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Original Research Article

Maternal and fetal factors for determining the cesarean section type (scheduled/emergency) in bitches

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A B S T R A C T

One hundred and forty bitches and their offspring (689 puppies) were involved in this study. The influence of different maternal features such as age, breed (brachycephalic/non-brachycephalic), previous births (primiparous/multiparous), health status (complete/incomplete) and litter size over the type of cesarean sections (scheduled/emergency), the neonatal survival, and the incidence of congenital malformations were also examined. Scheduled cesareans were predominant (104/140), of which 90 % were brachycephalic breeds and females were mostly between 2 and 4 years old (54.8 %), multiparous (88.4 %) and with a correct health status (67.3 %). Emergency cesarean sections mainly involved non-brachycephalic breeds (80 %) and were carried out mostly in females under 4 years of age (72.2 %), primiparous (77.7 %), with incomplete health status and a large litter size (47.2 %). Perinatal mortality was notably higher in emergency C-sections (3.25 % and 13.3 %, scheduled and emergency C-sections, respectively); the highest incidence of neonatal mortality was recorded in young females (<2, 2–4 years old), primiparous and with incomplete health status. Congenital anomalies were observed in 4.50 % (31/689) of the puppies, with anasarca (38.71 %) and cleft palