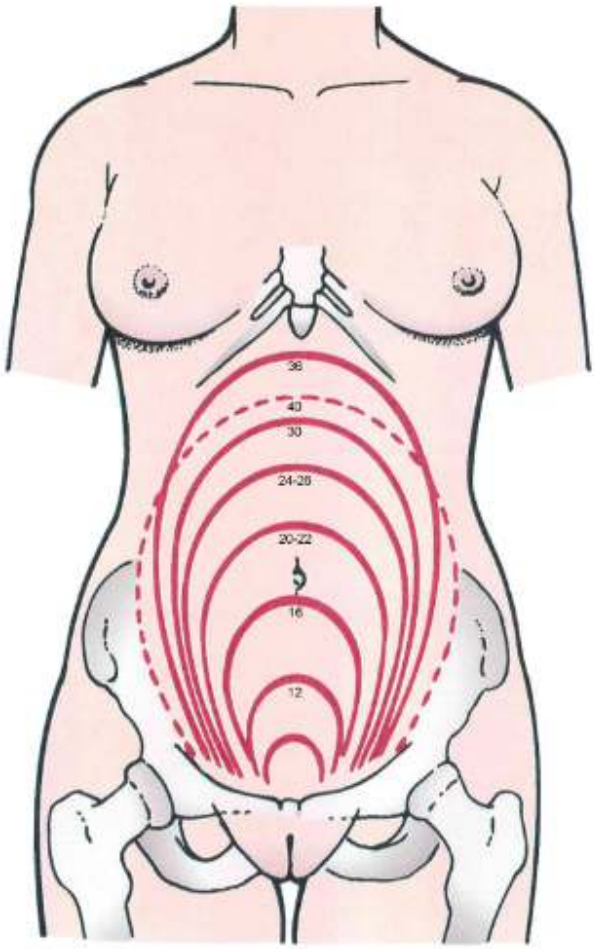

Fig. 2. Location and size of uterus during different stages of pregnancy. The numbers indicate weeks of gestation. (Modified with permission from Wilson SF ed. Assessment of the Pregnant Patient. *Health Assessment for Nursing Practice*. 4th ed. Mosby; 2009.) (Color version of figure is available online.)

Fig. 3. Exploratory laparotomy in a pregnant patient at approximately 26 weeks of gestation. (From Dr Patrizio Petrone's personal archives.) (Color version of figure is available online.)

of advanced neonatal supportive capabilities, newborns weighing 500-600 g can be supported in appropriate neonatal intensive care units with 20%-30% chance of meaningful survival. Decisions regarding fetal viability are based on the assessed gestational age by ultrasonography; however, it must be mentioned that even with the use of the most advanced technology, gestational age is subject to an error of 1-2 weeks. A rule of thumb assessment of gestational age in the trauma bay uses the umbilicus as the landmark of potential fetal viability. If the fundus of the uterus extends above the umbilicus, the fetus is considered potentially viable. A discrepancy between gestational dates and uterine size is suggestive of uterine rupture or uterine hemorrhage. Uterine rupture is suspected by the presence of peritonitis, findings of extrauterine fetal parts on abdominal palpation, as well as the inability to palpate the fundus of the uterus. However, the abdominal examination may be unreliable and cannot be relied upon as the sole diagnostic modality. An algorithm for initial maternal and fetal assessment is presented in Figure 4.[49]

There are 6 conditions suggesting potential harm to the pregnancy itself in a patient who has experienced a traumatic event that must be assessed at the time of the evaluation of the pregnant patient.[48] They include one or more of the following conditions:

1. Vaginal bleeding: it can suggest premature cervical dilation, early labor, placental abruption or placenta previa.

Table 2
Patient stratification by category.

Category	Considerations
Potentially pregnant	History alone is unreliable in excluding pregnancy Perform a pregnancy test on all women of childbearing age who sustained trauma Where pregnancy is confirmed after a trauma event, provide counseling on the implications (ie, radiographic studies)
Previable gestation (< 24 wk)	Dates and estimations of gestational age may be inaccurate or unreliable Where in doubt, presume viability Document presence or absence of fetal heart rate
Viable gestation	Gestation greater than 24 wk Start cardiotocograph monitoring
Perimortem	Evaluate to perform cesarean delivery

Adapted with permission from Queensland Clinical Guidelines.[47]

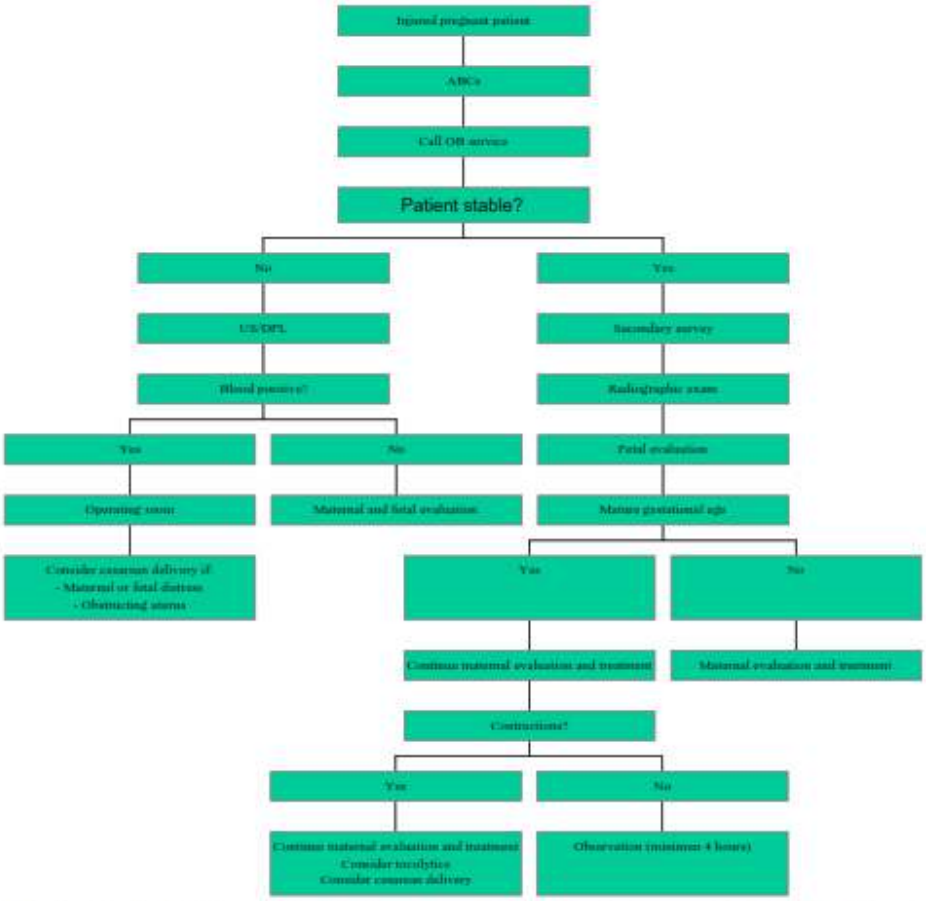

Fig. 4. Algorithm for initial maternal and fetal assessment. OB, obstetrics; US, ultrasound. (Color version of figure is available online.)

2. Ruptured membranes: prolapse of the umbilical cord can occur, resulting in compression of the umbilical vein and arteries.
3. Bulging perineum: caused by pressure from extrauterine located parts of the fetus.
4. Presence and patterns of contractions: their presence is important, so preparation for an eventual and early delivery can be made.
5. Abnormal fetal heart rate and rhythm.
6. Kleihauer-Betke test: is used after maternal injury to identify fetal blood in the maternal circulation (fetomaternal hemorrhage).

Fetomaternal hemorrhage

FMH, the transplacental hemorrhage of fetal blood into the normally separate maternal circulation, is a unique complication of trauma during pregnancy.[51] The reported incidence of FMH after trauma is approximately 10%-30%.[52] There is no proven correlation between the severity of trauma, gestational age, and frequency and volume of FMH. Complications of FMH include Rh sensitization in the mother, fetal anemia, fetal paroxystic atrial tachycardia, fetal hypoxia, intrauterine death from exsanguination, or neonatal neurologic damage.[53]

Theoretically, FMH is possible by the fourth week of gestation; some authors suggest that FMH becomes a concern only after 12 weeks of gestation when the uterus rises above the pelvis and becomes an organ susceptible to direct trauma. FMH is detected by the KB test, an acid elution technique on maternal blood. On examination, adult cells remain colorless, whereas fetal red blood cells turn bright purple-pink. The ratio of fetal cells to maternal cells is recorded, enabling calculation of the volume of fetal blood leaked into the maternal circulation.

The management of the FMH includes continuous electronic fetal monitoring of the viable fetus, abdominal ultrasound to detect fetal heart activity, placental location, amniotic fluid index, and excluding intraperitoneal bleeding. Elevated peak systolic velocity of the fetal middle cerebral artery correlates with fetal anemia.[54,55] Occasionally, emergency cesarean delivery may be indicated.[47]

Most clinical laboratories screen 1000 red blood cells taken from the mother. A maternal blood volume of 5 L is commonly assumed in the laboratory formulas used; therefore, the presence of 1 fetal cell per 1000 cells counted corresponds to a FMH of 5 mL. However, the amount of FMH sufficient to sensitize most Rh-negative women is well less than the 5-mL sensitivity level of the standard laboratory's KB test. As little as 1 mL of Rh-positive blood can sensitize 70% of Rh-negative women. Currently, several commercial kits expedite and simplify the test process. Unfortunately, the sensitivity of the KB test remains low. Therefore, all Rh-negative mothers who present with a history of abdominal trauma should receive 1 prophylactic dose of 300 μg of Rho(D) immune globulin (RHOgam) within 72 hours of the traumatic event. Although controversial, the KB test should be reserved for Rh-negative women who are at risk for massive FMH that would exceed the efficacy of 1 dose of immune globulin (ie, more than 30 mL). According to some studies, less than 1% of all trauma cases and only 3.1% of major trauma cases exceed the coverage provided by 1 dose of 300 μg Rh immune globulin. As a general rule, 300 μg of Rh immune globulin should be given for every 30 mL of fetal blood found in the maternal circulation. The KB test should be performed in all pregnant patients with gestational age more than 12 weeks.[56–58] For cases of documented FMH, some studies recommend repeating the KB test in 24 hours to check for ongoing bleeding.

Radiographic examination

Indicated radiographic studies should be performed independent of the status of the pregnancy (Fig 5). The effect of radiation on the pregnancy is completely dependent on the gestational age of the fetus.[59] Before the third week of gestation, during preimplantation and early implantation, exposure to radiation can result in death of the embryo. Between 3 and 16 weeks of gestation, during organogenesis, radiation can damage the developing fetal tube, resulting in anomalies in the central nervous system. After 16 weeks, neurologic defects are the most common complications.[60] Prenatal radiation exposure may be associated with some childhood cancers.[61]

Most of the human data on exposure to radiation are not based on doses applied during normal diagnostic studies. Although there is existing concern about radiation exposure during pregnancy, in general, the benefits of the radiological investigations outweigh the risks associated with it. However, unnecessary duplication of films should be avoided. It is generally believed that exposure of the fetus to less than 5-10 rad causes no increase in the risk of congenital malformations, intrauterine growth retardation, or miscarriage. Radiation doses from common imaging studies are shown in Table 3.[61–63] The American College of Obstetricians and Gynecologists (ACOG) has published a consensus statement[64] with the following recommendations: (a) Women should be counseled that x-ray exposure from a single diagnostic procedure does not result in harm to the fetus or the pregnancy; (b) Concern about possible effects of high-dose ionizing radiation should not prevent medically indicated diagnostic x-ray procedures from being performed during pregnancy; (c) Consultation with an expert in dosimetry calculation may be helpful when several diagnostic x-rays are required. Specifically, exposure to less than 5 rad has not been associated with an increase in fetal anomalies or pregnancy loss.[64]

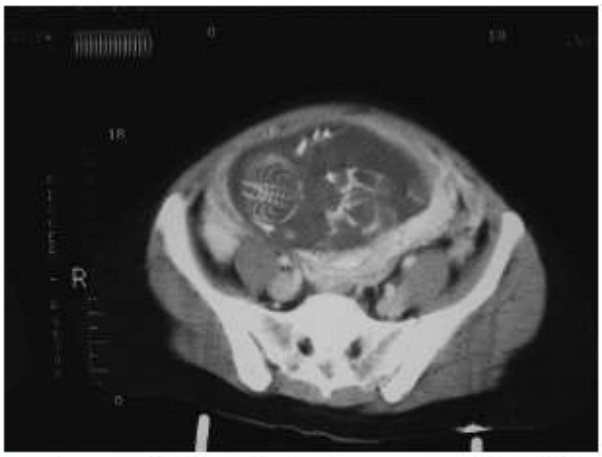

Fig. 5. Abdominal computed tomography (CT) scanning in a pregnant woman. (From Dr Patrizio Petrone's personal archives.)

Important statements on radiographic studies were also made by the American College of Radiology and the National Council on Radiation Protection, including that no single diagnostic procedure results in a radiation dose that threatens the well-being of the developing embryo and fetus.[63] Furthermore, fetal risk is considered negligible at 5 rad or less when compared with the other risks of pregnancy, and the risk of malformations is significantly increased only when levels of radiation exposure exceed 15 rads.[66]

Although there have been no documented adverse effects reported, the National Radiological Protection Board arbitrarily advises against the use of magnetic resonance imaging in the first trimester.[64] There have been no reports of documented adverse fetal effects from diagnostic ultrasound procedures, including duplex Doppler imaging, and there are no contraindications to ultrasound procedures during pregnancy. Ultrasonography has largely replaced x-ray as the primary method of fetal imaging during pregnancy.[64]

In summary, the following guidelines are suggested: First, limit the number of radiographic studies to the minimum necessary to establish the diagnosis, avoiding unnecessary duplications. Second, shield the abdomen with a lead apron when a radiological study does not involve

Table 3
Estimated fetal exposure.

Procedure	Fetal exposure (rad)	Number of studies required for a cumulative 5-rad dose
Chest x-ray (2 views)	0.00007	71,429
Abdominal film (multiple view)	0.245	20
Cervical spine	0.002	2500
Upper or lower extremity	0.001	5000
Thoracic spine	0.009	555
Lumbosacral spine	0.359	13
Pelvis	0.040	125
Hip (single view)	0.213	23
Head CT (10 slices/10 mm)	< 0.050	> 100
Chest CT (10 slices/10 mm)	< 0.100	> 50
Abdomen/lumbar spine CT	3.5	1

CT, computed tomography. (Modified with permission from Queensland Clinical Guidelines[47] and Tillou and Petrone.[49])

investigation of the abdomen. Third, limit the number of radiographs required over a protracted intensive care unit stay in critically ill patients.

Fetal assessment

Fetal evaluation begins with checking the fetal heart rate and documenting the presence of fetal movement. Currently, the most valuable information regarding fetal viability can be obtained by a combination of monitoring of the fetal heart rate and ultrasound imaging. Fetal heart tones can be detected by auscultation or Doppler probe. This should be accomplished early in the secondary survey and repeated frequently. The normal range for the fetal heart rate is 120-160 beats per minute. Continuous electronic fetal heart rate monitoring remains the most widely used modality for evaluation of the fetus and is an adjunct to the monitoring of the maternal condition. The use of electronic fetal heart rate monitoring permits prompt identification of fetal distress including the possibility of asphyxia and fetal death. Any viable fetus of 24 or more weeks of gestation requires monitoring after a trauma event. This includes patients with no obvious signs of external abdominal injury, because direct impact is not necessary for fetoplacental pathology to occur.[50,51]

The objective of the monitoring is to identify premature labor, placental abruption, and fetal distress. The combination of high-resolution real-time ultrasonography and cardiotocographic monitoring (CTM) appears to have the highest sensitivity and specificity. They should both be instituted as soon as feasible without interfering with maternal resuscitative efforts.[51]

The most common obstetrical problem caused by trauma is the occurrence of premature uterine contractions. Myometrial and decidual cells, damaged by contusion or placental separation, release prostaglandins that stimulate uterine contractions. Progression from uterine contractions to actual labor depends on the size of uterine damage, the amount of prostaglandins released, and the gestational age of the pregnancy. Some studies question the routine use of tocolytics for the prevention of premature labor after trauma, because most of the contractions (90%) stop spontaneously, and persistent contractions are often pathologic in origin, thus, in itself, a contraindication to tocolytic therapy.[51]

Blunt trauma to the abdomen can result in uterine rupture, but this event is uncommon and usually rapidly fatal for the fetus. A much more common event is placental separation from the uterus because of the shearing forces following blunt injury. This separation is called placental abruption.[67] Although placental abruption involving more than 50% separation of the placenta from uterus is uniformly fatal for the fetus, minor cases may initially go undetected. Placental abruption after trauma occurs in 2%-4% of minor accidents and in up to 50% of major injuries. Separation results as the inelastic placenta shears away from the elastic uterus during sudden deformation of the uterus. Abruption can occur with little or no external signs of injury to the abdominal wall. Maternal mortality from abruption is less than 1%, but fetal death rates range from 20%-35%. Clinical findings suggestive of abruption include vaginal bleeding, abdominal cramps, uterine tenderness, amniotic fluid leakage, maternal hypovolemia, a uterus larger than normal for the gestational age, or a change in the fetal heart rate. When present after trauma, vaginal bleeding is an ominous sign often indicative of placental separation. The first test to confirm the presence of abruption is the transabdominal ultrasound (less than 50% accurate). CTM is more sensitive in detecting placental abruption by fetal distress than ultrasound by visualization. CTM should be started in the resuscitation room and continued for a minimum of 6 hours. A minimum of 24 hours of CTM is recommended for patients with frequent uterine activity (more than 6 contractions per hour), abdominal or uterine tenderness, ruptured membranes, vaginal bleeding, or hypotension. Fetal distress is associated with placental abruption 60% of the time.[50,51]

Table 4
The American Association for the Surgery of Trauma-Organ Injury Scale (AAST-OIS) for gravid uterus.

Grade	Injury description	AIS-90 score
I	Hematoma or contusion without placental abruption	2
II	Superficial laceration < 1 cm in depth or partial placental abruption 25%	3
III	Deep laceration 1 cm in depth in second trimester or placental abruption 25% but < 50%; deep laceration in third trimester	3-4
IV	Laceration extending to the uterine artery; deep laceration 1 cm with 50% placental abruption	4
V	Uterine rupture in second or third trimester; complete placental abruption	4-5

AIS, abbreviated injury scale. (Adapted with permission from Tillou and Petrone.[49])

Abdominal evaluation

Accurate evaluation of the abdomen in a pregnant patient may be challenging. Special attention should be given to the evaluation of pregnant women who have 1 or more of the following: rib or pelvic fractures; unexplained hypotension; vaginal blood loss; hematuria; or altered sensorium due to drugs, alcohol, or brain injury.

A diagnostic peritoneal lavage (DPL) can be performed safely and has the same sensitivity as in nonpregnant patients. DPL should be performed superior to the umbilicus using an open technique. Abdominal computed tomography scanning can also be performed safely with an evaluation of both the mother and the fetus, but the patient must be hemodynamically stable. Focused abdominal sonography for trauma has a major role in the abdominal evaluation because it can rapidly detect intra-abdominal and pericardial fluid in the mother as well as assess the general fetal condition. The American Association for the Surgery of Trauma-Organ Injury Scale (AAST-OIS) for gravid uterus is shown in Table 4.[08]

Mechanisms of injury

Differences regarding the mechanisms of injury in pregnancy must be recognized in gravid patients. Overall, 17% of injured pregnant patients experience trauma because of assaults, and 60% of pregnant women have been exposed to repeated episodes of domestic violence.[48] Table 5 shows the leading causes of maternal traumatic injury and death.[3,44]

Blunt injury

The most frequent blunt mechanism of injury is motor vehicle collision, followed by assault and falls. Nonoperative management of hemodynamically stable patients with solid abdominal organ injury can be accomplished successfully in most pregnant patients. In contrast, unstable

Table 5
Causes of maternal traumatic injury and death.

Motor vehicle collision
Violence and assault
Gunshots
Stabbing
Strangulation
Falls
Auto vs pedestrian
Suicide
Drug overdose
Poisoning
Burns

patients or stable patients with suspected intestinal injury benefit from early operative treatment, as hypotension and sepsis can be harmful or even lethal for the fetus.

In the first and early second trimester, the pregnant uterus is an endopelvic rather than an abdominal organ. At 13-14 weeks of gestation, the uterus is just above the pubic symphysis and therefore is unlikely to be subjected to direct trauma because it is protected by the bony pelvis. Fetal loss in the first trimester is rarely attributable to direct uterine trauma but usually is due to maternal hypotension and the consequent hypoperfusion of the uterus and the developing fetus, or to the mother's death.

The management of pelvic fractures can be particularly challenging in pregnant patients. Leggon and colleagues[10] reported on 101 cases of pelvic or acetabular fractures in pregnant women from 1932-2000. This report identified 3 mechanisms of injury: motor vehicle collisions (73%), falls (14%), and pedestrian struck by a car (13%). The mortality rate correlated with mechanism of injury and the injury severity score. The overall fetal mortality rate in patients with pelvic and acetabular fractures was 35%, compared with a 9% maternal mortality.[10] Hemorrhage from dilated retroperitoneal veins can cause hemorrhagic shock and death.[61]

In nonpregnant patients, bleeding from complex pelvic fractures is usually controlled with angioembolization; however, the dose of radiation necessary to achieve control of bleeding with angioembolization in pregnant patients exceeds the upper limit of what is considered safe during pregnancy.

The abdominal wall, uterine myometrium, and amniotic fluid act as a cushion to direct forces from blunt trauma, but in some instances, blunt trauma can be so severe that it may cause uterine rupture (Fig 6). Uterine rupture occurs in less than 1% of pregnant trauma victims but has an obvious grave prognosis for the fetus and the mother.[69–71] As the uterus becomes an

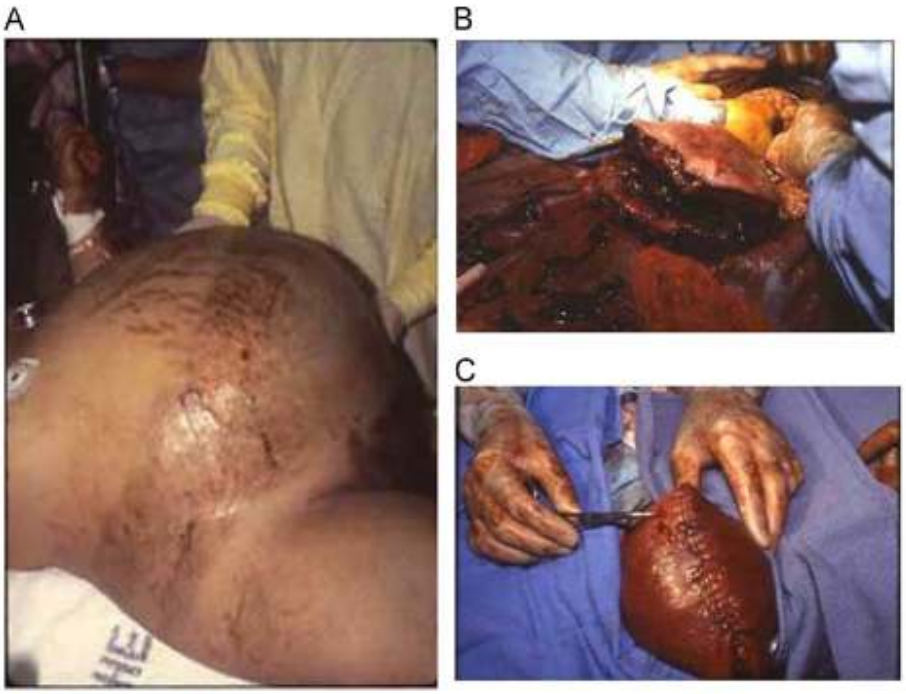

Fig. 6. (A) Pregnant patient unrestrained ejected through the windshield and rollover by a car. The tire mark on the abdomen is shown. (B) Rupture of the uterus of the same patient. She was pregnant with triplets; all of them died. (C) Reconstruction of the uterus was accomplished. (From Dr Patrizio Petrone's personal archives.) (Color version of figure is available online.)

abdominal organ, the risk of direct uterine trauma and rupture increases. The enhanced uterine vascularity and blood flow associated with the advancing pregnancy increase the possibility of massive hemorrhage if the uterus is injured and the uterine vasculature is disrupted.[72,73] The extent of uterine damage and injury to adjacent organs cannot be predicted on clinical presentation and is typically not apparent until exploratory surgery is performed. However, surgeons must be prepared to act quickly to avoid the consequences of severe hemorrhage and to prevent the development of the deadly triad of hypothermia, acidosis, and coagulopathy. If the uterus is severely damaged and cannot be repaired expeditiously, then hysterectomy is appropriate to prevent further deterioration in the woman's condition and the associated maternal morbidity and mortality.

The most common causes of fetal death include placental abruption due to anoxia, prematurity, and exsanguination. The manifestations include vaginal bleeding, abdominal pain, uterine tenderness, and contractions.[67] One of the most serious complications associated with abruption is the occurrence of disseminated intravascular coagulation, activated by the migration of thromboplastin from the placenta into the maternal circulation. In this setting, cesarean delivery should be avoided because it is associated with a very high risk of hemorrhage, hysterectomy, and subsequent death.

Because of evidence that the use of car restraint reduces both maternal and fetal morbidity and mortality, the ACOG recommends seat belt use in pregnant women to reduce both maternal and fetal morbidity and mortality.[64,74] Education on the proper use of restraints should be a standard component of all prenatal care programs. The use of 3-point seat belt restraints during pregnancy is highly recommended. The National Highway Transportation Safety Administration (NHTSA) recommends that pregnant women wear their seatbelts between the breasts, and the lap belt portion under the pregnant abdomen as low as possible on the hips and across the upper thighs, and not above or over the abdomen.

Penetrating injury

As the uterus increases in size and expands out of the pelvis, it becomes more vulnerable to penetrating trauma. Penetrating injuries are exceedingly uncommon in the pregnant population; this is reflected by the absence of larger series on the topic. Nevertheless, Aniulene and colleagues[75] reported, in a MEDLINE-based review encompassing 13 years, that 16% of injuries in pregnant women were caused by penetrating injury. Likewise, in the series by Petrone and colleagues[76] of abdominal injuries in pregnancy, 9% of the cohort reported in the review sustained a penetrating insult, with more than 70% of penetrating injuries caused from gunshot wounds.

Because of the thickness of the uterine musculature, the uterus can absorb the energy from low-velocity penetrating injuries; therefore, maternal death is relatively uncommon with injuries limited to the uterus. In contrast, because of the upward displacement of the intestine from the enlarged gravid uterus, penetrating injuries to the upper abdomen tend to be more frequently associated with massive bowel injury that may cause maternal death.

However, the extent of injury from single gunshot wounds depends on the type of firearm, the size and muzzle velocity of the bullet, the distance from perpetrator to the victim, and the anatomical region penetrated by the bullet and on the subsequent secondary missiles created by the impact of the bullet. Although maternal deaths are relatively rare with penetrating injuries limited to the uterus, fetal injury and fetal mortality rates are very high if the uterus is the main organ affected by either stabbing or gunshot wounds.[64] Fetal death is dependent on the amount of placental or umbilical cord disruption. Up to 60%-70% of the fetuses sustain injuries after abdominal gunshot wounds, with a fetal death rate reported to be as high as 71% with gunshot injuries[77] (Fig 7) and 42% with stabbings.[78] Gunshot wounds to the uterus carry a maternal mortality rate of 7%-9%.[77]

Pregnant women with gunshot wounds to the abdomen should undergo exploratory surgery with debridement of damaged tissues. Stab wounds to the abdomen should be managed in a

Fig. 7. Entrance of the bullet in the head of fetus. Delivered by cesarean section. (From Dr Patrizio Petrone's personal archives.) (Color version of figure is available online.)

manner similar to the management in nonpregnant patients if intra-abdominal injury is suspected. In cases of gunshot wounds, if the bullet has penetrated the uterus and the fetus is viable, cesarean delivery is indicated.

If a surgical procedure other than a nonobstetric procedure is required, it is extremely important to maintain adequate maternal oxygenation, circulating blood volume, and uterine perfusion. DPL can be performed safely in all trimesters using an open direct visualization technique through a supraumbilical incision[78] or under ultrasound guidance at a point above the umbilicus. Tube thoracostomy should be performed 1 or 2 interspaces higher than usual because of elevation of the diaphragm. The surgical team should never allow the enlarged uterus to compromise surgical exploration. However, the performance of an exploratory laparotomy is not in itself a justification for the delivery of the fetus. If there is significant potential for coagulopathy such as from a placental abruption, it may be beneficial to proceed with evacuation of the uterus whether the fetus is viable. Coagulopathy further complicates the hemorrhagic picture and leads to a more complicated perioperative management and the possibility of the development of the adult respiratory distress syndrome. Fetal heart monitoring should be performed throughout surgery. Hysterectomy is required if the uterus is injured beyond repair from penetrating trauma.

Perimortem cesarean delivery

The fetus is considered viable after 25 weeks of gestation, which corresponds to a fundal height halfway between the umbilicus and the costal margin. Cesarean delivery at this stage of gestation is indicated after maternal death, as the fetus has a 40%-70% chance of survival.[80,81] An important variable affecting the survival and functional outcome of the fetus is the time interval between maternal death and the cesarean delivery. If the cesarean delivery is accomplished within 5 minutes or less of maternal death, the fetus has an excellent probability of survival.[49] As the time increases, the chance of meaningful survival decreases dramatically.[80,81] The indications for perimortem cesarean delivery are shown in Table 6.[82] In the rare case in which the mother is declared brain dead but remains stable from the respiratory and hemodynamic standpoints, the fetus can be allowed to grow and mature before delivery.

An important technical aspect of a perimortem cesarean delivery is to make a vertical midline incision through all the layers into the uterus because this is safer, faster, and avoids the high risk of adding more damage to the uterine vessels. Clearly, this approach facilitates the delivery of a fetus by trauma surgeons who are less familiar with the transverse incision on the lower

Table 6
Indications for cesarean delivery during trauma.[49]

Maternal shock
Threat to life from exsanguination from any cause
Mechanical limitation for maternal repair
Irreparable uterine injury
Fetal distress in viable fetus
Unstable thoracolumbar spine injury
Instability in a potentially viable fetus
Maternal death

Adapted with permission from Tillou and Petrone.[49]

segment of the uterus, typically used by obstetricians. An algorithm for emergency cesarean delivery is shown in Figure 8.

During maternal resuscitation, adequate oxygenation, fluid loading, and left lateral decubitus positioning should be tried to see if maternal circulation can be improved. If there is no response to advanced cardiac life support within 2-3 minutes, maternal CPR must be continued, anterior thoracotomy with open-chest cardiac massage (OCM) but without aortic cross-clamping should be considered, and emergency cesarean delivery for a viable fetus should be performed. It is known that conventional external cardiac massage (ECM) is less effective as the patient approaches term because of mechanical factors. The only method of assessing adequacy of fetal oxygenation during CPR is to monitor the fetal heart rate. Carotid pulse and end-tidal CO_2 monitoring should be used to monitor adequacy of maternal vital organ perfusion during CPR.[51]

When the gestational age is less than 24 weeks, emergency cesarean delivery is usually not indicated because the fetus is too small to survive and the birth is unlikely to have much effect on

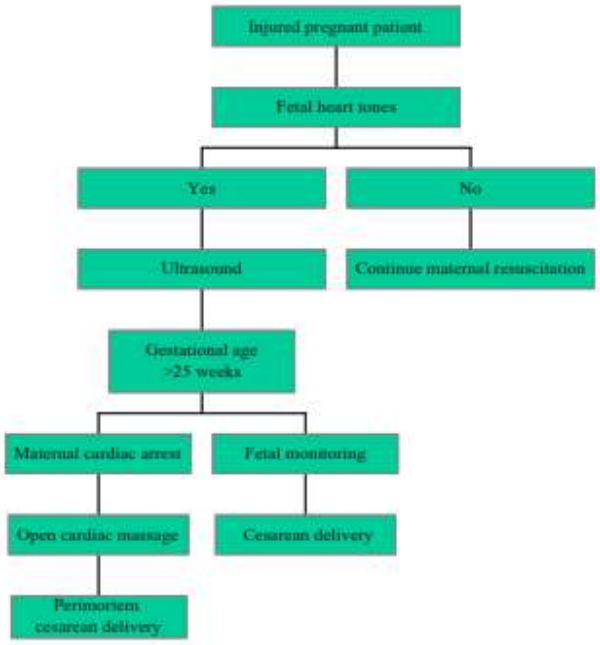

Fig. 8. Algorithm for emergency cesarean section after trauma. (Color version of figure is available online.)

maternal hemodynamics. However, when gestational age is greater than 24 weeks, emergency cesarean delivery favorably affects maternal or fetal outcome. At a gestational age of 26-32 weeks, when ECM is not effective, as indicated by failure to generate a carotid pulse, inadequate end-tidal CO_2 levels, or fetal bradycardia, OCM should be seriously considered before an emergency cesarean delivery is performed. If OCM proves successful, the delivery may be delayed so that chances of postnatal survival improve. Even slight prolongation of fetal intrauterine life probably improves the chances of fetal survival, especially when gestational age is less than 28 weeks. However, if OCM proves to be ineffective, the fetus must be delivered immediately.[51]

After 32 weeks of gestation, when ECM is not effective, an emergency cesarean delivery must be performed immediately. Delivering the infant improves maternal cardiac filling, thereby improving the success of CPR. The longer the delay between the onset of cardiac arrest and delivery, the less are the chances of fetal and maternal survival. In contrast, if the ECM appears to be effective, it may be continued for 5 minutes. If a spontaneous circulation is not restored within 5 minutes, an emergency cesarean delivery must be performed. If this fails to revive the mother, OCM may be considered.[51]

Complications

One of the most lethal complications, associated with 80% maternal mortality, is the occurrence of amniotic fluid embolism, which together with pulmonary thromboembolism remains the leading cause of maternal mortality in the United States.[83] In addition to complications involving hemodynamic instability and pulmonary compromise, pregnant women with traumatic injuries may develop minor alterations in the platelet count or the more serious complication of disseminated intravascular coagulation.

Although thromboembolic events remain the most common cause of morbidity and mortality during normal pregnancy, they may become even more frequent after traumatic injuries owing to the added hypercoagulability associated with trauma and are a frequent cause of maternal morbidity and death. The pregnancy is a hypercoagulable state due to the increased levels of fibrinogen and factors V, VII, VIII, IX, X, and XII, and placental inhibitor of fibrinolysis. There is also a release of tissue thromboplastin into the circulation at placental separation, venous stasis of the lower extremities, and an endothelial damage associated with parturition. Conversely, there is a decrease of fibrinolytic activity.[50]

Another important complication during pregnancy is the development of pregnancy-induced hypertension, occasionally with systolic blood pressure of 160 mm Hg and diastolic blood pressure of 110 mm Hg, which must be taken into account when treating a pregnant woman with traumatic injuries.

Predictive factors of outcome

The predictive factors can be subdivided depending if they pertain to the fetus or to the mother. There are several factors associated with risk to the fetus.[3,49,50] The most common factors are (1) maternal death, (2) maternal hypotension, (3) maternal traumatic brain injury, (4) high injury severity score, (5) pelvic fracture, (6) ejection of pregnant woman from a vehicle, and (7) severe abdominal injury to pregnant women. The predictive factors associated with maternal mortality include[3] (1) amniotic fluid embolism, (2) deep venous thrombosis and pulmonary embolism, and (3) infections.

Medico-legal implications

Depending on the outcome of the mother and the fetus after a motor vehicle collision or assault, physicians treating pregnant patients subjected to trauma are at risk of being involved in

legal and medico-legal actions that may require the treating physician to testify about the care rendered to the mother and the fetus. Therefore, it is imperative that all findings identified on serial examinations and by diagnostic studies, in addition to the degree of monitoring of the mother and the fetus, be accurately documented. Therefore, the evaluation and the recommendation for monitoring of the mother and the fetus for up to 4 hours after an accident or injury is not only necessary for maternal and fetal treatment but also to have complete documentation of maternal and fetal status during the stay at the trauma center while they received treatment.[44]

Injury prevention during pregnancy

Injury prevention deserves specific attention during pregnancy. The first area of prevention is related to the use of drugs and alcohol. The use of these substances is not only harmful to the fetus, but it is also associated with a high risk of injuries. In the same context, domestic violence is becoming a major cause of injury during pregnancy.[11] A study noted a 17% prevalence of physical or sexual abuse during pregnancy, with 60% of women having 2 or more episodes of assault.[84] Interpersonal violence is not dependent on race, age, marital status, or socioeconomic status; therefore, all pregnant women are potential victims of abuse.[84]

Conclusions

Injuries to the gravid uterus are rare and should be suspected in all assault victims and all patients with direct perineal trauma,[85] pelvic fractures, or penetrating injury to the pelvis. Thorough physical examination, preferably in the operating room, with prompt surgical treatment improves the outcome of these potentially challenging injuries. An obstetrician is an essential member of the multidisciplinary team for the initial assessment, stabilization, and subsequent management of a pregnant trauma victim. Pregnant women must be educated on the proper use of restraints, and screening for domestic abuse and depression are essential components of quality care of this unique population.

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REVIEW ARTICLE

Traumatic injuries to the pregnant patient: a critical literature review

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Abstract
Introduction Trauma during pregnancy is the leading non-obstetrical cause of maternal death and a significant public health burden. This study reviews the most common causes of trauma during pregnancy, morbidity, and mortality, and the impact upon perinatal outcomes associated with trauma, providing a management approach to pregnant trauma patients.
Materials and methods A systematic review of the current literature from January 2006 to July 2016 was performed.
Results Fifty-one articles were identified, including a total of 95,949 patients. Motor vehicle crash was the most frequent cause of blunt trauma, followed by falls, assault both domestic and interpersonal violence, and penetrating injuries (gunshot and stab wounds).
Conclusions Trauma in pregnant women is associated with high rates of adverse maternal and neonatal outcomes. Knowledge of the mechanism of injury is important to identify the potential injuries and the complexity of the management of these patients. As in all traumatic events, prevention is of paramount importance.

Keywords Trauma · Pregnancy · Fetal injuries · Blunt · Penetrating

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Introduction

Trauma is the leading non-obstetrical cause of maternal death during pregnancy. However, it may be an underestimation of the true incidence of trauma during pregnancy due to the under-reporting of trauma, especially trauma from interpersonal violence [1]. The aim of this article is to review the literature regarding trauma during pregnancy focusing on the most common mechanisms of injury, and maternal and fetal outcomes.

Materials and methods

Articles in the English language between January 2006 and July 2016 on trauma during pregnancy were identified using the following key words: trauma and pregnancy, blunt trauma, penetrating wound, injury during pregnancy, motor vehicle accident/crash, falls, assault, interpersonal violence, fetal monitoring, perimortem cesarean section, obstetrical patient, pregnant trauma patient, and mortality and pregnancy.

Results

Of the 200 articles identified, 51 were included in this study for a total of 95,949 patients.

Blunt trauma is the most common mechanism of trauma among pregnant women accounting for 69% of the total number of traumas, whereas penetrating trauma accounts for only 1.5% of episodes of trauma during pregnancy. In 37 articles reviewed herein, MVC is not only the most common but also the most life-threatening of mechanisms on injury. Mortality occurred in 100 of 728 (13.7%) mothers

and 78/728 (10.7%) fetuses. The frequency of use of seat belts by pregnant women was available in 8 of the 37 articles in which MVC was reported mechanism of injury, which ranged from a low of 21% to high value of 98%.

The second most common cause of trauma during pregnancy, especially during the second and third trimester due primarily, amongst other reasons, to weight gain, and changes in the center of gravity. The reported prevalence of interpersonal violence ranges between 1 and 20% of all pregnant women. During pregnancy, there is a spatial redistribution of the viscera inside the abdominal cavity due to the progressive increase in the size of the uterus.

The impact of abdominal trauma on the fetus depends to high degree on the gestational age at the time of the trauma. Direct injury to the uterus and fetus is unlikely during the first 12 weeks of gestation due to the protective effect of the bony pelvis, unless the traumatic event has caused complex pelvic fractures.

Table 1 includes the total number of patients stratified by the mechanism of injury, whereas Table 2 reports prevalence rates based on the causes of trauma. Maternal and fetal mortality rates have been derived from 28 of the 51 articles that included maternal and fetal mortality data (Table 3).

Table 1 Mechanisms of injury

Author (year)	Total *n*	Blunt *n*	Penetrating *n*
Metz (2006) [2]	30	30	0
El Kady (2006) [3]	3292	3292	0
Barré (2006) [4]	95	95	0
Amiliene (2006) [5]	372	312	60
Weintraub (2006) [6]	54	54	0
Sperry (2006) [7]	151	NS	8
Hitosugi (2006) [8]	135	135	0
Kuo (2007) [9]	16,982	7100	335
Aboutanos (2007) [10]	294	259	NS
Greene (2007) [11]	352	NR	NR
Patteson (2007) [12]	188	NR	4
Kvarnstrand (2008) [13]	2270	2270	0
Weiss (2008) [14]	7350	3939	739
Cahill (2008) [15]	317	NR	NR
Klinich (2008) [16]	57	57	0
Aboutanos (2008) [17]	148	148	0
Schiff (2008) [18]	693	693	0
Nannini (2008) [19]	1468	1468	0
Dunning (2010) [20]	1070	1070	0
Cannada (2010) [21]	65	65	0
Tinker (2010) [22]	490	NR	NR
Vlahutin (2010) [23]	34	34	0
Schiff (2010) [24]	3348	3348	0
Petrone (2011) [1]	321	292	29
Preeti (2011) [25]	3763	NR	121
Vivian-Taylor (2012) [26]	2147	2147	0
Fischer (2011) [27]	5352	NR	NR
Lin (2011) [28]	27	NR	18
Meuleners (2011) [29]	468	468	0
Melamed (2012) [30]	411	411	0
Karadas (2012) [31]	139	NR	NR
Mesdaghinia (2012) [32]	32	32	0
Njoku (2013) [33]	63	56	5
Lailey (2013) [34]	126	126	0
Vlahutin (2013) [35]	25,168	25,168	0
Periyanayagam (2014) [36]	635	NR	NR
Brookfield (2013) [37]	351	284	67
Zangene (2014) [38]	102	69	33
Wall (2014) [39]	42	24	9
Okeke (2014) [40]	108	108	0
Harland (2014) [41]	1488	372	NR
Ibrahim (2015) [42]	819	819	0
Chibber (2015) [43]	728	728	0
Jackson (2015) [44]	36	36	0
Azar (2015) [45]	5936	5936	0
Van der Knoop (2015) [46]	16	16	0
Shakerian (2015) [47]	74	74	0
Weiner (2016) [48]	946	946	0
Miller (2016) [49]	3794	3794	0
Battaloglu (2016) [50]	173	164	9

Epidemiology

Trauma is the leading cause of death in pregnant women, and it is responsible for a high rate of maternal and fetal morbidity. While the reported rate of complications of pregnancy due to trauma appears low, this rate is likely underestimated due to under-reporting particularly in cases of domestic violence [1].

Based on our review, blunt trauma is the most common mechanism of trauma among pregnant women accounting for 69% of the total number of traumas, whereas penetrating trauma accounts for only 1.5% of episodes of trauma during pregnancy (Table 1). Among the causes of blunt trauma, MVC is the most frequent cause of injury followed by falls, assault, gunshot, and stab wounds (Table 2). The severity of gravid uterus injuries is graded using the Organ Injury Scale of the American Association for the Surgery of Trauma (AAST-OIS) [54] (Table 4).

In a review of 102 trauma pregnant patients by Zangene et al. [38], blunt trauma was found to be the cause of trauma in 68% of pregnant women compared to 32% who had penetrating trauma. The most common mechanism of injury was MVC followed by domestic violence. The traumatic event caused maternal injuries, mostly lower extremity injuries, in 67% of patients, and it was associated with a 13% incidence of fetal complications [placental abruption (PA) and preterm]. Wall and others [39] have reported blunt trauma as a MOI in 57% of all cases compared to 21% where the MOI was penetrating

Table 1 (continued)

Author (year)	Total *n*	Blunt *n*	Penetrating *n*
Distelhorst (2016) [51]	3429	NR	NR
Total	95,949	66,439 (69%)	1437 (1.5%)

NR not recorded, *NS* not specified

trauma. Of note, in this study, interpersonal violence was the most common cause of injury followed by MVC, 52 and 26%, respectively. Fetal deaths occurred in 90% of patients with severe injuries (ISS > 15) and urgent laparotomy was required in 86% of women presenting with direct trauma to the abdomen.

In 37 articles reviewed herein, MVC is not only the most common but also the most life-threatening of mechanisms on injury [12]. Chibber et al. [43] have reported that 647 of 728 (89%) pregnant women involved in MVC presented with maternal and fetal complications (placental and preterm labor, 59 and 40% respectively). Mortality occurred in 100 of 728 (13.7%) mothers and 78/728 (10.7%) fetuses. Ninety-one perimortem cesareans sections were performed with a maternal mortality of 66% (60/91) and a much lower fetal mortality rate, 18.6% (17/91).

Vivian-Taylor et al. [26] have reported a series of 2147 pregnant women involved in MVC. In 72 of 2147 (3.3%) patients, the traumatic event caused delivery during the trauma hospitalization, five (7%) of whom suffered pelvic fractures, six (8%) presented intra-abdominal injuries, and seven (10%) were admitted to the ICU, three of whom subsequently died. They concluded that the injuries from an MVC during pregnancy are independent risk factors for induced delivery with poor perinatal outcomes.

The association of maternal fractures and perinatal outcomes has been investigated in a retrospective cohort study of 3292 pregnant women by El Kady et al. [3]. In their cohort study, fractures were identified in 44% of pregnant patients involved in an MVC. Pelvic fractures increased the morbidity and mortality not only of mothers, but also of fetuses. Aboutanos [17] reported a 48-fold increase in fetal death in patients with pelvic and acetabular fractures from MVC. However, due to the absence of specific information regarding the type of pelvic and acetabular fractures in the study population, these authors were unable to establish a causal relationship between the fractures themselves and fetal mortality. It is likely that the presence of either pelvic or acetabular fractures is a marker of the severity of the transfer of energy to the pregnant uterus and that the type and/or complexity of the fractures itself is less important from the standpoint of the risk of fetal mortality. One finding of interest in this study is that the presence of pelvic fractures is an independent risk factor for stillbirth regardless of gestational age. Similar conclusions were reported in a study by Cannada et al. [21] in which pelvic fractures and acetabular fractures were shown to be associated with a 30% rate of fetal death.

The severity of the injuries sustained during MVC depends not only on the characteristics of the accident itself, but also on the appropriate use of safety devices such as airbags and seat belts on the part of the pregnant woman. The frequency of use of seat belts by pregnant women was available in 8 of the 37 articles in which MVC was the reported mechanism of injury, which ranged from a low of 21% to high value of 98%. The type and the severity of maternal and fetal injury in MVC accidents are related to the appropriate use of seat belts and/or the presence of frontal and lateral airbags. Five of the six deaths reported in a series of 160 pregnant women involved in MVC were unrestrained women, two drivers, and three passengers [12]. There is a high correlation between the absence of use of seat belts and the revised trauma score (RTS) severity of injury suffered by pregnant women involved in MVC. Additional supportive evidence of the value of seat belt use by pregnant women in MVC is provided by Luley et al. [34]. These authors have shown that women who do not wear seat belts suffer more severe injuries; furthermore, they require more frequently non-obstetric surgery, primarily orthopedic procedures, as a result of the injuries sustained when compared to pregnant women wearing seat belts, 25% as opposed to 7%, respectively. While airbag deployment was more frequent in patients who had abruption placenta and fetal loss, there was no statistically significant correlation between the both. It is very likely that the abruption placenta and fetal loss are the result of the force of the impact and the transfer of the kinetic energy to the pregnant uterus from the MVC rather than the abdominal trauma caused by the deployed airbag. The absence of causal relationship between airbag deployment and placental abruption was investigated by Metz and his collaborators [2] in a retrospective study of 30 pregnant women (20 or more weeks' gestation) who were involved in a MVC with a reported median speed of 35 mph. Among the 30 women, one experienced PA with subsequent intrauterine fetal demise. This study suggests that PA occurs with a low frequency with airbag deployment. Based on computer modeling in crash tests dummies, airbag deployment may be a risk factor for PA and fetal loss in unbelted pregnant women, but it does not increase the risk of PA and fetal loss in properly restrained pregnant women [53].

Klinich et al. [16] investigated how restraint conditions and crash characteristics affected the fetal outcome in 57 pregnant women. Fetal loss occurred in 12 of 41 properly restrained occupants (29%), in contrast to three of the six (50%) improperly restrained women. Eight of the ten (80%) unrestrained women had adverse fetal outcomes. The rate of fetal death in unbelted women was 62%, while 79% of properly restrained women had only minor complications.

Table 2 Prevalence of the causes of trauma

Author (year)	MVC (%)	Fall (%)	Assault (%)	GSW (%)	SW (%)	Others (%)
Metz (2006) [2]	100	0	0	0	0	–
El Kady (2006) [3]	44	25	10	0	0	–
Barré (2006) [4]	51	41	0	0	0	8
Aniulione (2006) [5]	NS	NS	NS	NS	NS	–
Weintraub (2006) [6]	NS	NS	NS	0	0	–
Sperry (2006) [7]	25	46	23	NR	NR	–
Hirasugi (2006) [8]	100	0	0	0	0	–
Kuo (2007) [9]	48	52	NS	1	NR	85
Abouzanos (2007) [10]	NS	NS	NS	NS	NS	–
Greene (2007) [11]	95	3	NR	NR	NR	–
Patterson (2007) [12]	85	6	2	1	NR	2
Kvarnstrand (2008) [13]	100	0	0	0	0	–
Weiss (2008) [14]	25	18	NS	0.1	NR	36
Cahill (2008) [15]	29	48	19	NR	NR	–
Klinich (2008) [16]	100	0	0	0	0	–
Abouzanos (2008) [17]	100	0	0	0	0	–
Schiff (2008) [18]	0	100	0	0	0	–
Nannini (2008) [19]	0	0	100	0	0	–
Dunning (2010) [20]	0	100	0	0	0	–
Canada (2010) [21]	40	41	8	0	0	6
Tinker (2010) [22]	34	52	NR	NR	NR	15
Vladutiu (2010) [23]	0	64	0	0	0	–
Schiff (2010) [24]	100	0	0	0	0	–
Petrone (2011) [1]	NR	NR	11	73	25	–
Peetti (2011) [25]	NR	NR	NR	NR	NR	–
Vivian-Taylor (2012) [26]	100	0	0	0	0	–
Fischer (2011) [27]	20	20	9	NR	NR	–
Lin (2011) [28]	0	0	34	48	18	–
Meeleners (2011) [29]	0	0	100	NR	NR	–
Melamed (2012) [30]	39	50	3	0	0	–
Karadas (2012) [31]	21	56	NR	NR	NR	23
Mesdaghinia (2012) [32]	13	28	47	0	0	–
Njoku (2013) [33]	30	14	46	6	NR	–
Luley (2013) [34]	100	0	0	0	0	–
Vladutiu (2013) [35]	100	0	0	0	0	–
Periyanayagam (2014) [36]	75	NR	9	NR	NR	11
Brookfield (2013) [37]	72	4	4	10	9	–
Zangene (2014) [38]	47	26	25	NR	2	–
Wall (2014) [39]	26	7	52	10	7	–
Okeke (2014) [40]	0	100	0	0	0	–
Harland (2014) [41]	30	46	NR	NR	NR	–
Ibrahim (2015) [42]	0	0	100	0	0	–
Clubber (2015) [43]	100	0	0	0	0	–
Jackson (2015) [44]	0	0	100	0	0	–
Azar (2015) [45]	100	0	0	0	0	–
Van der Knoop (2015) [46]	50	44	6	0	0	–
Shakerian (2015) [47]	81	7	8	0	0	–
Weiner (2016) [48]	26	58	9	0	0	–
Miller (2016) [49]	100	0	0	0	0	–
Battaloglu (2016) [50]	56	32	11	NR	NR	–
Distelhorst (2016) [51]	33	32	5	NR	NR	–

NR not recorded, *NS* not specified, *MVC* motor vehicle collision, *GSW* gunshot wound, *SW* stab wound

Table 3 Maternal and fetal mortality

Author (year)	Maternal mortality (%)	Fetal mortality (%)
Metz (2006) [2]	NR	3
El Kady (2006) [3]	0.39	1
Barré (2006) [4]	NR	1
Aniniliene (2006) [5]	4	9
Hitosugi (2006) [8]	NR	55
Aboutanos (2007) [10]	0	4
Greene (2007) [11]	0	1
Patteson (2007) [12]	3	8
Kvarnstrand (2008) [13]	29	2
Weiss (2008) [14]	NR	1
Klinich (2008) [16]	NR	21
Aboutanos (2008) [17]	NR	5
Schiff (2008) [18]	NR	1
Schiff (2010) [24]	NR	0.4
Petrone (2011) [1]	9	83
Vivian-Taylor (2012) [26]	NR	31
Lin (2011) [28]	100	100
Meuleners (2011) [29]	NR	1
Melamed (2012) [30]	NR	1
Mesdaghinia (2012) [32]	0	1
Njoku (2013) [33]	2	8
Luley (2013) [34]	NR	4
Periyanayagam (2014) [36]	8	NR
Wall (2014) [39]	2	36
Chibber (2015) [43]	14	11
Shakerian (2015) [47]	NR	1
Miller (2016) [49]	NR	0.2
Distelhorst (2016) [51]	1	2

NR not recorded

Based on the results of their study, these authors conclude that women restrained by three-point seat belts are less likely to suffer severe injuries, with an 84% estimated reduction of the risk of fetal complications, potentially preventing an estimated 192 fetal losses.

Falls are the second most common cause of trauma during pregnancy, especially during the second and third trimester due primarily, amongst other reasons, to weight gain, and changes in the center of gravity. Most falls in pregnant women tend to be from a standing height. Schiff et al. [18] studied 693 women who fell during pregnancy, 79% of whom fell during the third trimester. The hospitalization rate was twice higher than in non-pregnant women, and resulted in a twofold increase in the risk of stillbirth. Although 54% of the patients had an ISS between one and eight, 90% required induction of labor, and 30% an emergency cesarean section. Okeke [40] has reported a 32.5% incidence of falls in a cross-sectional study of 332 pregnant women presenting in labor for delivery at the University of Nigeria Teaching Hospital Enugu, in Nigeria. This is similar to the 27% reported incidence of falls among pregnant women in the US [54].

Interpersonal violence during pregnancy poses also a high risk to both the mother and fetus. In the majority of cases, the injuries are limited to the soft tissues, head, neck, and torso sparing the abdomen. When the physical aggression is directed to the abdomen, there is an increased incidence of antepartum hemorrhage (AP) with subsequent perinatal complications. The reported prevalence of interpersonal violence ranges between 1 and 20% of all pregnant women, with the domestic partner identified as the aggressor in the majority of the cases [22]. However, the prevalence of interpersonal violence is affected by several factors, including socioeconomic factors, cultural upbringing, the status of women in the specific society, and the normative use of violence in conflict situations as it relates to different countries. Mesdaghinia et al. [32] have reported a 47% of incidence of domestic violence in Iran, especially during the second trimester of pregnancy. Ibrahim and others [42] have reviewed a series of 1857 Egyptian pregnant women to study the incidence of intimate partner abuse. In their study, 44% of pregnant women were found to have experienced some form of interpersonal violence, including physical violence (16%) and sexual assault (10%). According to the study of Meuleners et al. [29] that included 465 pregnant women exposed to interpersonal violence, injury associated with interpersonal violence resulted in a 1.7-fold risk in maternal

Table 4 AAST-OIS for gravid uterus [52]

Grade	Injury description
I	Hematoma or contusion without placental abruption
II	Superficial laceration < 1 cm in depth or placental abruption < 25%
III	Deep laceration 1 cm in depth in second trimester or placental abruption 25% but < 50%. Deep laceration in third trimester
IV	Laceration extending to the uterine artery. Deep laceration 1 cm with 50% placental abruption
V	Uterine rupture in second or third trimesters. Complete placental abruption

AAST-OIS American Association for the Surgery of Trauma Organ Injury Scale

complications (abortions, preterm, AP), and twofold risk in fetal adverse outcomes (low weight at birth, fetal distress, and fetal death). The risk of fetal death is directly correlated to the severity of maternal injuries. In the study by Njoku et al. [33] with a 50% reported incidence of domestic violence in pregnant women, 80% of fetal deaths occurred in women who had suffered severe maternal injuries, compared to a fetal loss rate of 20% in pregnant women with less severe injuries.

Pathophysiology

During pregnancy, there is a spatial redistribution of the viscera inside the abdominal cavity due to the progressive increase in the size of the uterus. The abdominal viscera are displaced cephalad as the uterus reaches the central region of the abdomen. That is the reason why penetrating abdominal injuries during the third trimester of pregnancy are associated not only with high maternal morbidity, but also with a significant increased incidence of uterine and fetal injury (60–70%), including a very high fetal death rate (40–65%). As reported by Shakerian et al. [47], the fetal death rate from stab and gunshot wounds is 42 and 71%, respectively. In a study by Petrone et al. [1], penetrating injuries, mostly gunshot wounds (73%) accounted for 9% of the mechanism of trauma in 321 pregnant women with abdominal trauma. The cohort of women suffering penetrating injuries had a significantly higher maternal morbidity (66 vs. 10%), as well as fetal mortality (73 vs. 10%) when compared to pregnant women who had blunt abdominal trauma.

The impact of abdominal trauma on the fetus depends to high degree on the gestational age at the time of the trauma. Direct injury to the uterus and fetus is unlikely during the first 12 weeks of gestation due to the protective effect of the bony pelvis, unless the traumatic event has caused complex pelvic fractures [55]. Miscarriage is uncommon following abdominal trauma during the first trimester unless the pregnant woman has suffered sustained hypotension leading to uterine hypoperfusion from extracavitary blood loss. Trauma during pregnancy can cause immediate fetal compromise; however, it can also be associated with delayed complications, such as delayed placenta abruption, which has been reported to occur up to 6 days after the traumatic event [56]. It is for this reason that prolonged fetal heart monitoring is required in pregnancies that have reached viability. Abdominal trauma may cause a subclinical chronic PA that may evolve into an acute episode of PA, preterm labor, premature membrane rupture, and placental insufficiency that may, in turn, cause fetal growth retardation, oligohydramnios, and low birth weight. The short- and long-term complications of blunt trauma during pregnancy were investigated by Melamed et al. [30] in a retrospective cohort study of 411 pregnant women. Thirteen women who had immediate complications were compared to 398 women who did not suffer any complications. In addition, 303 pregnant women who did not deliver at the time of the traumatic event were compared to a normal cohort of 909 matched by maternal age and parity to assess the impact of trauma on the outcome of the pregnancy. Immediate complications in the form of preterm labor and AP occurred in 3.2% of women. Independent risk factors for immediate complications included high severity of trauma, multiple gestations, vaginal bleeding, and the development of uterine contractions. Late-term complications, including preterm labor, PA, and perinatal morbidity, were also associated with a high ISS and the requirement for laparotomy at the time of the trauma.

Primary treatment

After the 10th week of pregnancy, there is an increase in plasma volume by up to 50% with a dilutional anemia secondary to a lesser increase in the red blood cell mass (15–30%) relative to the expansion of the plasma volume. These changes can provide some maternal tolerance to hemorrhagic shock. Therefore, symptoms such as tachycardia or hypotension may not occur until there is a blood loss, as high as 35% [57]. Blood pressure less than 80/40 mmHg, a pulse greater than 140 or less than 50 beats per minute, a respiratory rate less than 10 or greater than 24, and a fetal heart rate less than 110 or greater than 160 beats per minute are associated with the presence of shock. If used, the abdominal portion of the military anti-shock trousers (MAST) should be deflated en route, since compression can reduce blood flow to the placenta [57, 58]. The presence of any of the above reflects the severity of trauma and should alert the trauma surgeon to a high risk of maternal and fetal morbidity and mortality. In addition, during the second and third trimesters of pregnancy, the compression of the inferior vena cava in the supine position by the gravid uterus can contribute to a state of hypotension because of the decreased venous return. To avoid this, the patient must be placed in the 15°–30° left tilt position by placing a firm wedge underneath the right buttock/hip, manually displacing the uterus if necessary, always ensuring the immobilization of the cervical spine [57, 59].

The use of vasopressors, such as norepinephrine or phenylephrine, is not recommended, since they reduce placental perfusion, unless the patient does not respond to appropriate volume loading with crystalloids. Both the mother and the fetus are extremely vulnerable to hypoxia due to the respiratory changes associated with pregnancy, namely, a shallow breathing pattern, decreased functional residual capacity, and the increased oxygen consumption by 20%; therefore, the administration of supplemental oxygen is always required. The elevation of the diaphragm up to 4 cm compared to its normal anatomical position must be taken

into account when undertaking any thoracic procedure such as the performance of tube thoracostomy [56]. If necessary, the chest tube should be placed one or two intercostal spaces above the fifth intercostal space to avoid abdominal injuries. Due to the increased uterine size, there is a displacement of the lower esophageal sphincter that reduces its competence. In addition, the physiological inhibition of gastric motility and the increased relaxation of the lower esophageal sphincter predispose the pregnant woman to the risk of aspiration. To avoid aspiration, placement of a decompressive nasogastric tube is warranted [57, 59].

Definitive treatment

After the initial assessment is performed (Fig. 1) [60], and once maternal hemodynamic stability is reached, fetal monitoring should be initiated immediately. Information about the obstetric history such as gestational age, fetal maturity, date of delivery, and any other complication during pregnancy

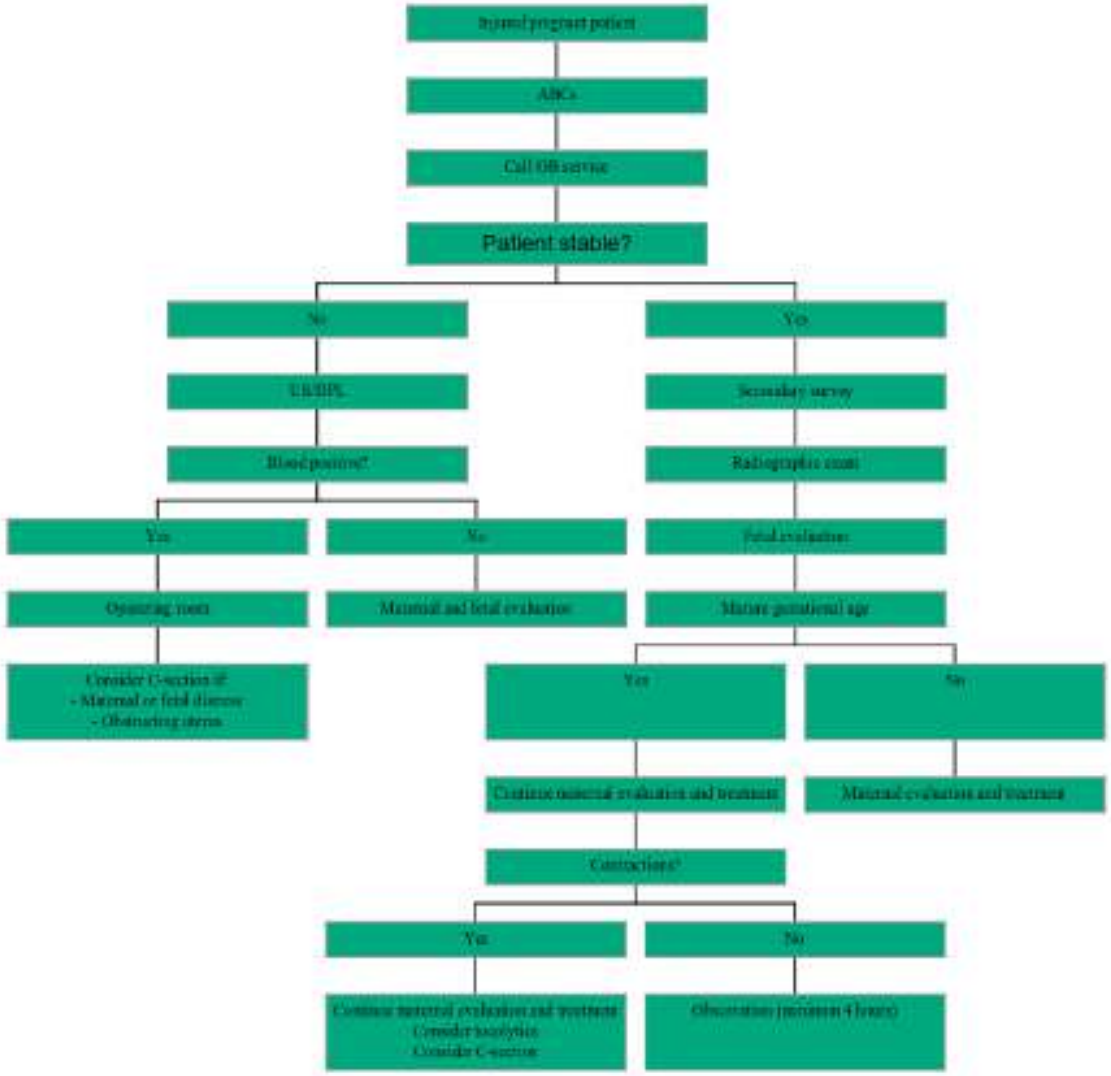

Fig. 1 Algorithm for initial maternal and fetal assessment [60]. *OB* Obstetrics, *US* ultrasound, *DPL* diagnostic peritoneal lavage, *C-section* cesarean section. Modified from Petrone P, Tillou A. Gynecologic injuries: trauma to gravid and nongravid uterus and female genitalia. In: Current therapy of trauma and surgical critical care. (Elsevier, Philadelphia, 2016), pp 401–407

must be obtained [59]. During the physical examination, particular attention should be paid to signs of trauma such as vaginal bleeding, spontaneous rupture of membranes, presence, intensity and frequency of uterine contractions, and abnormal fetal heart rate [58]. The possibility of bleeding and fetal-placental transfusion must be evaluated using the Kleihauer–Betke test, with appropriate administration of AntiD immunoglobulin in Rh negative mothers. A multidisciplinary assessment that includes evaluation by the obstetrician is recommended [60].

Imaging during pregnancy and the negative impact that radiation may have on fetal development remain controversial. However, if these tests are clinically justified, the indications for imaging are the same as for any other non-pregnant trauma patient, and do not have to be delayed as the benefits outweigh the risks. Fetal harm due to radiation depends on the gestational age of exposure, with the most vulnerable time being within the first 16 weeks of gestation [57]. Computed tomography (CT) scans can identify maternal and fetal injuries, but should be only performed when the patient is hemodynamically stable. Despite the high sensitivity and specificity of CT, focused abdominal sonography for trauma (FAST) is considered the gold standard due to its safety and a non-invasive nature. FAST can identify solid organs injuries, the presence of free fluid, fetal well-being, gestational age, amniotic fluid volume, and location of the placenta. Other diagnostic techniques, such as diagnostic peritoneal lavage (DPL) can be safely done, if performed above the umbilicus.

Maternal pelvic fractures are the most common cause of fetal death amongst traumatic injuries. When taken in isolation, pelvic fractures do not represent an indication for emergency cesarean section, since vaginal delivery can be performed safely, even in the third trimester of pregnancy in most cases [3, 21, 59]. Angioembolization is the ideal treatment for pelvic or retroperitoneal hemorrhage, although the radiation dose is considered excessive and it is not exempted of fetal complications [57].

When the fetus is viable (more than 24 weeks' gestation) continued fetal monitoring must be provided. A minimum of 2–6 h and up to 48 h of monitoring is recommended, as some cases of placental abruption have been reported more than 24 h after the initial injury. Fetal arrhythmia may be the first sign of maternal hemodynamic compromise. As placental perfusion and oxygenation depend directly on maternal cardiorespiratory condition, continuous fetal monitoring is recommended in cases of maternal acute respiratory distress syndrome, severe lung damage, or abnormal heart rhythm. In low-risk patients with minor trauma and once any maternal injury are excluded, fetal monitoring for 4 h appears to be a sufficient period of monitoring.

Perimortem cesarean section in viable fetuses can be successful if performed no later than 4 min following maternal cardiac arrest. Fetal survival rates are excellent with a reported fetal survival rate of 70%. A vertical uterine midline section is recommended to avoid injury to the uterine vessels. The recommendations [60, 61] for emergency cesarean section are listed in Table 5.

Table 5 Indications for emergency cesarean section [60, 61]

Viable pregnancies (> 24 weeks) or near term
Maternal death
Trauma patients with cardiac arrest
No later than 4 min of properly performed cardiopulmonary resuscitation that has failed
Loss of fetal well-being in viable fetus
Irreparable uterine rupture
Massive hemorrhage/shock
Threat to life from exsanguination from any cause
Mechanical limitation for maternal repair
Unstable thoracolumbar spine injury

Conclusion

Trauma in pregnant women represents a significant public health burden and a clinical challenge for the trauma surgeon given the complexity of the pregnant woman. The priority should always lie with the mother. While injuries to the gravid uterus are uncommon, they should be suspected in all assault victims and all patients with direct perineal trauma, pelvic fractures, or penetrating injury to the pelvis. An obstetrician is an essential member of the multidisciplinary team for the initial assessment, stabilization, and subsequent management of a pregnant trauma victim. Pregnant women must be educated on the proper use of restraints, and screening for domestic abuse and depression are essential components of quality care of this unique population. It is of a great importance that all professionals specializing in treating trauma patients recognize and are aware of the anatomic and physiologic changes that occur to pregnant women and how these changes can impact the evaluation and treatment of this unique patient population.

Compliance with ethical standards

Conflict of interest Patrizio Petrone, Patricia Jiménez Morillas, Alexander Axelrad, and Corrado P. Marini declare that they have no conflict of interest.

Informed consent This research consisted of literature review only, and, therefore, did not involve human participants or animals.

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F. Discusión

El traumatismo es considerado como la principal causa de muerte de origen no obstétrico durante el embarazo. Fildes[1] informó que alrededor del 50% de las muertes maternas están relacionadas con traumatismos, y del 6% al 7% de todos los embarazos sufren complicaciones debido a ellos, de los cuales el 0,4% requieren hospitalización para el tratamiento de las lesiones.[2]

Es esencial que los profesionales que se especializan en tratar pacientes víctimas de traumatismos puedan reconocer los cambios anatómicos y fisiológicos que ocurren en las mujeres embarazadas y cómo esos cambios impactan en la evaluación y el tratamiento de esta población única. Para poder salvar el embarazo debe incluirse la evaluación del feto. En la asistencia a una mujer embarazada debemos tener presente en todo momento que estamos tratando dos vidas, la madre y su hijo, y que el feto puede sufrir tanto lesiones directas como derivadas de las alteraciones maternas. Los efectos del traumatismo durante la gestación van a estar determinados por los siguientes condicionamientos:

- Edad gestacional
- Tipo y severidad del traumatismo
- Alteraciones en la fisiología feto-placentaria

Los casos más antiguos de lesión traumática en el embarazo fueron descriptos en el Código de Hammurabi (siglo XV, AC)[3] y en el Viejo Testamento (Éxodo 22:21). Las lesiones penetrantes del útero grávido con objetos como lanzas, ramas o cuernos de animales han sido observadas desde la antigüedad. Ambroise Paré,[4] famoso cirujano militar de origen francés, fue el primero en describir el tratamiento de lesiones penetrantes

uterinas. El traumatismo durante el embarazo recibió un interés más exhaustivo en la literatura médica reciente. Los artículos más antiguos describían casos relacionados con caídas, apaleamientos y agresiones,[5] pero conforme la sociedad se tornó más industrializada, los informes clínicos se centraron en lesiones penetrantes y en colisiones automovilísticas o MVC (*motor vehicle collision* de la literatura sajona).

Un detallado estudio epidemiológico de un año de evolución, publicado por Weiss,[6] del Center for Injury Research and Control, dependiente de Presbyterian University Hospital y University of Pittsburgh, Pennsylvania, incluyó a todas las mujeres en edad fértil que hayan requerido hospitalización a causa de un traumatismo. De un total de 16.722 mujeres admitidas, se identificaron 761 (4,6%) embarazadas, con una media de 25 años de edad. Las causas más comunes fueron MVC (33,6%), caídas (26,4%) y envenenamiento (16%). Luego el mismo autor dio a conocer otro estudio,[7] esta vez de tres años de duración, en el que identificó 240 muertes fetales de origen traumático (3,7 muertes fetales por 100.000 nacidos vivos). MVC representó el principal mecanismo (82%), seguido de lesiones por arma de fuego (6%) y caídas (3%).

En un estudio sobre mortalidad fetal, de dos años de duración y con información proveniente de un solo Estado, Weiss[8] encontró 7.131 muertes fetales de las cuales 31 fueron identificadas de origen traumático (6,5 muertes fetales por 100.000 nacidos vivos). MVC también fue la principal causa de lesión (81%), y la disrupción placentaria el principal diagnóstico (42%). Nuevamente se informó que la mujer embarazada joven se encontraba expuesta a un mayor riesgo, con una media de 25 años de edad.

Leggon y colaboradores[9] realizaron una extensa revisión de la literatura, comprendiendo los años 1932 a 2000, en la que incluyeron 101 fracturas pélvicas y de acetábulo durante el embarazo. Encontraron que el promedio de edad fue también de 25 años, y las lesiones maternas asociadas estuvieron presentes en el 60% de las pacientes. El mecanismo de lesión más común fue MVC (73%), seguidos por caídas (14%) y atropellamiento vs. peatón (13%). La mortalidad materna global fue 9% y la mortalidad fetal global fue 35%. Los autores estratificaron la mortalidad según el mecanismo de lesión y encontraron que las colisiones auto vs. peatón estaban asociadas con una mortalidad materna de 27% (3 de 11) y una mortalidad fetal de 45% (5 de 11). En el caso de MVC se asoció con una mortalidad materna de 6% (4 de 63) y fetal de 36% (23 de 63), mientras que las caídas (n=12) no presentaron mortalidad materna, pero sí fetal (8%; 1 de 12). Los autores concluyeron que las colisiones de automóvil vs. peatón presentaban una tendencia estadística mayor tanto para mortalidad materna como para mortalidad fetal.

En el año 2011, Petrone y colaboradores[10] realizaron un estudio de 13 años de duración en dos centros de trauma Nivel 1, Los Angeles County + University of Southern California Trauma Center (Los Angeles, California) y University of Southern Nevada Las Vegas Trauma Center (Las Vegas, Nevada). En el mismo incluyeron 321 pacientes embarazadas, de las cuales 291 (91%) presentaban traumatismo contuso mientras que 30 (9%) fueron víctimas de traumatismo penetrante. Los autores informaron una morbilidad materna de 66% y una mortalidad fetal de 73% luego de un traumatismo abdominal penetrante. La severidad de la lesión abdominal, el mecanismo penetrante y la presencia de hipotensión materna al ingreso fueron identificados como factores de riesgo asociados a muerte fetal luego de un hecho traumático.

Es de importancia remarcar la relación entre los estudios radiológicos y sus efectos teratogénicos. Existen tres fases de daño fetal relacionado con la radiación dependiendo de la edad gestacional.[11] Antes de las 3 semanas, previo e inmediatamente después de la implantación, la exposición a la radiación puede derivar en la muerte del embrión. Entre las semanas 3 y 16 de gestación, durante la organogénesis, la radiación puede dañar el tubo neural, y ocasionar anomalías en el sistema nervioso central. Después de las 16 semanas, la complicación más común comprende defectos neurológicos.[11] La exposición prenatal a las radiaciones puede llegar a asociarse con algunos tipos de cáncer de la infancia.[12]

Los estudios por imágenes radiográficas deben realizarse como en cualquier otro tipo de pacientes, siempre considerando que los beneficios superen a los riesgos. La exposición fetal a radiación menor de 10 rad (*radiation absorbed dose*) no presenta un riesgo mayor, aunque es obvio que se deben evitar estudios y duplicaciones innecesarias. Las dosis de radiación de los estudios por imágenes más comunes se muestran en la siguiente tabla:[13]

Dosis de Radiación de Estudios por Imágenes	
Rx AP de tórax	< 0,005 rad
Rx de pelvis	< 0,4 rad
TC cerebral (cortes de 1 cm)	0,05 rad
TC de abdomen (20 cortes de 1 cm)	3,0 rad
TC de pelvis (10 cortes de 1 cm)	3,0-9,0 rad

La evaluación del abdomen en la paciente embarazada suele ser un desafío, y se debe prestar especial atención a la presencia de una fractura costal o pélvica, hipotensión

sin origen obvio que la justifique, pérdida sanguínea, hematuria, o alteración del sensorio debido a drogas, alcohol o por una lesión cerebral.

La ecografía (*Focused Abdominal Sonography for Trauma*, FAST) tiene un papel preponderante en la evaluación abdominal y es considerada de elección, ya que puede detectar líquido libre abdominal y pericárdico de manera rápida y no invasiva, así como también investigar la condición general del feto.[14] El lavado peritoneal diagnóstico (LPD) puede realizarse de forma segura y posee la misma sensibilidad que en cualquier paciente, solo que técnicamente el LPD debe realizarse por encima del ombligo utilizando la técnica abierta. La tomografía computarizada (TC) de abdomen también puede realizarse con seguridad, y evalúa tanto a la madre como al feto, pero la paciente debe hallarse hemodinámicamente estable. El Comité de Escalas de Lesión de Órganos de la Asociación Americana de Cirugía del Trauma (*American Association for the Surgery of Trauma-Organ Injury Scale Committee*, AAST-OIS) clasificó a las lesiones del útero grávido en grados tal como se muestra en la siguiente tabla:[15]

Escala de Lesión del Útero Grávido		
Grado	**Descripción**	**AIS-90 Score**
I	Hematoma o contusión sin disrupción placentaria.	2
II	Laceración superficial <1 cm de profundidad o disrupción parcial placentaria <25%.	3
III	Laceración de 1 cm de profundidad en el segundo trimestre o disrupción placentaria de 25% pero <50%; laceración profunda en el tercer trimestre.	3-4
IV	Laceración hasta la arteria uterina; laceración profunda de 1 cm con 50% de disrupción placentaria.	4
V	Ruptura uterina en el segundo o tercer trimestre; disrupción placentaria completa.	4-5

G. Violencia Interpersonal

El número real de mujeres embarazadas que sufren traumatismos no se conoce a ciencia cierta ya que muchos de ellos no se informan, especialmente aquellos debidos a violencia interpersonal (*interpersonal violence*, IPV). Los traumatismos y la violencia doméstica son las causas más frecuentes de muerte en la mujer en edad fértil. Paradójicamente es un problema de salud que afecta a las sociedades más desarrolladas en las que el índice de natalidad es decreciente. Así, la violencia interpersonal es hoy un problema de salud pública, ya que existe un aumento del riesgo de maltrato y abuso durante el embarazo difícil de cuantificar por las dificultades sociales que plantea.

El Comité de Violencia Familiar del Instituto Nacional de Salud (NIH) de Estados Unidos ha propuesto definir a la IPV como "actos que son física y emocionalmente dañinos o que tienen el potencial de causar daño físico, y que incluyen coacción sexual o asaltos, intimidación física, amenazas de matar o dañar, restricción de actividades normales o la libertad, y la negación de acceso a los recursos".[16] Esta última definición incluye los tres tipos principales de IPV reconocidos en la literatura: violencia física, sexual y emocional/psicológica/verbal.[17] El uso intencional de la fuerza física se incluye en "violencia física" y el uso de la fuerza para obligar a una persona a participar en un acto sexual es lo que se conoce como "violencia sexual".[18] Bajo los términos violencia "emocional", "psicológica" o "verbal", incluye amenazas, humillación, control de actividades, aislamiento, insultos, e infundir temor.

La IPV no solo es una gran preocupación mundial a nivel social y de la sanidad, también lo es desde el punto de vista económico y de salud pública. El costo anual en salud

en los Estados Unidos relacionado a la IPV supera el billón de dólares,[19,20] y por sí misma se encuentra en el 20% de todos los crímenes violentos.[21] Es señalada como una cuestión de proporciones epidémicas,[22] situación que no debería sorprendernos si analizamos el contexto mundial. El Departamento de Justicia de los Estados Unidos estima que el 52% de las mujeres experimenta IPV a lo largo de su vida, y de ellas el 45% reporta haber sido forzadas a tener relaciones sexuales,[23] lo que implica que entre 1,5 y 4 millones de mujeres americanas son victimizadas por su pareja.[24,25] La prevalencia en otros países también se ha estudiado. Así, en un estudio poblacional de Australia del 2005 reportó un 15% de IPV,[26] 15% en Canadá,[27] y 20% en Ucrania,[28] mientras que en España se encontró un 32%,[29] 35% en Ruanda,[30] 40% a 52% en Nicaragua,[30] y 45% en Perú.[32]

Si bien estas tasas son alarmantes, la prevalencia real de IPV durante el embarazo puede ser incluso mayor debido a la renuencia de las mujeres a reportarlo, especialmente durante el embarazo.[33] Además, existen estudios que han indicado que ciertas mujeres pueden estar en mayor riesgo de IPV durante el embarazo debido al estatus socioeconómico, edad, estado civil o cuando pertenecen a una minoría. Mientras que la IPV se encuentra en todos los niveles socioeconómicos, muchos estudios identifican un mayor riesgo cuanto más bajo es el mismo, tanto en mujeres embarazadas como no embarazadas.[34,35] Un proyecto que involucró a más de 1000 mujeres embarazadas en Estados Unidos reveló que los niveles de ingresos y de educación fueron los factores predictivos más significativos de violencia durante el embarazo.[36] Siguiendo con esta línea, un estudio poblacional realizado en Chile, Egipto, India y Filipinas demostró que los indicadores socioeconómicos fueron también universalmente considerados como factores de riesgo de IPV.[37]

Además de la relación con el nivel sociocultural, también se han observado otros factores de riesgo como: la edad, siendo más frecuente en las mujeres jóvenes,[38,39] sobre todo menores de 20 años;[40] estado civil: las madres solteras[41] tienen cuatro veces más posibilidades de ser víctimas cuando se las compara con mujeres casadas; y minorías raciales: en Estados Unidos se ha observado un mayor riesgo en aborígenes nativas americanas y afroamericanas.[42] Por último, existen otros factores de riesgo observados a tener en cuenta, que en forma aislada o combinados entre ellos o con los anteriores, plantean una mayor complejidad para su correcto manejo. Entre ellos se cuentan el estrés, que se incrementa durante el embarazo, mayormente en estratos sociales bajos,[43,44] los celos y la sospecha de infidelidad, que puede exacerbarse en parejas con conducta violenta previa,[45] y el exceso de alcohol, que contribuye a aumentar el riesgo de IPV en presencia de los factores anteriores.[46,47]

Algunos trabajos[48] han demostrado que el 10% al 30% de las mujeres sufren abuso durante el embarazo, y que el 5% deriva en muerte fetal. El abuso físico es sospechado cuando las lesiones se localizan principalmente en la parte proximal y en la línea media corporal antes que distalmente. Es más evidente cuando ocurren en el cuello, mamas, cara, parte superior de los brazos y lateral de los muslos. También son altamente sospechosas las lesiones bizarras como quemaduras de cigarrillos y mordeduras.[49] Si bien los casos de violencia doméstica se asocian con un amplio abanico de condiciones psicológicas, psicosomáticas y físicas, su diagnóstico eficaz y oportuno requiere de ciertas habilidades clínicas. Los síntomas más comunes son cefalea, dolor crónico inespecífico, estrés postraumático, síntomas ginecológicos, lesiones agudas y crónicas (como las descriptas anteriormente), y abuso de sustancias, entre otras condiciones.[50] Aproximadamente el 33%

presentan ansiedad y depresión, mientras que el 26% sufre de intentos de suicidio, aunque este número podría llegar a ser superior debido a la falta de informes o publicaciones.

Según la Organización Mundial de la Salud (OMS), la IPV aumenta los factores de riesgo durante el embarazo al retrasar el cuidado prenatal y no concurrir a las visitas médicas periódicas durante el mismo, posiblemente porque el compañero abusivo evita que la mujer salga de su casa, o bien porque ella misma no puede concurrir debido a las lesiones o por temor a que ellas sean descubiertas. Como mecanismo para enfrentar la situación dan comienzo a conductas tóxicas, como fumar, utilizar drogas o abusar del alcohol.[51]

Por otro lado, la IPV está estrechamente relacionada con un aumento del riesgo de ser víctimas de homicidio por parte de sus parejas. De hecho, el femicidio es la segunda causa de muerte en mujeres embarzadas, luego de las colisiones automovilísticas. Según la Coalición Nacional Contra la Violencia Doméstica (*National Coalition Against Domestic Violence*, NCADV)[52] reportó que entre 1990 y 2004 en los Estados Unidos, 1300 mujeres embarazadas fueron asesinadas, de las cuales el 56% fue por arma de fuego, y el 44% restante lo fue por arma blanca o estrangulamiento. Más del 75% fue asesinada durante su primer trimestre de gestación.

H. Prevención

La prevención merece una atención especial durante el embarazo, sobre todo en lo relacionado con el uso de drogas y alcohol, que no solo es perjudicial para el feto sino también se asocia con un alto riesgo de lesiones. En el mismo contexto, la violencia doméstica es una causa mayor de lesión durante el embarazo.[47] Se ha publicado que el 60% de las mujeres que padecieron IPV de tipo físico, sexual o emocional, tienen mayores posibilidades de ser víctimas de dos o más episodios de agresión,[48] por lo que se considera que todas las mujeres embarazadas son potenciales víctimas de violencia interpersonal.[53,54] Se han publicado encuestas en que el tamizaje y el cuestionario que investiga la posibilidad de IPV se realizaba solo en el 18% de las mujeres embarazadas evaluadas, por lo que una de las herramientas más efectivas para identificar esta problemática sería realizarlo tanto en las salas de emergencias como también en las consultas periódicas y programadas con el especialista.[55]

I. Conclusions

1. Trauma has become the leading cause of death in young pregnant women.
2. Trauma in pregnant women represents a significant public health burden and a clinical challenge for the trauma surgeon given its complexity.
3. The evaluation of a female patient of childbearing age who is a trauma victim should always include the possibility of pregnancy.
4. Injuries to the gravid uterus are rare and should be suspected in all assault victims and all patients with direct perineal trauma, pelvic fractures, or penetrating injury to the pelvis.
5. Thorough physical examination, preferably in the operating room, with prompt surgical treatment improves the outcome of these potentially challenging injuries.
6. The physiological and pathological changes during pregnancy affect all aspects of a traumatic injury, requiring detailed evaluation and meticulous management of this unique patient population.
7. Following penetrating abdominal injury, fetal mortality and overall maternal morbidity remains exceedingly high, at 73% and 66%, respectively.
8. Penetrating injury mechanism, severity of abdominal injury and maternal hypotension on admission are independently associated with an increased risk for fetal demise following traumatic insult during pregnancy.
9. An obstetrician is an essential member of the multidisciplinary team for the initial assessment, stabilization, and subsequent management of a pregnant trauma victim.

10. Pregnant women must be educated on the proper use of restraints while they are in cars, regardless if they are drivers or passengers.
11. Screening for domestic abuse and depression are essential components of quality care of this unique population.
12. Intervention on each risk factor individually does not guarantee the solution or the prevention of the trauma derived from interpersonal violence, taking into consideration the complex interaction of the social conditioning factors.

J. Palabras Finales

Esta tesis ha cumplido con los objetivos establecidos en la sección B. El objetivo general de describir los cambios anatómicos y fisiológicos que ocurren durante la gestación normal y la fisiopatología de las lesiones se detalla ampliamente en las publicaciones I, III y VI. Los objetivos específicos también se completaron con sus correspondientes publicaciones de la siguiente manera:

- Identificar los factores de riesgo de morbilidad y mortalidad fetal y materna: publicaciones II, IV y V.

- Desarrollar un algoritmo de diagnóstico de evaluación inicial para la madre y el feto: publicaciones III, IV y V.

- Diseñar un algoritmo para cesárea de emergencia después de un traumatismo severo: publicaciones III, V y VII.

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L. APÉNDICES

Apéndice 1: Factor de impacto de las revistas

Revista	Abreviatura	Factor de impacto
Current Problems in Surgery	*Curr Probl Surg*	2,955
Injury, International Journal of the Care of the Injured	*Injury*	2,409
Scandinavian Journal of Surgery	*Scand J Surg*	2,197
European Journal of Trauma and Emergency Surgery	*Eur J Trauma Emerg Surg*	1,704

Apéndice 2: Resúmenes de los artículos en inglés traducidos al español

Artículo I. *Petrone P, Asensio JA. (2006). Trauma in pregnancy: assessment and treatment. Scandinavian Journal of Surgery. 95, 4-10.*

Las mujeres entre las edades de 10 y 50 años tienen el potencial de embarazo; por lo tanto esta condición debe ser tomada en consideración cuando una mujer es examinada en la Sala de Urgencias luego de sufrir un evento traumático. El embarazo produce significativos cambios fisiológicos y anatómicos en todos los sistemas del cuerpo femenino. La evaluación de la paciente embarazada traumatizada, el enfoque y la interpretación de las pruebas diagnósticas debe ser acompañada por el completo conocimiento de todos cambios que ocurren durante el embarazo. En el mismo contexto, a pesar de que el médico trata a una mujer embarazada víctima de trauma debe recordar que hay dos pacientes, las prioridades de tratamiento son las mismas que para la paciente traumatizada no embarazada El mejor tratamiento inicial para el feto es la óptima resucitación de la madre. Debe realizarse un examen exhaustivo para descubrir las condiciones únicas que pueden estar presentes en la paciente embarazada tal como lesiones uterinas contusas o penetrantes, disrupción placentaria, embolia de líquido amniótico, isoinmunización, y ruptura prematura de membranas. Los obstetras deberían estar presentes siempre y ser considerados parte del equipo de trauma en la evaluación y tratamiento de la paciente embarazada.

Artículo II. *Petrone P, Talving P, Browder T, Teixeira PG, Fisher O, Lozornio A, Chan LS. (2011). Abdominal injuries in pregnancy: a 155-month study at two level 1 trauma centers. Injury, International Journal of the Care of the Injured. 42, 47-49.*

El objetivo de este estudio fue examinar los resultados de las pacientes embarazadas que hayan sufrido una lesión abdominal. Se trata de un análisis retrospectivo de todas las pacientes gestantes admitidas en dos centros de trauma de nivel 1 durante 155 meses. Se incluyeron datos como mecanismo de lesión, parámetros fisiológicos al ingreso, índice de severidad lesional (ISS), escala abreviada de lesión abdominal (AIS), edad gestacional, procedimientos diagnósticos y quirúrgicos

realizados, complicaciones y mortalidad materna y fetal. Se utilizó análisis univariante y de regresión logística. Se incluyeron 321 pacientes embarazadas, de las cuales 291 (91%) sufrieron una lesión contusa, mientras que 30 (9%) fueron víctimas de un trauma penetrante. De las lesiones penetrantes, 22 (73%) fueron heridas de bala, 7 (23%) heridas de arma blanca y 1 (4%) herida de escopeta. La maternidad general y la mortalidad fetal fue del 3% (n = 9) y del 16% (n = 45), respectivamente. La edad promedio fue 22,6 años de edad, y la media ISS fue 12±16. El AIS abdominal medio total fue de 2±1.2. Cuando se ajusta por edad, AIS abdominal, ISS y presión arterial diastólica, el grupo de trauma penetrante experimentó una mayor mortalidad materna [7% vs. 2% (OR ajustado: 7, IC 95%: 0.65-79), p= 0.090], mortalidad fetal significativamente más alta [73% vs. 10% (OR ajustado: 34; IC del 95%: 11-124), p<0,0001] y morbilidad materna [66% frente a 10% (OR ajustada: 25; IC del 95%: 9-79) p<0,0001]. La mortalidad fetal y la morbilidad materna general siguen siendo excesivamente altas (73% y 66%, respectivamente), después de una lesión abdominal penetrante. El mecanismo de lesión penetrante, la severidad de la lesión abdominal y la hipotensión materna al ingreso se asociaron de forma independiente con un aumento del riesgo de muerte fetal luego de un insulto traumático durante el embarazo.

Artículo III. *Petrone P, Marini CP. (2015). Trauma in pregnant patients. Current Problems in Surgery. 52, 321-352.*

Las lesiones traumáticas ocurren en al menos 1 de 20 mujeres embarazadas y actualmente representan la principal causa de muerte materna durante el embarazo. La posibilidad de embarazo debe ser considerado en todas las mujeres en edad reproductiva, por ello es esencial que los médicos tratantes de pacientes víctimas de trauma estén bien entrenados en la fisiología del embarazo y su efecto en la respuesta y manejo de tales lesiones. Este trabajo ofrece una perspectiva integral sobre este tema. Comienza con una perspectiva histórica, seguida de la epidemiología de esta condición. Una discusión a fondo de lo anatómico y los cambios fisiológicos del embarazo proporcionan una base para su revisión de la evaluación y manejo. La evaluación abdominal y los mecanismos de lesión están cubiertos en detalle. Las secciones

siguientes tratan sobre el parto por cesárea perimortem, complicaciones, predicción de resultados, implicaciones médico-legales, e incluso prevención de lesiones durante el embarazo, presentándose la evidencia de manera objetiva y con una perspectiva equilibrada, recursos valiosos para los médicos que tratan con pacientes traumatizados.

Artículo IV. *Petrone P, Jiménez-Morillas P, Axelrad A, Marini CP. (2017). Traumatic injuries to the pregnant patient: a critical literature review. European Journal of Trauma and Emergency Surgery. Sep 15. doi: 10.1007/s00068-017-0839-x.*

El trauma durante el embarazo es la principal causa no obstétrica de muerte materna y una carga importante en términos de salud pública. Este estudio revisa las causas más comunes de trauma durante el embarazo, morbilidad y mortalidad, y el impacto perinatal de los resultados asociados con trauma, proveyendo un abordaje a las pacientes embarazadas que hayan sufrido un traumatismo. Se realizó una revisión sistemática de la literatura más actual desde enero de 2006 a julio de 2016. Se identificaron 51 artículos, incluyendo un total de 95.949 pacientes. Las colisiones automovilísticas fue el mecanismo de trauma contuso más frecuente, seguido por caídas, asaltos por violencia doméstica e interpersonal, y lesiones penetrantes (por arma de fuego y por arma blanca). Los traumatismos en mujeres embarazadas se asocian con altas tasas de resultados adversos tanto maternos como neonatales. El conocimiento del mecanismo de lesión es importante para identificar las lesiones potenciales y la complejidad del manejo de estos pacientes. Como en todos los eventos traumáticos, la prevención es de suprema importancia.

Apéndice 3

or reconstruction. If operative correction is indicated, endoscopic urethrotomy is usually successful.

GENITAL INJURY

Penile fracture, although uncommon, demands immediate diagnosis and correction. The patient will have a history of a loud cracking sound while engaging in sexual activity, and in all cases an erection is present. A transverse tear in the tunica albuginea that surrounds the erectile bodies occurs as a result of the force applied to the area. Immediate detumescence occurs, and a hematoma develops on the penile shaft. This is often described as an "eggplant" deformity. In approximately 20% of cases, the urethra will be injured as well. These tunica injuries should be surgically corrected and involve degloving the penis, controlling the bleeding, and reapproximation of the tunica albuginea with interrupted polyglycolic acid sutures. Patients treated promptly in this manner almost always have a return of normal sexual function.

Blunt trauma to the scrotum may result in large hematoceles and testicular rupture. Testicular rupture is best diagnosed by ultrasonography, which will demonstrate areas of relative lucency of the echogenic patterns within the testicle parenchyma. Surgical correction of the ruptured testicle should be done by a trans-scrotal approach with evacuation of the hematoma and repair of the injury. The nonviable parenchyma that extrudes freely into the scrotal space should be removed, and the tunica albuginea of the testicle should be approximated with a running polyglycolic suture. These testicles heal after reconstruction and are useful for hormone production and cosmetic appearance. Return of spermatogenesis after such an injury is unpredictable. The need for complete orchiectomy is not often necessary when injury results from blunt trauma, particularly if diagnosed within 48 hours of injury.

Major skin loss to the penis and scrotum occurs from avulsion injuries, burns, gunshot wounds, and stab wounds. Urethrography should be done to determine whether concomitant urethral injury is present. Management should be aimed at reconstruction, using all attached salvageable skin. When local skin is not available, split-thickness skin grafts can be used to cover the testicles and penis. If the wound seems severely contaminated, testicles can be placed in subcutaneous pouches on the medial aspect of the thigh. More recent trends in management have involved wet-to-dry dressing changes to the exposed testicles, with grafting with split-thickness grafts once tissue bed is healthy. This has diminished the necessity of the thigh pouch technique, and delayed reconstruction. Third-degree burns of the penile shaft and scrotum should be corrected with total skin excision and immediate replacement with split-thickness skin grafts. With these methods, acceptable cosmetic and functional results can be expected.

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GYNECOLOGIC INJURIES

Areti Tillou and Patrizio Petrone

TRAUMA IN PREGNANCY

Gynecologic trauma includes a large variety of relatively rare and challenging injuries from blunt and penetrating mechanisms. While motor vehicle crashes are the leading cause of major injury in pregnant women, penetrating trauma accounts for almost all injuries to the fallopian tubes, ovaries, and nongravid uterus. Pelvic fractures and straddle injuries often result in trauma to perineum, vagina, and less commonly the cervix and uterus. Injuries to the external genitalia are frequently associated with interpersonal violence and should be treated in that context.

In recent years, trauma has been recognized as the leading cause of death during pregnancy. As unsuspected pregnancy is relatively common in the reproductive years, this possibility must be considered when evaluating female trauma victims. Pregnancy produces significant physiologic and anatomic changes that must be recognized and understood by all health care providers treating pregnant trauma patients (Table 1).

Table 1: Changes in Maternal Physiology during Pregnancy

Change	Consequence
Cardiac output and blood volume increase	Shock after >40% of blood lost
Expansion of plasma volume	Physiologic anemia
Decline in arterial and venous pressure	Vital signs are not reflective of hemodynamic status
Increase of resting pulse	
Chest enlargement	Change in anatomic landmarks Caution during thoracic procedures (e.g., thoracostomy)
Diaphragm rise	
Substernal angle increase	
Decrease in functional residual capacity	Rapid decline in PO_2 during apnea or airway obstruction
Increase in oxygen consumption	
Airway closure when supine	
Increase in tidal volume and minute ventilation	Fall in PCO_2 and bicarbonates
Decrease in anesthetic requirements	Need for adjustment of sedative doses
Decreased gastric motility	Risk of aspiration
Relaxation of gastroesophageal sphincter	

Incidence

According to some authors, nearly 50% of maternal deaths are related to trauma. From 6%–7% of all pregnancies are complicated by trauma, and 0.4% of the patients require hospitalization for treatment of injuries. In 1995, Weiss reported an epidemiologic 1-year study in which all women of childbearing age who required hospitalization for injuries were screened for pregnancy; of 16,722 women, 761 were identified (4.6%) as being pregnant. The actual number of injured pregnant women is underestimated as many of them are unreported, especially with injuries resulting from domestic violence.

Mechanism of Injury

Motor vehicle collisions are the most common causes of injury during pregnancy. As the pregnancy progresses, the shift in the woman's center of gravity and diminished agility can result in falls and accidental injuries. Other common causes of injury include automobile–pedestrian collisions and firearm injuries. Younger women are at higher risk for injury during pregnancy, with a mean maternal age of 25 years.

Young pregnant women are also at high risk for injuries resulting from battery. It has been reported that 10%–30% of women are abused during pregnancy, and 5% of cases involving abuse result in fetal death. Of injured pregnant patients, 17% experience intentional trauma and 60% suffer repeated episodes of domestic violence. Physical abuse is suspected when the injuries are located proximally and in the midline, rather than distally, and trauma is evident to the neck, breast, face, upper arms, and lateral thighs, as well as with bizarre injuries such as cigarette burns or bites.

Diagnosis

Care is undertaken with attention to both mother and fetus. Uterine blood flow lacks autoregulation and is related directly to maternal blood pressure; consequently, treatment priorities are the same as for the nonpregnant trauma patient, as the best initial treatment for the fetus is the optimal resuscitation of the mother. A thorough physical exam complemented by imaging studies is necessary to identify some of the unique problems that might be present in any pregnant patient, including blunt or penetrating injury to the uterus, placental abruption, amniotic fluid embolism, isoimmunization, or premature rupture of membranes.

Prehospital Care

As a result of significant changes in maternal physiology (see Table 1), supplemental oxygen should be administered to prevent maternal and fetal hypoxia during transport and in the resuscitation room. Fluid resuscitation should be initiated even in the absence of signs of hypovolemia and shock. To avoid supine hypotension associated with the uterine compression of the inferior vena cava (IVC), patients in the second or third trimester of pregnancy should be transported on a backboard tilted to the left, with special attention to immobilization of the cervical spine. If the patient is kept in a supine position, the right hip should be elevated 4–6 inches, and the uterus should be displaced manually to the left. This maneuver increases cardiac output by 30% and restores circulating blood volume. Although only about 10% of pregnant patients at term develop symptoms of shock in the supine position, fetal distress may be present even in normotensive mothers; therefore, right hip elevation should be maintained at all times including during operative procedures.

Hospital Care

Primary survey includes assessment of airway, breathing, and circulation (ABCs), including volume replacement and hemorrhage control. Secondary survey includes the obstetrical history, physical examination, and evaluation and monitoring of the fetus. The history should include the date of the last menstrual cycle, expected date of delivery, and any problems or complications of the current and previous pregnancies such as preterm labor or placental abruption. Comorbidities such as pregnancy-induced hypertension and diabetes mellitus should also be documented.

The abdominal examination is critically important, as is a determination of uterine size, which provides an approximation of gestational age and fetal maturity. A discrepancy between dates and uterine size suggests uterine hemorrhage or rupture. Uterine rupture is suspected with peritoneal signs, abdominal palpation of fetal parts due to extrauterine location, and inability to palpate the uterine fundus. However, as the uterus enlarges, it displaces the intestines upward and laterally, stretching the peritoneum and making the abdominal physical examination unreliable.

Determination of gestational age is particularly important because this will guide the decision for a premature delivery if indicated. Most institutions will accept a 24–26 week pregnancy as viable, with a probability of survival ranging from 20%–70%. Radiographic estimation of gestational age is bound to an error of 1–2 weeks. Unless the date of the conception is known exactly, gestational age is particularly difficult to determine. A good rule of thumb is to consider patients with a uterus halfway between the umbilicus and the costal margin as having a viable pregnancy (Figure 1). An algorithm for initial maternal and fetal assessment is presented in Figure 2.

Physical evaluation of the pregnant patient must be directed to the detection of the following six pregnancy-related acute conditions.

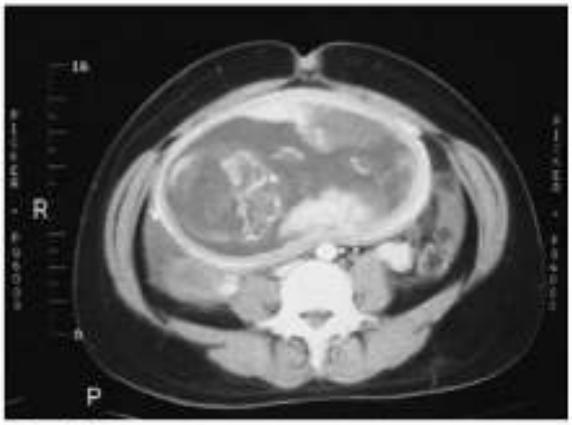

Figure 1 Computed tomography scan showing pregnant uterus above the level of umbilicus indicating a viable fetus.

Vaginal bleeding

This is an ominous sign that suggests premature cervical dilation, early labor, placental abruption, or placenta previa. Placental abruption after trauma occurs in 2%–4% of minor accidents and in up to 50% of major injuries. Maternal mortality from abruption is less than 1%, but fetal death ranges from 20% to 35%. Both fetal heart monitoring and sonographic evaluation should be used to investigate the possibility of abruption that most frequently becomes evident within several hours after trauma.

Ruptured membranes

In addition to increased risk of infection, prolapse of the umbilical cord can occur, resulting in compression of the umbilical vein and arteries.

Bulging perineum

This is caused most commonly by pressure from extrauterine location of fetal parts.

Presence and patterns of contractions

Direct or indirect trauma to the myometrium may result in release of arachidonic acid that can cause uterine contractions. Although most contractions will cease spontaneously, preparation for a premature delivery should be made.

Abnormal fetal heart rate and rhythm

An abnormal fetal heart rate may be the first indication of a major disruption in fetal homeostasis. During trauma resuscitation, evaluation of the fetus should begin with auscultation of heart tones and continuous electronic fetal heart rate monitoring (EFM). Any viable fetus of 24 or more weeks gestation requires monitoring after trauma. Cardiotocographic monitoring should be started in the resuscitation room and continued for a minimum of 4 hours; a

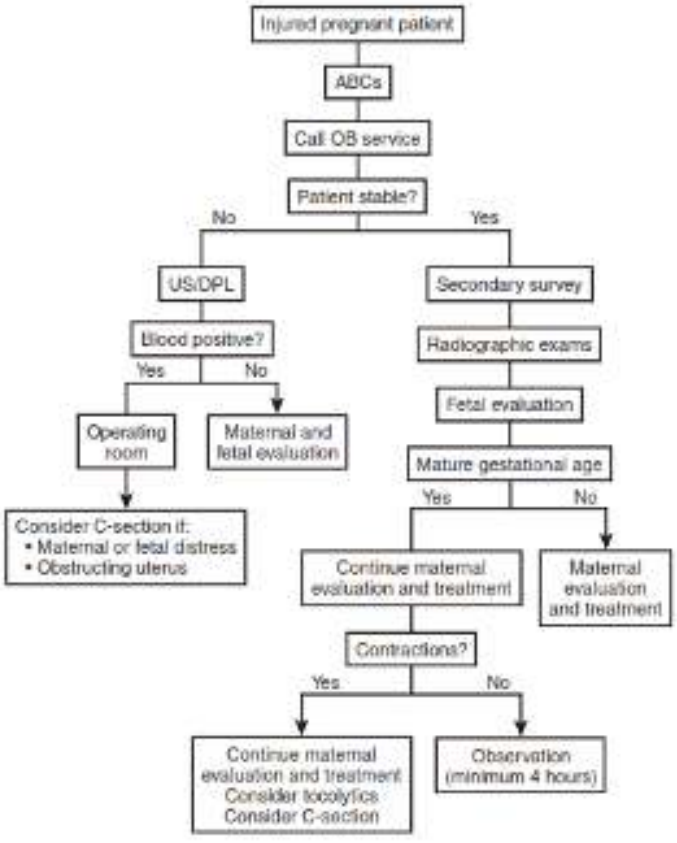

Figure 2 Algorithm for initial maternal and fetal assessment. OB, Obstetrics; US, ultrasound; DPL, diagnostic peritoneal lavage; C-section, cesarean section. *(Adapted from Knudson MM, Rozycki GS, Pasquale MM: Reproductive system trauma. In Moore EE, Feliciano DV, Mattox KL, editors: Trauma, 5th ed. New York, McGraw-Hill, 2004, pp. 851–873.)*

minimum of 24 hours is recommended for patients with frequent uterine activity (more than six contractions per hour), abdominal or uterine tenderness, ruptured membranes, vaginal bleeding, or hypotension.

Fetomaternal hemorrhage

Fetomaternal hemorrhage (FMH) is the transplacental hemorrhage of fetal blood into the normally separate maternal circulation and occurs in 8%–30% of patients with trauma during pregnancy. The severity of injury and the gestational age have no correlation with the frequency and volume of FMH. The Kleihauer-Betke (KB) test is used after maternal injury to identify fetal blood in the maternal circulation. The ratio of fetal to maternal cells is recorded, allowing calculation of the volume of fetal blood leaked to the maternal circulation. Complications of FMH include Rh sensitization in the mother, fetal anemia, fetal paroxysmal atrial tachycardia, and fetal death from exsanguination. As the volume of FMH sufficient to sensitize most Rh-negative women is well below the 5-ml sensitivity level of the typical laboratory's KB test, all Rh-negative mothers who present with a history of abdominal trauma should receive one 300-mcg prophylactic dose of Rh immune globulin (anti-D immunoglobulin; Rhogam) within 72 hours of the traumatic event. An additional 300 mcg of Rh immune globulin should be given for every 30 ml of fetal blood found in maternal circulation. Only 1.1% of major trauma cases require more than one 300-mcg Rh immune globulin dose. The KB test is probably unnecessary before 16 weeks gestation because the fetal blood volume is below 30 ml at this gestational age.

Radiographic Examination

There are three phases of radiation damage related to gestational age of the fetus. Before 3 weeks of gestation, during preimplantation and early implantation, exposure to radiation can result in death of the embryo. Between 3 and 16 weeks of gestation, during organogenesis, radiation can damage the developing fetal tube, resulting in anomalies in the central nervous system. After 16 weeks, neurologic defects are the most common complication. Prenatal radiation exposure may be associated with certain childhood cancers.

Although there is existing concern about radiation exposure during pregnancy, in most instances the benefits outweigh the risks. It is generally believed that exposure of the fetus to less than 5–10 rad causes no significant increase in the risk of congenital malformations, intrauterine growth retardation, or miscarriage. Radiation doses from common imaging studies are shown in Table 2. All indicated radiographic studies should be performed, as for nonpregnant patients (Figure 3). It is obvious that unnecessary duplication of studies should be avoided.

Abdominal Evaluation

Evaluation of the abdomen in the pregnant patient may be challenging. Superior displacement of the viscera by the expanding uterus changes the anatomical relation of the intra-abdominal organs (Figure 4). Special attention is needed for patients with rib or pelvic fractures, unexplained hypotension, blood loss, hematuria, or altered sensorium caused by drugs, alcohol, or brain injury.

Table 2: Radiation Doses from Plain Radiographs and CT

Plain anteroposterior chest x-ray	<0.005 rad
Pelvic x-ray	<0.4 rad
CT scan of head (1-cm cuts)	0.05 rad
CT scan of upper abdomen (20 1-cm cuts)	3.0 rad
CT scan of lower abdomen (10 1-cm cuts)	3.0–9.0 rad

CT, Computed tomography.

Figure 3 Pelvic x-ray of a pregnant patient after blunt trauma. Vertebrae and other parts of the fetus can be seen.

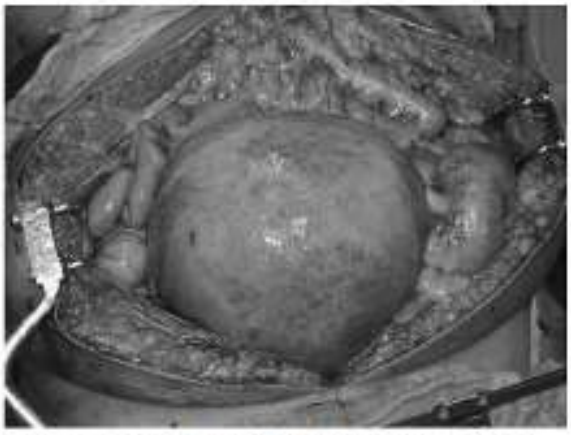

Figure 4 Exploratory laparotomy after motor vehicle collision. Gravid uterus displacing viscera.

Focused abdominal sonography for trauma (FAST) has a major role in the abdominal evaluation because it provides rapid detection of intra-abdominal and pericardial fluid in the mother as well as quick assessment of fetal condition. In the hemodynamically normal patient, abdominal CT scanning can also be done safely to evaluate both mother and fetus. If CT scan is necessary, both oral and intravenous contrast media should be administered as needed. The main drawback of a diagnostic peritoneal lavage (DPL) is its invasiveness, although the procedure can be done safely and has the same sensitivity as in the nonpregnant patient. DPL should be performed above the umbilicus using an open technique.

The American Association for the Surgery of Trauma (AAST) Organ Injury Scale for gravid uterus is shown in Table 3.

Surgical Treatment

Blunt Injury

Solid organ injuries may be managed nonoperatively in the hemodynamically stable pregnant patient. In contrast, unstable patients or those with intestinal injury clearly require early operation, as hypotension and infection can be harmful or even lethal for the fetus.

Table 3: AAST-OIS for Gravid Uterus

Grade	Injury Description	AIS-90 Score
I	Hematoma or contusion without placental abruption	2
II	Superficial laceration <1 cm in depth or partial placental abruption <25%	3
III	Deep laceration 1 cm in depth in second trimester or placental abruption 25% but <50%; deep laceration in third trimester	3–4
IV	Laceration extending to the uterine artery; deep laceration 1 cm with 50% placental abruption	4
V	Uterine rupture in second or third trimester; complete placental abruption	4–5

American Association for the Surgery of Trauma (AAST).
Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (nonpregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39(6):1069–1070, 1995.

Pelvic fractures represent the most challenging blunt injuries during pregnancy. Hemorrhage from dilated retroperitoneal veins can cause massive and fatal hemorrhagic shock. Maternal pelvic fracture is the most common cause of fetal death, with a fetal mortality approaching 25%. In nonpregnant patients, angioembolization is the usual treatment for pelvic hemorrhage, but the radiation dose for the procedure is considered excessive during pregnancy.

The abdominal wall, uterine myometrium, and amniotic fluid act as a cushion to direct forces from blunt trauma. Placental abruption is the most common cause of fetal death, resulting from anoxia, prematurity, or exsanguination. Manifestations include abdominal pain, vaginal bleeding, uterine tenderness, and contractions. One of the most serious complications associated with abruption is disseminated intravascular coagulation (DIC), caused when placental thromboplastin enters maternal circulation.

Penetrating Injury

As the uterus grows and expands out of the pelvis, it becomes an easier target for penetrating trauma. The thick density of its musculature allows the uterus to absorb energy from low-velocity penetrating injuries; maternal death is very uncommon except for injuries in the upper abdomen, which usually produce severe maternal damage. Gunshot wounds cause fetal injuries in 60%–70% of cases, with fetal death in 40%–65%. If the bullet has penetrated the uterus and the fetus is viable, cesarean section is indicated. Indications for C-section at celiotomy are summarized in Table 4.

Perimortem C-section is indicated in the case of maternal death if the fetus is viable (24 weeks). Timing is critical, as the probability of fetal survival is excellent when delivery occurs within 5 minutes or less of maternal demise. As the time increases, the chance of survival diminishes. In the rare situation where the mother is declared brain dead but maintains good vital signs, the fetus can be allowed to mature before delivery (Figure 5).

When performing an emergency C-section on a trauma patient, instead of the commonly used transverse incision, a vertical incision through all the layers into the uterus is safer and faster. This incision avoids injury to the uterine vessels, which enter the uterus from both sides.

Between gestational age 24–32 weeks, open cardiac massage (OCM) without aortic cross clamping should be seriously considered before an emergency C-section is performed. If OCM proves successful, the delivery may be delayed so that chances of postnatal survival improve. A proposed algorithm for emergency C-section after trauma is presented in Figure 6.

Table 4: Indications for C-Section during Laparotomy for Trauma

Maternal shock
Threat to life from exsanguinations from any cause
Mechanical limitation for maternal repair
Irreparable uterine injury
Fetal distress in viable fetus
Unstable thoracolumbar spine injury
Pregnancy near term
Maternal death

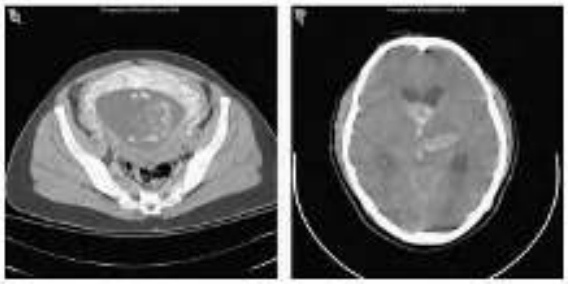

Figure 5 Intracranial hemorrhage (right panel) in an 18-week pregnant patient declared brain dead. As the fetus was not viable (left panel), the patient's family agreed to organ donation.

Morbidity and Mortality

Trauma has become the most frequent cause of maternal death in the United States. Older reports attributed 80% maternal mortality to amniotic fluid embolism, which together with pulmonary thromboembolism was cited as the leading cause of maternal mortality. In contrast to declining maternal mortality from infection, hemorrhage, hypertension, and thromboembolism, accidental deaths during pregnancy have risen steadily. According to the latest statistics, as many as 36% of maternal deaths are caused by penetrating trauma. While overall maternal mortality from abdominal gunshot wounds is low (3.9%), fetal mortality ranges between 40% and 70%. Risk factors associated with poor fetal outcome are listed in Table 5.

Conclusions

Trauma has become the leading cause of death in women aged 34 and younger, including pregnant patients. Pathophysiologic changes in pregnancy affect all aspects of traumatic injury and require detailed assessment and meticulous management.

TRAUMA TO NONGRAVID UTERUS AND FEMALE GENITALIA

There is a relative abundance of information on trauma in pregnancy and a relative paucity regarding injuries to the female genitalia. Although these injuries are uncommon in the nonpregnant patient, they

Figure 6 Algorithm for emergency cesarean section after trauma. *C-section*, Cesarean section; *CPR*, cardiopulmonary resuscitation. *(Adapted from Mann JA Jr, Rosenbower TJ, Jurkovich GJ, et al: Infant survival after cesarean section for trauma, Am Surg 223:481–488, 1996.)*

Table 5: Predictors of Fetal Outcome

Maternal death
Maternal hypotension
Maternal traumatic brain injury
High Injury Severity Score (ISS)
Pelvic fracture
Ejection of pregnant woman from a vehicle
Severe abdominal injury to pregnant woman

are more often seen in cases where there is pathologic enlargement of the internal genitalia or in the early postpartum period. Missed or improperly treated female genital injuries can result in hemorrhage, sepsis, and loss of endocrine and reproductive function.

Incidence

The incidence of injuries to the female genitalia is largely unknown. Most information on the subject comes from isolated case reports or small series of patients. Vaginal lacerations complicate approximately 3.5% of pelvic fractures in female patients. Urethral and bladder injuries are also commonly present.

Mechanism of Injury

Blunt injuries involving the female genitalia are most frequently associated with pelvic fractures. Injuries to the external genitalia can also be the result of straddle injuries or accidental penetration. Water skiing, gymnastics, and bicycling accidents have been reported as the causes of blunt trauma to the lower genitalia. Penetrating injuries are almost exclusively responsible for injuries to the upper genital organs, although several reports of blunt trauma to normal ovaries and uterus have been reported.

Many of the injuries to the external genital organs are the result of violent acts in pregnant as well as nonpregnant women. This possibility should be always be considered, especially when the mechanism of injury is unclear. If sexual assault has occurred, informed consent for the remainder of the assessment must be obtained.

Domestic violence crosses lines of ethnicity/race, age, national origin, sexual orientation, religion, and/or socioeconomic status, although an overwhelming majority of the victims in heterosexual relationships are women. Typically, battery tends to occur as a pattern of violence rather than a one-time event. Physicians treating trauma victims should able to recognize the signs of domestic violence, refer patients to appropriate agencies, and provide social and other support.

Diagnosis

Initial assessment and resuscitation are performed as for any trauma patient. The secondary survey should include a detailed physical examination of the perineum. Examination under anesthesia may be needed for patients with severe pain or active bleeding. A complete examination should include bimanual palpation and speculum examinations of vagina and anorectum. Some authors recommend anesthesia for all patients with perineal trauma in order to evaluate the extent of the injury.

Intra-abdominal genital injuries are usually diagnosed at laparotomy for associated injuries. As blunt injury is more common with pathologically enlarged internal genitalia in the nongravid patient, CT scan of the abdomen or DPL may aid the diagnosis, although the latter is very rarely used. Detailed grading of gynecologic injuries is presented in Tables 6 through 10.

Table 6: AAST-OIS for Gynecologic Injuries: Vagina

Grade	Injury Description	AIS-90 Score
I	Contusion or hematoma	1
II	Superficial laceration involving mucosa	1
III	Deep laceration extending into submucosal fat or muscle	2
IV	Complex laceration extending into the cervix or peritoneum	3
V	Injury to adjacent organs	3

American Association for the Surgery of Trauma (AAST).
Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (nonpregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39(6):1069–1070, 1995.

Table 7: AAST-OIS for Gynecologic Injuries: Vulva

Grade	Injury Description	AIS-90 Score
I	Hematoma or contusion	1
II	Superficial laceration involving skin only	1
III	Deep laceration extending into subcutaneous fat or muscle	2
IV	Avulsion of skin, fat, or muscle	3
V	Injury to adjacent organs	3

American Association for the Surgery of Trauma (AAST).
Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (nonpregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39(6):1069–1070, 1995.

Table 8: AAST-OIS for Gynecologic Injuries: Nongravid Uterus

Grade	Injury Description	AIS-90 Score
I	Hematoma or contusion	2
II	Superficial laceration <1 cm in depth	2
III	Deep laceration 1 cm in depth	3
IV	Laceration extending to uterine artery	3
V	Devascularization or avulsion	3

American Association for the Surgery of Trauma (AAST).
Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (nonpregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39(6):1069–1070, 1995

Table 9: AAST-OIS for Gynecologic Injuries: Fallopian Tube

Grade	Injury Description	AIS-90 Score
I	Hematoma or contusion	2
II	Laceration involving <50% of circumference	2
III	Laceration involving 50% of circumference	2
IV	Complete transection	2
V	Devascularized segment	2

American Association for the Surgery of Trauma (AAST).
Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (nonpregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39(6):1069–1070, 1995

Table 10: AAST-OIS for Gynecologic Injuries: Ovary

Grade	Injury Description	AIS-90 Score
I	Contusion or hematoma	1
II	Superficial laceration <0.5 cm in depth	2
III	Deep laceration 0.5 cm in depth	3
IV	Partial disruption of blood supply	3
V	Complete parenchymal disruption or avulsion	3

American Association for the Surgery of Trauma (AAST).
Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (nonpregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39(6):1069–1070, 1995.

Surgical Management

Isolated perineal lacerations should be repaired after appropriate irrigation and debridement with or without placement of drains. Large perineal hematomas require incision and drainage because of the high associated incidence of infection and sepsis. Vulvar lacerations may be closed primarily with absorbable sutures.

Repair of vaginal and cervical lacerations may be challenging because of the abundant blood supply. Absorbable sutures including the mucosal and submucosal layers are commonly used. These injuries must be diagnosed promptly in patients with pelvic fractures, as any delay can result in sepsis and death.

Injuries to the uterus are repaired in two layers using slowly absorbable running or interrupted figure-of-eight sutures. Hysterectomy for trauma is extremely rare and is only needed in extreme cases of massive destruction or exsanguinating hemorrhage. Injuries to the fallopian tubes and ovaries are also managed by either primary repair or excision according to injury severity. Vaginal packing with antibiotics is frequently used for 24 hours after procedures involving the vagina, cervix, or uterus.

Morbidity and Mortality

Morbidity is primarily determined by the associated injuries. Profuse bleeding from the perineal wounds as well as vagina, cervix, and uterus may be the cause of hemorrhagic shock. These wounds may be difficult to control. Missed perineal injuries in association with pelvic fracture may be fatal. Long-term complications include sexual dysfunction and infertility.

Conclusions

Injuries to the nongravid uterus as well as female genital organs are rare and should be suspected in all assault victims and all patients with direct perineal trauma, pelvic fractures, or penetrating injury to the pelvis. Thorough physical examination, preferably in the operating room, with prompt surgical treatment improves the outcome of these potentially challenging injuries.

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Apéndice 4

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Traumatismo en la mujer embarazada
Trauma in pregnant women

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Introducción

El traumatismo es considerado como la principal causa de muerte de origen no obstétrico durante el embarazo. Fildes[1] informó que alrededor del 50% de las muertes maternas están relacionadas con traumatismos, y del 6 al 7% de todos los embarazos sufren complicaciones debido a estos, de los cuales el 0,4% requieren hospitalización para el tratamiento de las lesiones.[2] El número real de mujeres embarazadas que sufren traumatismos no se conoce a ciencia cierta ya que muchos de ellos no se informan, especialmente los debidos a violencia doméstica.

Es esencial que los profesionales que se especializan en tratar pacientes víctimas de traumatismo reconozcan y estén preparados ante los cambios anatómicos y fisiológicos que ocurren en las mujeres embarazadas y cómo esos cambios impactan en la evaluación y el tratamiento de esta población única y sepan que, para poder salvar el embarazo, las evaluaciones deben incluir la evaluación del feto.

Perspectiva histórica

Los casos más antiguos de lesión traumática en el embarazo fueron descriptos en el Código de Hammurabi (siglo XV, a. C.)[3] y en el Viejo Testamento (Éxodo 22:21). Lesiones penetrantes del útero grávido con objetos como lanzas, ramas o cuernos de animales han sido observadas desde la Antigüedad. Ambroise Paré, famoso cirujano militar de origen francés, fue el primero en describir el tratamiento de lesiones penetrantes uterinas.[4]

En la literatura médica de los últimos siglos, el tema del traumatismo durante el embarazo recibió un interés más detallado. Los artículos más antiguos describían casos relacionados con caídas, apaleamientos y agresiones,[5] pero conforme la sociedad se tornó más industrializada, los informes clínicos se centraron en incidentes automovilísticos (MVC, *motor vehicle collision*) y lesiones penetrantes.

Incidencia

El Centro de Prevención e Investigación de Lesiones en Pittsburgh, Pennsylvania, publicó un excelente estudio epidemiológico,[6] en el que incluyó a todas las mujeres en edad fértil durante un año, y que hayan requerido hospitalización a causa de traumatismo. De un total de 16.722 mujeres admitidas, se identificaron 761 (4,6%) como embarazadas, con una media de 25 años de edad. Las causas más comunes fueron MVC (33,6%), caídas (26,4%) y envenenamiento (16%). Más tarde, el mismo autor dio a conocer otro estudio,[7] esta vez de tres años de duración, en el que identificó 240 muertes fetales de origen traumático (3,7 muertes fetales por 100.000 nacidos vivos). Los MVC representaron el principal mecanismo (82%), seguido de lesiones por arma de fuego (6%) y caídas (3%). Weiss,[8] en un estudio acerca de mortalidad fetal de dos años de duración y con información de un solo estado, encontró 7 131 muertes fetales de los cuales 31 fueron identificadas como de origen traumático (6,5 muertes fetales por 100.000 nacidos vivos). Los MVC también fueron la principal causa de lesión (81%), y la disrupción placentaria, el principal diagnóstico (42%). Nuevamente se informó que la mujer embarazada joven se encuentra expuesta a un mayor riesgo, con una media de 25 años de edad.

Más recientemente Leggon y col.[9] realizaron una revisión extensa de la literatura, comprendiendo los años 1932 a 2000, en la que incluyeron 101 fracturas pélvicas y de acetábulo durante el embarazo. Encontraron

que el promedio de edad fue de 25 años, y las lesiones maternas asociadas estuvieron presentes en el 60% de las pacientes. El mecanismo de lesión más común fueron los MVC (73%), seguidos por las caídas (14%) y las colisiones automóvil vs. peatón (13%). La mortalidad materna global fue de 9% y la mortalidad fetal global fue de 35%. Los autores estratificaron la mortalidad según el mecanismo de lesión y encontraron que las colisiones auto vs. peatón estaban asociadas con una mortalidad materna de 27% (3 de 11) y una mortalidad fetal de 45% (5 de 11). En el caso de los MVC se asociaron con una mortalidad materna de 6% (4 de 63) y fetal de 36% (23 de 63), mientras que las caídas (n=12) no presentaron mortalidad materna, pero sí fetal (8%, 1 de 12). Los autores concluyeron que las colisiones automóvil vs. peatón presentaban una tendencia estadística mayor para mortalidad materna, mientras que tanto este como los MVC la presentaban para mortalidad fetal.

Existen informes[10] que dan cuenta de que el 10 al 30% de las mujeres son abusadas durante el embarazo, y el 5% derivó en muerte fetal. El abuso físico es sospechado cuando las lesiones se localizan principalmente en la parte proximal y en la línea media corporal antes que distalmente; es evidente en el cuello, mamas, cara, parte superior de los brazos y lateral de los muslos. También son altamente sospechosas las lesiones bizarras como quemaduras de cigarrillos y mordeduras[11]. Si bien los casos de violencia doméstica se asocian con un amplio abanico de condiciones psicológicas, psicosomáticas y físicas, su diagnóstico requiere ciertas habilidades clínicas. Los síntomas más comunes son cefalea, dolor crónico inespecífico, estrés postraumático, síntomas ginecológicos, lesiones agudas y crónicas como las descriptas más arriba, y abuso de sustancias, entre otras condiciones[12]. Aproximadamente el 33% presentan ansiedad y depresión, mientras que el 26% de los intentos de suicidio son mujeres que experimentan violencia interpersonal, aunque este número podría llegar a ser superior debido a la falta de informes.

En el año 2011, Petrone y col.[13] en un estudio de 13 años de duración realizado en dos centros de trauma Nivel 1, Los Angeles County + University of Southern California Trauma Center (Los Angeles, California) y University of Southern Nevada Las Vegas Trauma Center (Las Vegas, Nevada), incluyeron 321 pacientes embarazadas, de las cuales 291 (91%) presentaban traumatismo contuso mientras que 30 (9%) fueron víctimas de traumatismo penetrante. Los autores informaron una morbilidad materna de 66% y una mortalidad fetal de 73% luego de traumatismo abdominal penetrante. Este último mecanismo de lesión, la severidad de la lesión abdominal, y la presencia de hipotensión materna al ingreso fueron identificados como factores de riesgo asociados a muerte fetal luego de un hecho traumático.

Cambios anatómicos y fisiológicos

La evaluación inicial y la conducta frente a la paciente embarazada víctima de traumatismo son las mismas que para todos los pacientes traumatizados, aunque los cambios anatómicos y fisiológicos durante el embarazo pueden alterar la respuesta a dichas lesiones. Es esencial entender todos los cambios durante este período para proveer el cuidado apropiado tanto a la madre como al bebé por nacer.

A) Aparato cardiovascular

El volumen plasmático comienza a expandirse a partir de la semana 10 de gestación. El aumento de estrógeno, progesterona, renina y aldosterona contribuye a expandir el volumen plasmático 5% de los niveles pregrávidos, así como también aumenta la reabsorción tubular de sodio 950 mEq, y de 6 a 8 litros de retención de agua corporal.[14] Este estado hipervolémico ejerce una función de protección materna durante el potencial sangrado por una lesión y la prepara para la pérdida sanguínea sea durante el parto vaginal (500 mL) como la cesárea (1 000 mL). Este estado es conocido como "anemia fisiológica del embarazo" y, durante su etapa final, un hematocrito de 31 a 35% se considera normal. Debido al aumento en el volumen plasmático, la paciente embarazada puede tener hasta 35% de pérdida sanguínea antes de exhibir cualquier signo o síntoma de shock materno, ofreciendo una falsa sensación de seguridad. Otros cambios incluyen un aumento del recuento de glóbulos blancos, que pueden llegar hasta 25 000/mm^3 durante el trabajo de parto, un aumento de los factores de coagulación y del fibrinógeno, y una disminución de la actividad fibrinolítica, derivando esto último en un estado hipercoagulable y un riesgo aumentado de eventos tromboembólicos.

La frecuencia cardíaca aumenta gradualmente, de 10 a 15 latidos por minuto a través de todo el embarazo, debido a que el útero eleva el diafragma y desplaza el ápex cardíaco. El valor medio de la presión arterial durante el primer trimestre es de 105/60 mm Hg, 102/55 mm Hg para el segundo y 108/67 mm Hg para el final del embarazo, por lo que cualquier incremento significativo puede indicar hipertensión inducida por el embarazo.

Para el final del primer trimestre, el gasto cardíaco aumenta entre 1 y 1,5 L/minuto, lo que representa alrededor de un 25% por encima del valor normal debido a un aumento del volumen plasmático y una disminución de la resistencia vascular del útero y la placenta[15].

Hay un punto en el que vale la pena poner énfasis, y es acerca de la posición materna en el traslado durante la segunda mitad del embarazo. Cuando la paciente se encuentra en decúbito supino, la vena cava inferior se encuentra obstruida parcialmente por el útero

aumentado de tamaño, produciendo una disminución del retorno venoso hacia el lado derecho del corazón, lo que ocasiona una disminución del gasto cardíaco y causa el "síndrome de hipotensión supina", caracterizado por mareo, palidez, taquicardia, sudoración e hipotensión, condición que mejora cuando la paciente es colocada en decúbito lateral izquierdo.

B) Aparato respiratorio

El diafragma se eleva aproximadamente 4 cm y su diámetro aumenta 2 cm,[16] cambios que deben ser tenidos en cuenta al realizar procedimientos tóracicos. Los cambios más notables son el incremento de la ventilación por minuto y la disminución de la capacidad reidual funcional debido a una disminución de los volúmenes de reserva expiratoria y residual. La presión parcial de oxígeno (PaO^2) no sufre cambios, mientras que hay una disminución de la presión parcial de dióxido de carbono (PCO^2), con una disminución compensatoria en los niveles de bicarbonato.[17] La administración de oxígeno suplementario está siempre indicada ya que las pacientes embarazadas no toleran bien la apnea.

C) Aparato gastrointestinal

Tanto la motilidad, la secreción como la absorción gastrointestinal están inhibidas debido a un incremento en los niveles de progesterona y estrógeno durante el embarazo. Adicionalmente, el esfínter esofágico inferior se desplaza hacia el tórax, disminuyendo su competencia.[18] Por lo tanto, se debe asumir que el estómago de la paciente embarazada se encuentra siempre lleno, por lo que para evitar la broncoaspiración, se indica la descompresión a través de una sonda nasogástrica. Debido al continuo crecimiento del útero, el intestino delgado es desplazado lateral y superiormente.

D) Aparato urinario

El cambio más temprano del sistema urinario es el incremento del filtrado glomerular y del flujo renal sanguíneo en un 30%.[19] Al mismo tiempo hay un aumento del *clearance* de creatinina así como también una caída marcada de los niveles séricos de creatinina y del nitrógeno ureico en sangre (BUN). Conforme el útero continúa aumentando de tamaño, los uréteres y la vejiga son comprimidos, derivando en hidronefrosis e hidrouréter, por lo que un sistema colector dilatado en una paciente embarazada se considera normal.

E) Sistema endocrino

La glándula pituitaria aumenta aproximadamente 135% su tamaño original[20]. El shock puede producir necrosis de la parte anterior de la glándula, causando una insuficiencia pituitaria o síndrome de Sheehan, potencialmente fatal.

F) Aparato locomotor

El reblandecimiento y la relajación de los ligamentos interóseos durante el embarazo aumenta la articulación sacroilíaca, ensanchando la sínfisis en 8 mm. Debido a estos cambios el centro de gravedad materno se encuentra alterado y la mujer embarazada intenta compensarlo adoptando una posición lordótica, lo que da como resultado un riesgo aumentado de caídas.

G) Aparato neurológico

La hemorragia intracerebral es la causa de muerte en pacientes con hipertensión inducida por el embarazo y, debido a que ello puede producir convulsiones, puede aparentar una lesión cerebral. Debe sospecharse cuando la hipertensión está asociada a hiperreflexia, proteinuria y edema.

Evaluación y conducta

El personal prehospitalario debe estar consciente de los cambios fisiológicos durante el embarazo. De particular importancia es proveer oxígeno suplementario con el objeto de prevenir tanto la hipoxia fetal como la materna, así como administrar fluidos liberalmente por vía intravenosa durante el transporte de estas pacientes. Debido al aumento de volumen intravascular, pueden perder una cantidad significativa de volumen sanguíneo antes que aparezcan signos como taquicardia o hipotensión. Con el objetivo de evitar la hipotensión supina asociada a la compresión uterina de la vena cava inferior,[21] las pacientes en el segundo o tercer trimestre de embarazo deben ser transportadas en la tabla con inclinación hacia la izquierda, prestando especial atención a la inmovilización de la columna cervical. Si la paciente se encuentra en posición supina, la cadera derecha debería elevarse 15 cm, y el útero ser desplazado manualmente hacia la izquierda.[22]

Las prioridades en el tratamiento de las pacientes embarazadas son las mismas que para todos los pacientes. La evaluación primaria incluye la vía aérea, la ventilación y la circulación (ABC), incluido el control de la hemorragia y la administración de fluidos, es la madre quien recibe tratamiento primero.

La evaluación secundaria consiste en el examen físico, la evaluación y monitorización del feto, así como obtener la historia obstétrica de la paciente. A pesar del embarazo deben tomarse las radiografías necesarias. Algunos factores concomitantes como la hipertensión inducida por el embarazo y la diabetes

mellitus tienen que estar documentados para proveer el tratamiento necesario. La historia obstétrica incluye episodios de contracciones previas, disrupción placentaria, la fecha del último ciclo menstrual, la fecha estimada del parto, y cualquier otro problema o complicación tanto del embarazo actual como previos.

El examen abdominal es crítico. La determinación del tamaño uterino indica una aproximación de la edad gestacional y de la madurez fetal (Figura 1). Una discrepancia entre la fecha y el tamaño uterino es sugestiva de ruptura o hemorragia uterina. La ruptura es sospechada por signos de peritonismo pero el examen abdominal suele ser dificultoso. Otros hallazgos incluyen la palpación abdominal de partes fetales localizadas fuera del útero e imposibilidad de palpar el fundus uterino.

El examen físico de la paciente embarazada debe incluir las siguientes seis condiciones que indiquen el estado del embarazo:[23]

1. *Hemorragia vaginal:* sugiere dilatación cervical prematura, disrupción placentaria o placenta previa.
2. *Rotura de membranas:* puede ocurrir el prolapso del cordón umbilical y ocasionar compresión de las arterias y vena umbilicales.
3. *Abultamiento del periné:* causado por la presión extrauterina de partes fetales.
4. *Presencia y patrón de las contracciones:* su presencia es importante en preparación para un parto temprano.
5. *Frecuencia y ritmo cardíacos fetales anormales.*
6. *Test de Kleihauer-Betke (KB):* se usa luego del traumatismo para identificar la presencia de sangre fetal en la ciculación materna (transfusión feto-madre).

Exámenes radiográficos

Existen tres fases de daño fetal relacionado con la radiación dependiendo de la edad gestacional.[24] Antes de las 3 semanas, antes e inmediatamente después de la implantación, la exposición a la radiación puede derivar en la muerte del embrión. Entre las semanas 3 y 16 de gestación, durante la organogénesis, la radiación puede dañar el tubo neural, y ocasionar anomalías en el sistema nervioso central. Después de las 16 semanas, la complicación más común comprende defectos neurológicos.[24] La exposición prenatal a las radiaciones puede llegar a asociarse con algunos tipos de cáncer de la infancia.[25]

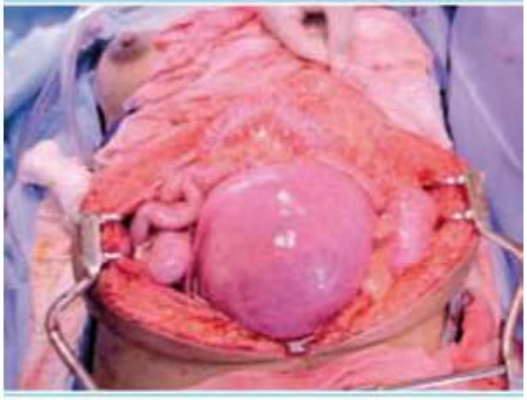
Los estudios radiográficos deben realizarse como en cualquier tipo de pacientes (Figura 2), sabiendo que los beneficios superan a los riesgos. La exposición fetal a radiación menor de 10 rad (*radiation absorbed dose*) no presenta un riesgo mayor, aunque es obvio que se deben evitar duplicaciones innecesarias. Las dosis de radiación de los estudios por imágenes más comunes se muestran en la Tabla 1.[26]

Evaluación abdominal

La evaluación del abdomen en la paciente embarazada suele ser un desafío, y se debe prestar especial atención a la presencia de una fractura costal o pélvica, hipotensión sin origen que la justifique, pérdida sanguínea, hematuria, alteración del sensorio debido a drogas, alcohol o por una lesión cerebral.

La ecografía (*Focused Abdominal Sonography for Trauma*, FAST) tiene un papel preponderante en la evaluación abdominal y es considerada de elección, ya que de manera rápida y no invasiva puede detectar líquido libre abdominal y pericárdico, así como también investigar la condición general del feto.[27] El lavado peritoneal diagnóstico (LPD) puede realizarse de forma

FIGURA 1



Laparotomía exploradora en una paciente embarazada luego de un MVC. Obsérvese el desplazamiento intestinal causado por el útero grávido. (Archivo personal del Dr. Petrone)

FIGURA 2

TC abdominal en una mujer embarazada. (Archivo personal del Dr. Petrone)

TABLA 1

Dosis de radiación de estudios por imágenes

Rx AP de tórax	<0,005 rad
Rx de pelvis	<0,4 rad
TAC cerebral (cortes de 1 cm)	0,05 rad
TAC de abdomen (20 cortes de 1 cm)	3,0 rad
TAC de pelvis (10 cortes de 1 cm)	3,0-9,0 rad

TABLA 2

Escala de lesión del útero grávido[28]

Grado	Descripción	AIS-90 Score
I	Hematoma o contusión sin disrupción placentaria	2
II	Laceración superficial <1 cm de profundidad o disrupción parcial placentaria <25%	3
III	Laceración de 1 cm de profundidad en el segundo trimestre o disrupción placentaria de 25% pero <50%; laceración profunda en el tercer trimestre	3-4
IV	Laceración hasta la arteria uterina; laceración profunda de 1 cm con 50% de disrupción placentaria	4
V	Ruptura uterina en el segundo o tercer trimestre; disrupción placentaria completa	4-5

FIGURA 3

Lesión contusa en una mujer embarazada a término ejectada del vehículo y luego arrollada. Obsérvese la marca del neumático sobre el abdomen. (Archivo personal del Dr. Petrone)

segura y posee la misma sensibilidad que en cualquier paciente, solo que, como detalle técnico, se debe tener en cuenta que el LPD debe realizarse por encima del ombligo utilizando la técnica abierta. La tomografía computarizada (TC) de abdomen también puede utilizarse con seguridad y evalúa tanto a la madre como al feto, pero la paciente debe estar hemodinámicamente estable. El Comité de Escalas de Lesión de Órganos de la Asociación Norteamericana de Cirugía del Trauma (American Association for the Surgery of Trauma-Organ Injury Scale Committee, AAST-OIS) clasificó las lesiones del útero grávido en grados tal como se muestra en la Tabla 2.[28]

Mecanismos de lesión

Como en todo evento traumático existen dos tipos de mecanismos de lesión: contuso y penetrante.

A) Lesión contusa

El manejo no operatorio de órganos sólidos abdominales usualmente se realiza con éxito en las pacientes embarazadas en condiciones estables. Sin embargo, las pacientes inestables o aquellas con lesiones intestinales se benefician con una intervención quirúrgica temprana, ya que tanto la hipotensión como la sepsis son perjudiciales y hasta mortales para el feto (Figura 3).

La fractura de pelvis es la lesión que implica un mayor desafío durante el embarazo. La hemorragia proveniente de las venas retroperitoneales dilatadas pueden causar shock hemorrágico y muerte.[28] La fractura de pelvis es la causa más común de muerte fetal con una mortalidad del 25%. En este tipo de trauma la angioembolización es el tratamiento indicado, pero la dosis de radiación excede lo que es considerado seguro durante el embarazo.

La pared abdominal, el miometrio y el líquido amniótico amortiguan las fuerzas que son aplicadas directamente en forma de traumatismo contuso. La causa más común de muerte fetal se debe a la disrupción placentaria, debida a anoxia o exsanguinación. Las manifestaciones incluyen hemorragia vaginal, dolor abdominal, reblandecimiento uterino y contracciones,[29] y una de las más serias complicaciones asociada a ella es la coagulación intravascular diseminada (CID), causada cuando la tromboplastina de la placenta entra en contacto con la circulación materna.

B) Lesión penetrante

A medida que el útero aumenta de tamaño y se expande por fuera de la pelvis, más fácilmente se convierte en blanco de lesiones penetrantes (Figura 4). Debido a que el espesor de la musculatura uterina es

capaz de absorber la energía proveniente de lesiones penetrantes de baja velocidad, la mortalidad materna en estos casos no es común, excepto cuandose lesiona el abdomen superior, lo que sí acarrea un daño severo. Hasta un 60%-70% de los fetos son lesionados luego de una herida abdominal por arma de fuego, y desafortunadamente del 40 al 65% de ellos fallece[31] (Figura5). Si el proyectil penetró el útero y el feto es viable, se indica la intervención por cesárea.

Cesárea perimortem

Por definición se considera a un feto viable cuando presenta 26 semanas de gestación. Una regla práctica es cuando la altura del fundus uterino se encuentra a mitad de camino entre el ombligo y el reborde costal. En estos casos se indica la cesárea luego de la muerte materna, ya que el feto posee entre el 40 y el 70% de probabilidades de sobrevida.[33,34] Otro factor muy importante para tener en cuenta es el tiempo transcurrido entre la muerte de la madre y la cirugía. Si la cesárea se realiza durante los primeros cinco minutos, la probabilidad de sobrevida es excelente, pero va disminuyendo conforme el tiempo va en aumento.[33,34]. Debido a que los cirujanos de traumatismo no estamos familiarizados con este tipo de cirugía, un abordaje técnico importante durante la realización de la cesárea es efectuar una incisión vertical en la línea media del útero, alejándose de este modo de los vasos uterinos.

Complicaciones

El embolismo de líquido amniótico se asocia con el 80% de mortalidad materna y, junto al tromboembolismo pulmonar, representa la principal causa de muerte materna en los Estados Unidos.[34] Además de la inestabilidad hemodinámica y el compromiso pulmonar, estas pacientes pueden desarrollar CID, y, debido a que el embarazo es un estado de hipercoagulabilidad, los episodios tromboembólicos permanecen como la causa más común de morbilidad y mortalidad durante este período.

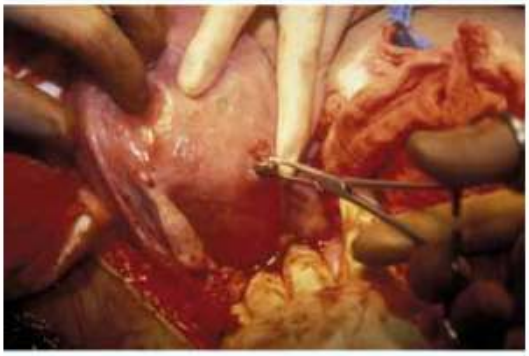
Se postulan varios factores predictivos que se asocian a un alto riesgo para el feto,[24] y los más comunes relacionados con la madre son:

- Muerte materna
- Hipotensión
- Lesión cerebral traumática
- Alto índice de severidad lesional
- Fractura pélvica
- Mujer embarazada eyectada del vehículo
- Lesión abdominal severa

Prevención

La prevención merece una atención específica durante el embarazo, sobre todo en lo relacionado con el uso de drogas y alcohol, que no solo es perjudicial para el feto sino también se asocia con un alto riesgo de lesiones. En el mismo contexto, la violencia doméstica es una causa mayor de lesión durante el embarazo.[10] Se informó el 17% de prevalencia de abuso físico o sexual durante este período, con el 60% de las mujeres teniendo dos o más episodios de agresión[11]. La violencia interpersonal no depende de la raza, edad, estado civil, ni estatus socioeconómico, por lo que todas las mujeres embarazadas son potenciales víctimas de abuso.[35]

FIGURA 4



Lesión penetrante abdominal por herida de arma de fuego impactando en la pared posterior del útero. Obsérvese la extracción del proyectil. (Archivo personal del Dr. Petrone)

FIGURA 5

Orificio de entrada de un proyectil en la cabeza de un feto luego una cesárea. (Archivo personal del Dr. Petrone)

Conclusión

El traumatismo se convirtió en la principal causa de muerte en pacientes embarazadas jóvenes. Luego de un traumatismo penetrante abdominal, la mortalidad fetal y la morbilidad global materna permanecen excesivamente altas.

La evaluación de una paciente en edad fértil víctima de traumatismo siempre debe incluir la posibilidad de embarazo. Los cambios patofisiológicos durante este afectan todos los aspectos de una lesión traumática y requieren una evaluación detallada y un manejo meticuloso de esta población particular de pacientes.

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Apéndice 5

Gynecologic Injuries: Trauma to Gravid and Nongravid Uterus and Female Genitalia

Patrizio Petrone and Areti Tillou

Gynecologic trauma includes a large variety of relatively rare and challenging injuries from blunt and penetrating mechanisms. Although motor vehicle crashes are the leading cause of major injury in pregnant women, penetrating trauma accounts for almost all injuries to the fallopian tubes, ovaries, and nongravid uterus. Pelvic fractures and straddle injuries often result in trauma to perineum, vagina, and less commonly the cervix and uterus. Injuries to the external genitalia are frequently associated with interpersonal violence and should be treated in that context.

TRAUMA DURING PREGNANCY

Trauma has been recognized as the leading cause of death during pregnancy and remains the most common cause of fetal demise. Women between the ages of 10 and 50 years have the potential for pregnancy, and this possibility must be taken into consideration when a female patient is examined in the emergency room after sustaining a traumatic event. Pregnancy produces significant physiologic and anatomic changes that must be recognized and understood by all health care providers treating pregnant trauma patients (Table 1).

Incidence

According to some authors, nearly 50% of maternal deaths are related to trauma. From 6% to 7% of all pregnancies are complicated by trauma, and 0.4% of the patients require hospitalization for treatment of injuries. In 1995, Weiss reported an epidemiologic 1-year study in which all women of childbearing age who required hospitalization for injuries were screened for pregnancy; of 16,722 women, 761 were identified (4.6%) as being pregnant. The actual number of injured pregnant women is underestimated as many of them are unreported, especially with injuries resulting from domestic violence.

In 2011, Petrone et al reported a 159-month study from two Level 1 trauma centers in which 321 pregnant patients were included, of which 291 (91%) sustained a blunt injury, and 30 (9%) were victims of penetrating trauma. One of the conclusions of this study was that fetal mortality rate and overall maternal morbidity rate remain exceedingly high, at 73% and 66%, respectively, following penetrating abdominal injury.

Mechanism of Injury

Motor vehicle collisions are the most common causes of injury during pregnancy. As the pregnancy progresses, the shift in the woman's center of gravity and diminished agility can result in falls and accidental injuries. Other common causes of injury include automobile-pedestrian collisions and firearm injuries. Younger women are at higher risk for injury during pregnancy, with a maternal age ranging from 22 to 25 years.

TABLE 1: Changes in Maternal Physiology during Pregnancy

Change	Consequence
Cardiac output and blood volume increase	Shock after >40% of blood lost
Expansion of plasma volume	Physiologic anemia
Decline in arterial and venous pressure	Vital signs are not reflective of hemodynamic status
Increase of resting pulse	
Chest enlargement	Change in anatomic landmarks Caution during thoracic procedures (e.g., tube thoracostomy)
Diaphragm rise	
Substernal angle increase	
Decrease in functional residual capacity	Rapid decline in P_{O_2} during apnea or airway obstruction
Increase in oxygen consumption	
Airway closure when supine	
Increase in tidal volume and minute ventilation	Fall in P_{CO_2} and bicarbonates
Decrease in anesthetic requirements	Need for adjustment of sedative doses
Decreased gastric motility	Risk of aspiration
Relaxation of gastroesophageal sphincter	

Young pregnant women are also at high risk for injuries resulting from battery. It has been reported that 10% to 30% of women are abused during pregnancy, and 5% of cases involving abuse result in fetal death. Of injured pregnant patients, 17% experience intentional trauma and 60% suffer repeated episodes of domestic violence. Physical abuse is suspected when the injuries are located proximally and in the midline, rather than distally, and trauma is evident to the neck, breast, face, upper arms, and lateral thighs, as well as bizarre injuries such as cigarette burns or bites.

Diagnosis

Care is undertaken with attention to both mother and fetus. Uterine blood flow lacks autoregulation and is related directly to maternal blood pressure; consequently, treatment priorities are the same as for the nonpregnant trauma patient, as the best initial treatment for the fetus is the optimal resuscitation of the mother. A thorough physical examination complemented by imaging studies is necessary to identify some of the unique problems that might be present in any pregnant patient, including blunt or penetrating injury to the uterus, placental abruption, amniotic fluid embolism, isoimmunization, and premature rupture of membranes.

Prehospital Care

As a result of significant changes in maternal physiology, supplemental oxygen should be administered to prevent maternal and fetal hypoxia during transport and in the resuscitation room. Fluid resuscitation should be initiated even in the absence of signs of hypovolemia and shock. To avoid supine hypotension associated with the uterine compression of the inferior vena cava (IVC), patients in the second or third trimester of pregnancy should be transported on a backboard tilted to the left, with special attention to immobilization of the cervical spine. If the patient is kept in a supine position, the right hip should be elevated 4 to 6 inches, and the uterus should be displaced manually to the left. This maneuver increases cardiac output by 30% and restores circulating blood volume. Although only about 10% of pregnant patients at term develop symptoms of shock in the supine position, fetal distress may be present even in normotensive mothers; therefore, right hip elevation should be maintained at all times including during operative procedures.

Hospital Care

Primary survey includes assessment of airway, breathing, and circulation (ABC), including volume replacement and hemorrhage control. Secondary survey includes the obstetric history, physical examination, and evaluation and monitoring of the fetus. The history should include the date of the last menstrual cycle, expected date of delivery, and any problems or complications of the current and previous pregnancies such as preterm labor or placental abruption. Comorbid conditions such as pregnancy-induced hypertension and diabetes mellitus should also be documented.

The abdominal examination is critically important, as is a determination of uterine size (Fig. 1), which provides an approximation of gestational age and fetal maturity. A discrepancy between dates and uterine size suggests uterine hemorrhage or rupture. Uterine rupture is suspected with peritoneal signs, abdominal palpation of fetal parts due to extrauterine location, and inability to palpate the uterine fundus. However, as the uterus enlarges, it displaces the intestines upward and laterally, stretching the peritoneum and making the abdominal physical examination unreliable.

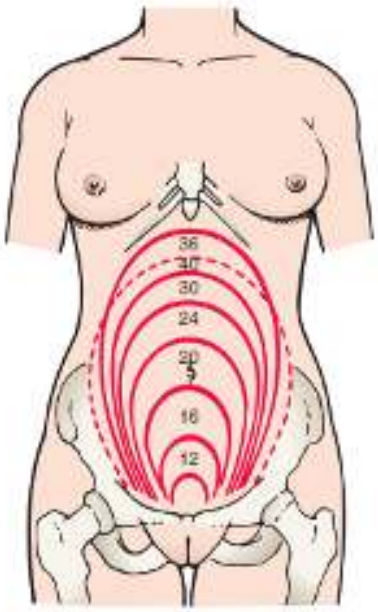

FIGURE 1 Location and size of uterus during different stages of pregnancy. *(Modified from Wilson SF, editor: Assessment of the pregnant client, Health assessment for nursing practice, ed 4, Mosby, 2009; Original credit Seidel et al, 2006.)*

Determination of gestational age is particularly important because this will guide the decision for a premature delivery if indicated. Most institutions will accept a 24- to 26-week pregnancy as viable, with a probability of survival rate ranging from 20% to 70%. Radiographic estimation of gestational age is bound to an error of 1 to 2 weeks. Unless the date of the conception is known exactly, gestational age is particularly difficult to determine. A good rule of thumb is to consider patients with a uterus halfway between the umbilicus and the costal margin as having a viable pregnancy. An algorithm for initial maternal and fetal assessment is presented in Figure 2.

Physical evaluation of the pregnant patient must be directed to the detection of the following six pregnancy-related acute conditions:

- *Vaginal bleeding:* This is an ominous sign that suggests premature cervical dilation, early labor, placental abruption, or placenta previa. Placental abruption after trauma occurs in 2% to 4% of minor accidents and in up to 50% of major injuries. Maternal mortality rate from abruption is less than 1%, but fetal death ranges from 20% to 35%.
- *Ruptured membranes:* In addition to increased risk of infection, prolapse of the umbilical cord can occur, resulting in compression of the umbilical vein and arteries.
- *Bulging perineum:* This is caused most commonly by pressure from extrauterine location of fetal parts.
- *Presence and patterns of contractions:* Direct or indirect trauma to the myometrium may result in release of arachidonic acid that can cause uterine contractions. Although most contractions will cease spontaneously, preparation for a premature delivery should be made.
- *Abnormal fetal heart rate and rhythm:* It may be the first indication of a major disruption in fetal homeostasis. During trauma resuscitation, evaluation of the fetus should begin with auscultation of heart tones and continuous electronic fetal heart rate monitoring (EFM). Any viable fetus of 24 or more weeks' gestation requires monitoring after trauma. Cardiotocographic monitoring should be started in the resuscitation room and continued for a minimum of 4 hours; a minimum of 24 hours is recommended for patients with frequent uterine activity (more than six contractions per hour), abdominal or uterine tenderness, ruptured membranes, vaginal bleeding, or hypotension.
- *Fetomaternal hemorrhage:* Fetomaternal hemorrhage is the transplacental hemorrhage of fetal blood into the normally separate maternal circulation and occurs in 8% to 30% of patients with trauma during pregnancy. The severity of injury and the gestational age have no correlation with the frequency and volume of fetomaternal hemorrhage. The Kleihauer-Betke (KB) test is used after maternal injury to identify fetal blood in the maternal circulation. The ratio of fetal to maternal cells is recorded, allowing calculation of the volume of fetal blood leaked to the maternal circulation. Complications of fetomaternal hemorrhage include Rh sensitization in the mother, fetal anemia, fetal paroxysmal atrial tachycardia, and fetal death from exsanguination. As the volume of fetomaternal hemorrhage sufficient to sensitize most Rh-negative women is well below the 5 mL sensitivity level of the typical laboratory's KB test, all Rh-negative mothers who present with a history of abdominal trauma should receive one 300 µg prophylactic dose of Rh immune globulin (anti-D immunoglobulin; RhoGam) within 72 hours of the traumatic event. An additional 300 µg of Rh immune globulin should be given for every 30 mL of fetal blood found in maternal circulation. Only 3.1% of major trauma cases require more than one 300 µg Rh immune globulin dose. The KB test is probably unnecessary before 16 weeks' gestation because the fetal blood volume is below 30 mL at this gestational age.

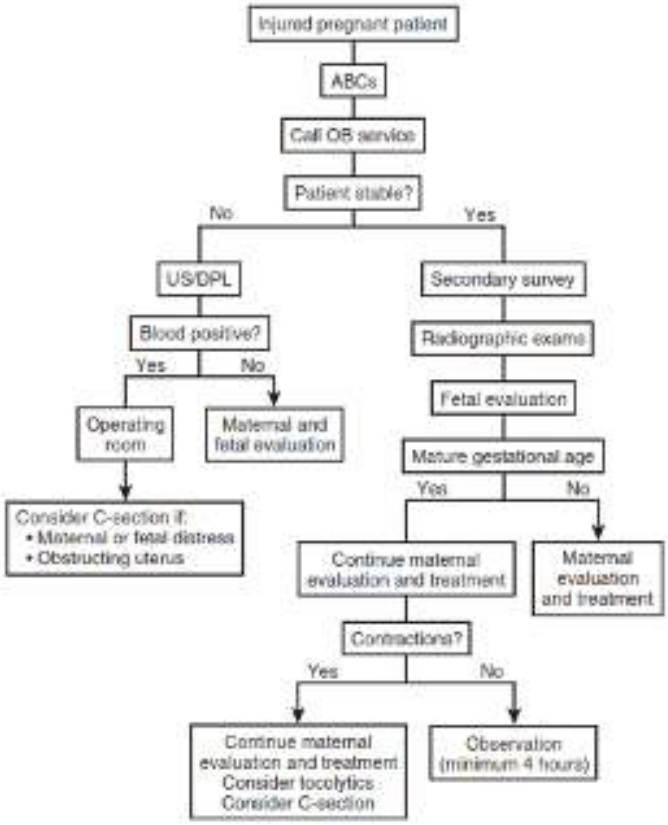

FIGURE 1 Algorithm for initial maternal and fetal assessment. ABC, Airway, breathing, and circulation; C-section, cesarean section; DPL, diagnostic peritoneal lavage; OB, obstetrics; US, ultrasound. *(Modified from Knudson MM, Rozycki GS, Poquin MM: Reproductive system trauma. In Moore EE, Feliciano DV, Mattox KL, editors: Trauma, 5th ed, New York, 2004, McGraw-Hill, pp 851–875.)*

Radiographic Examination

There are three phases of radiation damage related to gestational age of the fetus. Before 3 weeks of gestation, either during preimplantation and early implantation, exposure to radiation can result in death of the embryo. Between 3 and 16 weeks of gestation, during organogenesis, radiation can damage the developing fetal tube, resulting in anomalies in the central nervous system. After 16 weeks, neurologic defects are the most common complication. Prenatal radiation exposure may be associated with certain childhood cancers.

Although there is existing concern about radiation exposure during pregnancy, in most instances the benefits outweigh the risks. It is generally believed that exposure of the fetus to less than 5 to 10 rad causes no significant increase in the risk of congenital malformations, intrauterine growth retardation, or miscarriage. Radiation doses from common imaging studies are shown in Table 2. All indicated radiographic studies should be performed, as for nonpregnant patients (Fig. 3). It is obvious that unnecessary duplication of studies should be avoided.

Abdominal Evaluation

Evaluation of the abdomen in the pregnant patient may be challenging. Superior displacement of the viscera by the expanding uterus changes the anatomic relation of the intra-abdominal organs (Fig. 4). Special attention is needed for patients with rib or pelvic fractures, unexplained hypotension, blood loss, hematuria, or altered sensorium caused by drugs, alcohol, or brain injury.

TABLE 2: Radiation Doses from Plain Radiographs and CT

Plain anteroposterior chest radiograph	<0.005 rad
Pelvic radiograph	<0.4 rad
CT scan of head (1-cm cuts)	0.05 rad
CT scan of upper abdomen (20 1-cm cuts)	3.0 rad
CT scan of lower abdomen (10 1-cm cuts)	3.0–9.0 rad

CT, Computed tomography.

Focused assessment with sonography in trauma (FAST) has a major role in the abdominal evaluation because it provides rapid detection of intra-abdominal and pericardial fluid in the mother as well as quick assessment of fetal condition. In the hemodynamically normal patient, abdominal computed tomography (CT) scanning can also be done safely to evaluate both mother and fetus. If CT scan is necessary, both oral and intravenous contrast media should be administered as needed. The main drawback of a diagnostic peritoneal lavage (DPL) is its invasiveness, and DPL should be performed above the umbilicus using an open technique.

The American Association for the Surgery of Trauma (AAST) Organ Injury Scale for gravid uterus is shown in Table 3.

FIGURE 3 Pelvic radiograph of a pregnant patient after blunt trauma. Vertebrae and other parts of the fetus can be seen.

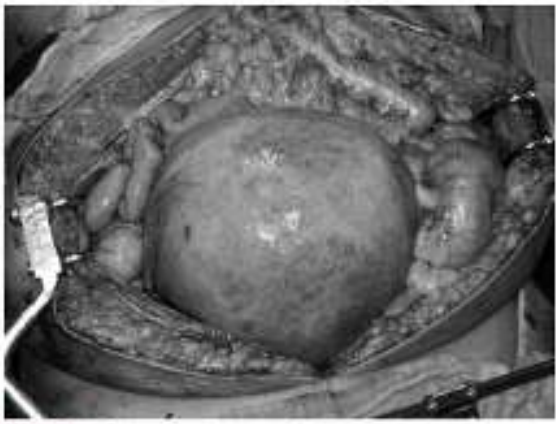

FIGURE 4 Exploratory laparotomy after motor vehicle collision. Gravid uterus displacing viscera.

Surgical Treatment

Blunt Injury

Solid organ injuries may be managed nonoperatively in the hemodynamically stable pregnant patient. In contrast, unstable patients or those with intestinal injury clearly require early operation, as hypotension and infection can be harmful or even lethal for the fetus.

Pelvic fractures represent the most challenging blunt injuries during pregnancy. Hemorrhage from dilated retroperitoneal veins can cause massive and fatal hemorrhagic shock. Maternal pelvic fracture is the most common cause of fetal death, with a fetal mortality rate approaching 25%. In nonpregnant patients, angioembolization is the usual treatment for pelvic hemorrhage, but the radiation dose for the procedure is considered excessive during pregnancy.

The abdominal wall, uterine myometrium, and amniotic fluid act as a cushion to direct forces from blunt trauma. Placental abruption is the most common cause of fetal death, resulting from anoxia, prematurity, or exsanguination. Manifestations include abdominal pain, vaginal bleeding, uterine tenderness, and contractions. One of the most serious complications associated with abruption is disseminated intravascular coagulation (DIC), caused when placental thromboplastin enters maternal circulation.

TABLE 3: AAST-OIS for Gravid Uterus

Grade	Injury Description	AIS-90 Score
I	Hematoma or contusion without placental abruption	2
II	Superficial laceration <1 cm in depth or partial placental abruption <25%	3
III	Deep laceration 1 cm in depth in second trimester or placental abruption 25% but <50%; deep laceration in third trimester	3–4
IV	Laceration extending to the uterine artery; deep laceration 1 cm with 50% placental abruption	4
V	Uterine rupture in second or third trimester; complete placental abruption	4–5

Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (non-pregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39:1069–1070, 1995.
AAST-OIS, American Association for the Surgery of Trauma Organ Injury Scale; AIS, Abbreviated Injury Scale.

Penetrating Injury

As the uterus grows and expands out of the pelvis, it becomes an easier target for penetrating trauma. The thick density of its musculature allows the uterus to absorb energy from low-velocity penetrating injuries; maternal death is very uncommon except for injuries in the upper abdomen, which usually produce severe maternal damage. Gunshot wounds cause fetal injuries in 60% to 70% of cases, with fetal death in 40% to 65%. If the bullet has penetrated the uterus and the fetus is viable, cesarean section is indicated (Table 4).

Perimortem cesarean section is indicated in the case of maternal death if the fetus is viable (24–26 weeks). Timing is critical, as the probability of fetal survival is excellent when delivery occurs within 5 minutes or less of maternal demise. As the time increases, the chance of survival diminishes. In the rare situation when the mother is declared brain dead but maintains good vital signs, the fetus can be allowed to mature before delivery (Fig. 5).

TABLE 4: Indications for Cesarean Section for Penetrating Trauma

Maternal shock
Threat to life from exsanguinations from any cause
Mechanical limitation for maternal repair
Irreparable uterine injury
Fetal distress in viable fetus
Unstable thoracolumbar spine injury
Pregnancy near term
Maternal death

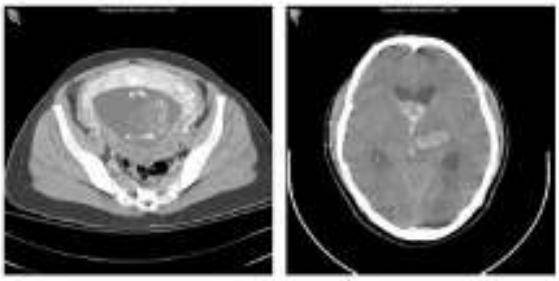

FIGURE 5 Intracranial hemorrhage (*right panel*) in an 18-week pregnant patient declared brain dead. As the fetus was not viable (*left panel*), the patient's family agreed to organ donation.

When performing an emergency cesarean section on a trauma patient, instead of the commonly used transverse incision, a vertical incision through all the layers into the uterus is safer and faster. This incision avoids injury to the uterine vessels, which enter the uterus from both sides.

Between gestational age 24 to 32 weeks, open cardiopulmonary resuscitation without aortic cross-clamping should be seriously considered before an emergency cesarean section is performed. If open cardiopulmonary resuscitation proves successful, the delivery may be delayed so that chances of postnatal survival improve. A proposed algorithm for emergency cesarean section after trauma is presented in Figure 6.

Morbidity and Mortality

Trauma has become the most frequent cause of maternal death in the United States. Older reports attributed 80% maternal mortality rate to amniotic fluid embolism, which together with pulmonary thromboembolism was cited as the leading cause of maternal fatality. In contrast to declining maternal mortality risks from infection, hemorrhage, hypertension, and thromboembolism, accidental deaths during pregnancy have risen steadily. Although overall maternal mortality rate from abdominal gunshot wounds is around 7%, fetal mortality rate reaches 73%, and overall maternal morbidity rate is 66%. Risk factors associated with poor fetal outcome are listed in Table 5.

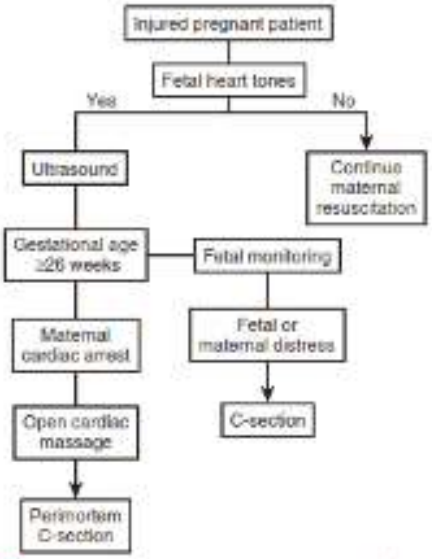

FIGURE 6 Algorithm for emergency cesarean section after trauma. C-section, Cesarean section. *(Modified from Morris JA Jr, Rosenbower TJ, Jurkovich GJ, et al. Infant survival after cesarean section for trauma. Ann Surg 223:481–488, 1996.)*

TABLE 5: Predictors of Fetal Outcome

Maternal death
Maternal hypotension
Maternal traumatic brain injury
High Injury Severity Score (ISS)
Pelvic fracture
Ejection of pregnant woman from a vehicle
Severe abdominal injury to pregnant woman

Conclusions

Trauma has become the leading cause of death in women aged 34 and younger, including pregnant patients. Assessment of a female trauma patient in the fertile age should always include the possibility of pregnancy. Pathophysiologic changes during pregnancy affect all aspects of traumatic injury and require a detailed and meticulous management.

TRAUMA TO NONGRAVID UTERUS AND FEMALE GENITALIA

Although injuries to the female genitalia are uncommon in the nonpregnant patient, they are more often seen in cases in which there is pathologic enlargement of the internal genitalia or in the early postpartum period. Missed or improperly treated female genital injuries can result in hemorrhage, sepsis, and loss of endocrine and reproductive function.

Incidence

The incidence of injuries to the female genitalia is largely unknown. Most information on the subject comes from isolated case reports or small series of patients. Vaginal lacerations complicate approximately 3.5% of pelvic fractures in female patients. Urethral and bladder injuries are also commonly present.

Mechanism of Injury

Blunt injuries involving the female genitalia are most frequently associated with pelvic fractures. Injuries to the external genitalia can also be the result of straddle injuries or accidental penetration. Water skiing, gymnastics, and bicycling accidents have been reported as the causes of blunt trauma to the lower genitalia. Penetrating injuries are almost exclusively responsible for injuries to the upper genital organs, although several reports of blunt trauma to normal ovaries and uterus have been reported.

Many of the injuries to the external genital organs are the result of violent acts in pregnant as well as nonpregnant women. This possibility should be always be considered, especially when the mechanism of injury is unclear. If sexual assault has occurred, informed consent for the remainder of the assessment must be obtained.

Domestic violence crosses lines of ethnicity and race, age, national origin, sexual orientation, religion, and socioeconomic status, although an overwhelming majority of the victims in heterosexual relationships are women. Typically, battery tends to occur as a pattern of violence rather than a one-time event. Physicians treating trauma victims should be able to recognize the signs of domestic violence, refer patients to appropriate agencies, and provide social support.

Diagnosis

Initial assessment and resuscitation are performed as for any trauma patient. The secondary survey should include a detailed physical examination of the perineum. Examination under anesthesia may be needed for patients with severe pain or active bleeding. A complete examination should include bimanual palpation and speculum examinations of vagina and anorectum. Some authors recommend anesthesia for all patients with perineal trauma in order to evaluate the extent of the injury.

Intra-abdominal genital injuries are usually diagnosed at laparotomy for associated injuries. As blunt injury is more common with pathologically enlarged internal genitalia in the nongravid patient, CT scan of the abdomen or DPL may aid the diagnosis, although the latter is very rarely used. Detailed grading of gynecologic injuries is presented (Tables 6 through 10).

Surgical Management

Isolated perineal lacerations should be repaired after appropriate irrigation and debridement with or without placement of drains. Large perineal hematomas require incision and drainage because of the high associated incidence of infection and sepsis. Vulvar lacerations may be closed primarily with absorbable sutures.

Repair of vaginal and cervical lacerations may be challenging because of the abundant blood supply. Absorbable sutures including the mucosal and submucosal layers are commonly used. These injuries must be diagnosed promptly in patients with pelvic fractures, as any delay can result in sepsis and death.

TABLE 6: AAST-OIS for Gynecologic Injuries: Vagina

Grade	Injury Description	AIS-90 Score
I	Contusion or hematoma	1
II	Superficial laceration involving mucosa	1
III	Deep laceration extending into submucosal fat or muscle	2
IV	Complex laceration extending into the cervix or peritoneum	3
V	Injury to adjacent organs	3

Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (non-pregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39:1069–1070, 1995.
AAST-OIS, American Association for the Surgery of Trauma Organ Injury Scale; AIS, Abbreviated Injury Scale.

TABLE 7: AAST-OIS for Gynecologic Injuries: Vulva

Grade	Injury Description	AIS-90 Score
I	Hematoma or contusion	1
II	Superficial laceration involving skin only	1
III	Deep laceration extending into subcutaneous fat or muscle	2
IV	Avulsion of skin, fat, or muscle	3
V	Injury to adjacent organs	3

Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (non-pregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39:1069–1070, 1995.
AAST-OIS, American Association for the Surgery of Trauma Organ Injury Scale; AIS, Abbreviated Injury Scale.

TABLE 8: AAST-OIS for Gynecologic Injuries: Nongravid Uterus

Grade	Injury Description	AIS-90 Score
I	Hematoma or contusion	2
II	Superficial laceration <1 cm in depth	2
III	Deep laceration 1 cm in depth	3
IV	Laceration extending to uterine artery	3
V	Devascularization or avulsion	3

Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (non-pregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39:1069–1070, 1995.
AAST-OIS, American Association for the Surgery of Trauma Organ Injury Scale; AIS, Abbreviated Injury Scale.

TABLE 9: AAST-OIS for Gynecologic Injuries: Fallopian Tube

Grade	Injury Description	AIS-90 Score
I	Hematoma or contusion	2
II	Laceration involving <50% of circumference	2
III	Laceration involving 50% of circumference	2
IV	Complete transection	2
V	Devascularized segment	2

Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (non-pregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39:1069–1070, 1995.
AAST-OIS, American Association for the Surgery of Trauma Organ Injury Scale; AIS, Abbreviated Injury Scale.

TABLE 10: AAST-OIS for Gynecologic Injuries: Ovary

Grade	Injury Description	AIS-98 Score
I	Contusion or hematoma	1
II	Superficial laceration <0.5 cm in depth	2
III	Deep laceration 0.5 cm in depth	3
IV	Partial disruption of blood supply	3
V	Complete parenchymal disruption or avulsion	3

Modified from Moore EE, Jurkovich GJ, Knudson MM, et al: Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (non-pregnant), uterus (pregnant), fallopian tube, and ovary. *J Trauma* 39:1069–1070, 1995.
AAST-OIS, American Association for the Surgery of Trauma Organ Injury Scale; AIS, Abbreviated Injury Scale.

Injuries to the uterus are repaired in two layers using slowly absorbable running or interrupted figure-of-eight sutures. Hysterectomy for trauma is extremely rare and is needed only in extreme cases of massive destruction or exsanguinating hemorrhage. Injuries to the fallopian tubes and ovaries are also managed by either primary repair or excision according to injury severity. Vaginal packing with antibiotics is frequently used for 24 hours after procedures involving the vagina, cervix, or uterus.

Morbidity and Mortality

Morbidity is primarily determined by the associated injuries. Profuse bleeding from the perineal wounds as well as vagina, cervix, and uterus may be the cause of hemorrhagic shock. These wounds may be difficult to control. Missed perineal injuries in association with pelvic fracture may be fatal. Long-term complications include sexual dysfunction and infertility.

CONCLUSIONS

Injuries to the nongravid uterus as well as female genital organs are rare and should be suspected in all assault victims and all patients with direct perineal trauma, pelvic fractures, or penetrating injury to the pelvis. Thorough physical examination, preferably in the operating room, with prompt surgical treatment improves the outcome of these potentially challenging injuries.

For the chapter's Suggested Readings list, please visit the book at www.ExpertConsult.inkling.com.

M. Publicaciones con Afiliación a la Universidad de Las Palmas de Gran Canaria

En el marco de este período académico, el Doctorando ha realizado trabajos de investigación como autor principal y como co-autor durante 2017 y 2018, mismos que contribuyeron a su base formativa investigadora. Estas publicaciones merecen ser mencionadas al presentar a la Universidad de Las Palmas de Gran Canaria (ULPGC) como institución de afiliación. Las referencias completas se encuentran a continuación:

1- **Petrone P**, Kassimi K, Jiménez-Gómez M, Betancourt A, Axelrad A, Marini CP. (2017). Management of esophageal injuries secondary to trauma. *Injury, International Journal of the Care of the Injured.* 48, 1735-1742.

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3- Betancourt-Ramírez A, SMolero S, **Petrone P**, Marini CP, Frankel HL. (2017). Bilateral pulmonary emboli and extensive inferior vena cava thrombosis in the setting of large subcapsular hematoma and liver laceration after blunt trauma. *The Journal of Trauma an Acute Care Surgery.* 83, 744-746.

4- Cetinkaya RA, Yilmaz S, Ünlü A, **Petrone P**, Marini C, Karabulut E, Urkan M, Karabacak K, Uyanik M, Eker I, Kilic A, Gunal A. (2017). The efficacy of platelet-rich plasma gel in MRSA-related surgical wound infection treatment: an experimental study in an animal model. *European Journal of Trauma and Emergency Surgery.* Sep 30. doi: 10.1007/s00068-017-0852-0.

5- **Petrone P**, Anduaga Peña MF, Servide Staffolani MJ, Brathwaite C, Axelrad A, Ceballos Esparagón J. (2017). Evolución en el tratamiento conservador del traumatismo esplénico contuso. *Cirugía Española.* 95, 420-427.

6- Granate M, Quaglia F, **Petrone P**, Cerciello G, Marini CP, Martinelli P. (2017). Systemic Lupus Erythemathosus-associated thrombocytopenia in pregnancy: Is splenectomy necessary at the time of delivery? *Panamerican Journal of Trauma, Critical Care & Emergency Surgery.* 6, 219-223.

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Review

Management of esophageal injuries secondary to trauma

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ABSTRACT

Traumatic esophageal injuries occur less than 10% of the time in the setting of blunt or penetrating trauma. The purpose of this literature review is to provide an update on the most recent changes involving the diagnosis and treatment of esophageal injuries. A literature search was conducted using PubMed, to identify articles written in English language with the terms "non- iatrogenic", "esophageal", "trauma", "diagnosis", "management", and "prognosis". Case reports and articles involving non-traumatic esophageal perforations were excluded. Fifty pertinent articles in English language from 1947 to 2015 were selected for review. Based on the review of all articles, we designed a diagnostic and therapeutic algorithm to facilitate the diagnosis and management of the traumatic esophageal injury.

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CASE REPORT

Rotura Esplénica Espontánea Secundaria A Angioma de Células Litorales

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[4]Ignacio Machado-Romero, [5]Patrizio Petrone

RESUMEN

Introducción: Presentamos un angioma de células litorales (LCA, por sus siglas en inglés), una rara neoplasia vascular esplénica que surge de las células que recubren los senos de la pulpa roja. Se considera una lesión benigna y de hallazgo accidental.

Presentación del caso: varón de 50 años acude con una rotura esplénica espontánea. Al principio del proceso, el paciente presentaba fatiga, debilidad y distensión abdominal. Se realizó una ecografía abdominal donde se observaron hemangiomas múltiples en el bazo. La tomografía computarizada reveló esplenomegalia con múltiples lesiones redondas e hiperdensas. El paciente fue sometido posteriormente a cirugía y se realizó una esplenectomía. Los estudios histológicos e inmunohistoquímicos confirmaron el diagnóstico de LCA.

Discusión: Un LCA es un tumor esplénico poco frecuente diagnosticado en pacientes que pueden o no presentar molestias abdominales. Suele presentarse con síntomas de hiperesplenismo, y debe realizarse el diagnóstico diferencial entre los tumores vasculares esplénicos divididos entre neoplasias benignas, indeterminadas, o neoplasias malignas.

Conclusión: Debido a la asociación de LCA a neoplasias de colon, riñón, páncreas, pulmón, ovario, leiomiosarcoma, melanoma y linfoma, se debe descartar el neoplasma visceral en estos pacientes. Pocos informes sobre este tipo de tumor han sido publicados, y de manera inconsistente. Presentamos pues un nuevo caso y revisión de la literatura actual.

Palabras Claves: Angioma de células litorales, Cirugía, Inmunohistoquímica e histología, Neoplasia vascular.

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ABSTRACT

Introduction: We present a littoral cell angioma (LCA), a rare splenic vascular neoplasm that arises from the cells lining the red pulp sinuses. It is deemed to be a benign and incidental lesion.

Case report: A 50-year-old male presented with a spontaneous splenic rupture. At the beginning of this process, the patient had abdominal distension, weakness and fatigue. An abdominal ultrasound was performed and multiple hemangiomas were observed in the spleen. Computed tomography scans revealed splenomegaly with multiple round and hyperdense lesions. The patient subsequently underwent surgery and a splenectomy was performed. Postoperative histological and immunohistochemical studies confirmed the diagnosis of LCA.

Discussion: LCA is an uncommon splenic tumor diagnosed in patients presenting with or without abdominal discomfort. It can present with symptoms of hyperesplenism, and the differential diagnosis of splenic vascular tumors can be divided into benigns, indeterminate, or malignant neoplasms.

Conclusion: Due to its association with neoplasms of the colon, kidney, pancreas, lung, ovary, leiomyosarcoma, melanoma and lymphoma, becomes mandatory to rule out a visceral neoplasm from these patients. Only a few case reports regarding this kind of tumor have been published with inconsistent results. In the present report, we present a case of LCA and a review of the literature.

Keywords: Immunohistochemistry and histology, Littoral cell angioma, Surgery, Vascular neoplasm.

INTRODUCCIÓN

El angioma de células litorales (ACL) es una neoplasia benigna del bazo que fue descrita por primera vez por Falk et al[1] en 1991, cuando se describen 17 casos de "un nuevo tipo de tumor vascular". Desde entonces, se han notificado alrededor de 80 casos adicionales.[2,3] La presentación clínica del ACL suele variar desde ser completamente asintomática y descubierta incidentalmente, hasta presentar una constelación de signos y síntomas como distensión abdominal, síntomas constitucionales complejos, esplenomegalia e hiperesplenismo. Aunque la tomografía computarizada (TC) y el ultrasonido (US) característicos de esta neoplasia han sido bien descritos, hay una falta de especificidad en la diferenciación del tumor de otros

Bilateral pulmonary emboli and extensive inferior vena cava thrombosis in the setting of large subcapsular hematoma and liver laceration after blunt trauma

Alejandro Betancourt-Ramirez, MD, Soraya SMolero, MD, Patrizio Petrone, MD, Corrado P. Marini, MD, *and* **Heidi L. Frankel, MD**, *Bay Shore, New York*

Figure 1. CT scan of the abdomen showing a grade 3 liver laceration with a large subcapsular hematoma involving more than 50% of the anterior surface of the liver.

A 44-year-old woman suffered right-sided blunt abdominal trauma after losing control of her Vespa scooter. At her initial presentation, the patient was hemodynamically normal complaining of right side abdominal pain. The FAST was positive. The CT scan of the abdomen showed a grade 3 liver laceration with a large subcapsular hematoma involving more than 50% of the anterior surface of the liver compressing the inferior vena cava without extravasation (Fig. 1). The patient was treated nonoperatively following our institution's solid organ protocol.

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ORIGINAL ARTICLE

The efficacy of platelet-rich plasma gel in MRSA-related surgical wound infection treatment: an experimental study in an animal model

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Abstract

Introduction The wound healing properties of platelet-rich plasma (PRP) gel have been documented in many studies. PRP gel has also become a promising agent for treating surgical site infections. In this study, we investigated the antibacterial activity and wound healing effectiveness of PRP in an animal model of Methicillin-resistant *Staphylococcus aureus* subsp. *aureus* (MRSA N315)-contaminated superficial soft tissue wounds.

Materials and methods Subcutaneous wounds in Wistar Albino male rats were created by making two cm midline incisions followed by inoculation of microorganisms. Study groups comprised of Sham (no treatment), PRP alone, MRSA alone, MRSA + PRP, MRSA + Vancomycin, and MRSA + Vancomycin + PRP groups. We inoculated 0.1 mL (3×10^8 CFU/mL) of MRSA in contaminated groups. After 8 days, all rats were killed, wounds were excised and subjected to histopathologic examination, and MRSA counts were determined.

Results MRSA counts in MRSA, MRSA + PRP, MRSA + Vancomycin and MRSA + Vancomycin + PRP groups were 5.1×10^6 (SD $\pm$ 0.4) CFU/mL, 4.3×10^5 (SD $\pm$ 0.7) CFU/mL, 2.3×10^5 (SD $\pm$ 0.3) CFU/mL, 1.1×10^5 (SD $\pm$ 0.4) CFU/mL, respectively. The inflammation scores

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CIRUGÍA ESPAÑOLA

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Revisión de conjunto

Evolución en el tratamiento conservador del traumatismo esplénico contuso

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RESUMEN

El bazo es uno de los órganos más frecuentemente dañado en el traumatismo abdominal cerrado. El manejo de la lesión esplénica ha evolucionado en los últimos años, con cada vez mayor tendencia al manejo conservador. El conocimiento de su función inmunológica ha sido el motor inicial para impulsar el desarrollo de técnicas de preservación del bazo. El mayor acceso a pruebas de imagen de alta resolución, así como a técnicas terapéuticas poco agresivas, como la angioembolización, ha permitido una mayor tasa de éxito en el manejo no quirúrgico de estos casos, con una disminución en la morbimortalidad global asociada a estos pacientes. El objetivo de esta revisión es dar a conocer el manejo actual de traumatismo esplénico basado en la bibliografía internacional de los últimos 30 años —se han identificado 63.205 pacientes— y, así, ofrecer al cirujano mejores herramientas a la hora de decidir el tratamiento recomendable en cada caso.

Evolution of the treatment of splenic injuries: from surgery to non-operative management

Keywords:
Splenic injury
Diagnostic
Non-operative management
Embolization
Follow-up

ABSTRACT

The spleen is one of the most frequently injured organs in blunt abdominal trauma. In the past decades, the treatment of patients with blunt splenic injury has shifted from operative to non-operative management. The knowledge of physiology and immunology of the spleen have been the main reasons to develop techniques for splenic salvage. The advances in high-resolution imaging techniques, as well as less invasive procedures, including angiography and angioembolization, have allowed a higher rate of success in the non-operative

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CASE REPORT

Systemic Lupus Erythematosus-associated Thrombocytopenia in Pregnancy: Is Splenectomy Necessary at the Time of Delivery?

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ABSTRACT

Background: Systemic lupus erythematosus (SLE)-associated thrombocytopenia in pregnancy is a rare condition associated with potential harm to the mother, the fetus, and/or newborn, if the thrombocytopenia is severe (<50,000/mm^3). Controversy persists regarding the role and the timing of splenectomy in patients with SLE-associated refractory immune thrombocytopenia in pregnancy. This report describes the use of splenectomy at the time of the cesarean section (CS) in a patient with refractory SLE-associated thrombocytopenia.

Case report: A 19-year-old gravida 2, para 1 woman with SLE-associated thrombocytopenia diagnosed at age 16 developed a platelet count of 10,000/mm^3 at the 18th week of gestation. She had been asymptomatic until that point, except for a previous spontaneous abortion at the 8th week of gestation in 2008. During this admission she was treated initially with methylprednisolone and enoxaparin, but following an episode of epistaxis she received intravenous immunoglobulin (IVIG). She was discharged home with a platelet count of 52,000/mm^3. She was readmitted on the 34th week of gestation with a platelet count of 15,000/mm^3 unresponsive to steroids and IVIG, she underwent a CS and an open splenectomy. Following surgery, she continued to receive maintenance dose steroids. She had a partial response to the splenectomy (platelet count on discharge 63,000/mm^3).

Conclusion: Splenectomy at the time of CS is a safe therapeutic option for women with SLE-associated refractory thrombocytopenia during pregnancy.

Keywords: Antiglycoprotein IIb/IIIa antibodies, Pregnancy, Splenectomy, Systemic lupus erythematosus, Thrombocytopenia.

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RESUMEN

Antecedentes: La trombocitopenia asociada al Lupus Eritematoso Sistémico (LES) en el embarazo es una afección rara asociada con daño potencial a la madre, al feto y/o al recién nacido, si la trombocitopenia es grave (<50.000/mm^3). La controversia persiste con respecto al papel y el momento de la esplenectomía en pacientes con trombocitopenia inmune refractaria asociada al LES en el embarazo. Este informe describe el uso de la esplenectomía en el momento de la cesárea (CS) en un paciente con trombocitopenia refractaria asociada al LES.

Caso: Paciente latinoamericana de 19 años de edad, con trombocitopenia asociada a LES diagnosticada a los 16 años, gravida 2, para 1, desarrolló un recuento de plaquetas de 10.000/mm^3 a la 18ª semana de gestación. Hasta ese momento había estado asintomática, excepto por un aborto espontáneo previo a la 8ª semana de gestación en 2008. Durante esta admisión se trató inicialmente con metilprednisolona y enoxaparina pero tras un episodio de epistaxis recibió inmunoglobulinas intravenosas (IVIG). Fue dada de alta con un recuento de plaquetas de 52.000/mm^3. Fue readmitida a la 34ª semana de gestación con un recuento de plaquetas de 15.000/mm^3 no responde a los esteroides y IVIG. Se sometió a un CS y una esplenectomía abierta. Después de la cirugía, continuó recibiendo dosis de mantenimiento de esteroides. Tuvo una respuesta parcial a la esplenectomía (recuento de plaquetas al alta 63.000/mm^3).

Conclusión: La esplenectomía en el momento del CS es una opción terapéutica segura para las mujeres con trombocitopenia refractaria asociada al LES durante el embarazo.

Palabras clave: Anticuerpos anti – GPIIb / IIIa, El embarazo, Esplenectomía, Lupus eritematoso sistémico, Trombocitopenia.

RESUMO

Antecedentes: A trombocitopenia associada ao Lupus Eritematoso Sistêmico (LES) na gravidez é uma condição rara associada a possíveis danos à mãe, ao feto e / ou ao recém nascido, se a trombocitopenia for grave (<50.000/mm^3). A controvérsia persiste em relação ao papel e ao momento da esplenectomia em pacientes com trombocitopenia imune refratária associada ao LES na gravidez. Este relatório descreve o uso de esplenectomia no momento da cesariana (CS) em um paciente com trombocitopenia associado ao LES.


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Manejo de las lesiones del diafragma

P. Petrone, J. Ceballos Esparragón

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Hematoma retroperitoneal. Trauma vascular abdominal

B. R. Hochman, J. L. Pascual, J. Ceballos Esparragón, P. Petrone

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P. Petrone

Introducción
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Fisiología
Hipotermia accidental
Trauma por congelamiento
Lesiones por quemaduras

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RESEARCH ARTICLE

Trauma Survey of 476 Doctors: Now We know What We Do not know

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RESUMEN

Introducción: En 2013, el Boletín del Instituto de Estadísticas de Turquía informó de 3.685 muertos y 274.829 heridos en 161.306 colisiones de tráfico. El objetivo de este estudio fue determinar las actitudes, la conciencia y los conocimientos generales de los médicos acerca del trauma.

Métodos: Se realizó una encuesta con un cuestionario entre febrero de 2015 y abril de 2015. Comprendía tres preguntas demográficas, siete de actitud y ocho de conocimiento sobre el trauma. Los médicos fueron estratificados como: Grupo 1 - médicos generales; Grupo 2 - residentes quirúrgicos; Grupo 3- cirujanos; Grupo 4 - especialidades quirúrgicas académicas.

Resultados: Se completó y analizó un total de 476 (75%) de los 636 cuestionarios. La mediana de edad fue de 36 años. Los médicos generalistas (38,7%) y los cirujanos (38,7%) representaron la mayoría de los encuestados. El nivel medio de confianza de los encuestados en la realización de intervenciones de salvamento fue 98 (53%), 25 (34%), 44 (24%) y 8 (24%), respectivamente. Por otra parte, 161 (88%), 68 (92%), 162 (88%) y 32 (94%) de los encuestados no eligieron el orden correcto de priorización en un escenario de tres víctimas, respectivamente. Sólo 36 (20%) en el grupo 1, 22 (30%) en el grupo 2, 40 (22%) en el grupo 3 y 7 (21%) en el grupo 4 calcularon correctamente el porcentaje de pérdida de sangre en el shock hemorrágico clase III.

Conclusiones: El estudio actual sugiere que Turquía todavía requiere un sistema de trauma bien organizado. Se necesitan más estudios para evaluar las capacidades del Sistema Turco de Emergencias.

Palabras clave: Encuesta; Médicos de urgencia; Sistema Turco de Trauma; Triage.

RESUMO

Introdução: Em 2013, o Boletim do Instituto de Estatística Turco informou 3.685 pessoas mortas e 274.829 feridas em 161.306 colisões de trânsito. O objetivo deste estudo foi determinar as atitudes, conscientização e conhecimento dos médicos em relação aos traumatismos.

Métodos: um questionário de pesquisa foi realizado entre fevereiro de 2015 e abril de 2015. Compreendeu três questões demográficas, de sete atitudes e oito de conhecimento sobre trauma. Os médicos foram estratificados como: Grupo 1 - médicos de clínica geral; Grupo 2 - residentes cirúrgicos; Grupo 3- cirurgiões; Grupo 4 - especialidades cirúrgicas acadêmicas.

Resultados: Um total de 476 (75%) dos 636 questionários foram concluídos e analisados. A idade média era de 36 anos. Os médicos de clínica geral (38,7%) e cirurgiões (38,7%) representaram a maioria dos entrevistados. O nível médio de confiança dos entrevistados na realização de intervenções de poupança de vida foi de 98 (53%), 25 (34%), 44 (24%) e 8 (24%), respectivamente. Além disso, 161 (88%), 68 (92%), 162 (88%) e 32 (94%) dos entrevistados não conseguiram escolher a ordem correta de priorização em um cenário de três acidentes, respectivamente. Apenas 36 (20%) no Grupo 1, 22 (30%) no Grupo 2, 40 (22%) no Grupo 3 e 7 (21%) no Grupo 4 calcularam corretamente a porcentagem de perda de sangue no choque hemorrágico Classe III.

Conclusões: O estudo atual sugere que a Turquia ainda exige um sistema de trauma bem organizado. São necessários mais estudos para avaliar as capacidades do Sistema de Emergência Turco.

Palavras-chave: Médicos de emergência; Pesquisa; Sistema de trauma turco; Triage.

ABSTRACT

Introduction: In 2013, the Turkish Statistical Institute Bulletin reported 3,685 people killed and 274,829 injured in 161,306 traffic collisions. The aim of this study was to determine medical doctors' general attitudes, awareness, and knowledge regarding trauma.

Methods: A survey questionnaire was conducted between February 2015 and April 2015. It comprised three demographic, seven attitude, and eight knowledge questions on trauma. Physicians were stratified as: group I—general practitioners; group II—surgical residents; group III—surgeons; group IV—academic surgical specialties.

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Revisión de conjunto

Abordaje y manejo de las lesiones retroperitoneales traumáticas

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RESUMEN

Las lesiones traumáticas retroperitoneales constituyen un desafío para el cirujano de traumatología. Ocurren generalmente en el contexto de un paciente politraumatizado, con múltiples lesiones asociadas y en el que los procedimientos invasivos tienen un rol preponderante en el diagnóstico de estas lesiones. El retroperitoneo es la región anatómica que presenta mayores tasas de mortalidad, por lo que el diagnóstico precoz y tratamiento de estas lesiones adquiere especial relevancia. El objetivo de este trabajo es presentar la evidencia científica publicada hasta el momento en cuanto a su prevalencia, mecanismo lesional, métodos diagnósticos y tratamiento mediante una revisión de la literatura internacional de los últimos 70 años. Como conclusión, en esta revisión sistemática se pone de manifiesto una creciente tendencia al manejo no quirúrgico de las lesiones que afectan al retroperitoneo.

Approach and Management of Traumatic Retroperitoneal Injuries

Keywords:
Retroperitoneum
Trauma
Prevalence
Injuries
Diagnosis
Management
Treatment

ABSTRACT

Traumatic retroperitoneal injuries constitute a challenge for trauma surgeons. They usually occur in the context of a trauma patient with multiple associated injuries, in whom invasive procedures have an important role in the diagnosis of these injuries. The retroperitoneum is the anatomical region with the highest mortality rates, therefore early diagnosis and treatment of these lesions acquire special relevance. The aim of this study is to present current published scientific evidence regarding incidence, mechanism of injury, diagnostic methods and treatment through a review of the international literature from the last

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RESEARCH ARTICLE

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Bringing Packed Red Blood Cells to the Point of Combat Injury: Are We There Yet?

Eritrosit Konsantrelerini Yaralanma Noktasına Götürmek: O Noktaya Ulaşabildik mi?

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Abstract

Objective: Hemorrhage is the leading cause of injury-related prehospital mortality. We investigated worst-case scenarios and possible requirements of the Turkish military. As we plan to use blood resources during casualty transport, the impact of transport-related mechanical stress on packed red blood cells (PRBCs) was analyzed.

Materials and Methods: The in vitro experiment was performed in the environmental test laboratories of ASELSAN®. Operational vibrations of potential casualty transport mediums such as Sikorsky helicopters, Kirpi® armored vehicles, and the NATO vibration standard MIL-STD-810G software program were recorded. The most powerful mechanical stress, which was created by the NATO standard, was applied to 15 units of fresh (≤7 days) and 10 units of old (>7 days) PRBCs in a blood cooler box. The vibrations were simulated with a TDS v896 Medium-Force Shaker Device. On-site blood samples were analyzed at 0, 6, and 24 h for biochemical and hemorheological analyses.

Results: The mean (±standard deviation) age of fresh and old PRBCs was 4.8±2.2 and 32.8±11.8 days, respectively. Six-hour mechanical damage of fresh PRBCs was demonstrated by increased erythrocyte fragmentation rates (p=0.015), hemolysis rates (p=0.003), and supernatant potassium levels (p=0.003) and decreased hematocrit levels (p=0.015). Old PRBC hemolysis rates (p=0.015), supernatant potassium levels (p=0.015), and supernatant hemoglobin (p=0.015) were increased and hematocrit levels were decreased (p=0.015) within 6 h. Two (13%) units of fresh PRBCs and none of the old PRBCs were eligible for transfusion after 6 h of mechanical stress.

Öz

Amaç: Kan kayıpları, hastane öncesi dönemdeki yaralanmalara bağlı ölümlerin en sık sebebidir. Türk ordusu için en kötü senaryoları ve olası ihtiyaçları araştırdık. Çalışma alanından nakil esnasında kan kaynaklarını kullanmayı planladığımız için nakil işleminden kaynaklı mekanik stresin eritrosit konsantreleri üzerine etkisini analiz ettimiyle.

Gereç ve Yöntemler: In vitro çalışmalar ASELSAN®'in dış ortam test laboratuvarlarında gerçekleştirildi. Çalışma alanında kan taşıma işleminde kullanılması muhtemel olan Sikorsky helikopteri ve Kirpi® araçlarının operasyonel vibrasyonları ve NATO MIL-STD-810G titreşim standart yazılımı kayıt altına alındı. NATO standardının en güçlü titreşime neden olduğu hesaplandı. Kan saklama çantası içindeki 15 ünite taze (≤7 gün) ve 10 ünite taze olmayan eritrosit konsantresi (>7 gün), NATO standardı olan mekanik strese maruz bırakıldı. Titreşim TDS v896 Medium-Force Shaker cihazı tarafından simüle edildi. Simülasyonun 0., 6. ve 24. saatinde biyokimyasal ve hiyomekanik analiz için kan örnekleri alındı.

Bulgular: Taze ve taze olmayan eritrosit konsantreleri sırasıyla ortalama 4,8 (standart deviasyon [SD] ±2,2) ve 32,8 (SD ±11,8) günlüktü. Taze eritrosit konsantrelerinde 6. saatte gelişen mekanik hasar; artmış eritrosit fragmentasyonu (p=0,015), hemoliz oranı (p=0,003) ve supernatant potasyum (p=0,015) düzeyleri ile gösterildi. Taze olmayan eritrosit konsantrelerinin 6. saatte hemoliz oranı (p=0,015) ve supernatant potasyum düzeyi (p=0,015) yükselirken, hematokrit değerleri (p=0,015) düştü. İlk 6 saat içerisinde taze eritrosit konsantrelerinin 2'si (%13) transfüze edilebilir kalitede kalırken, taze olmayanların ise hiçbirisi uygun değildi.

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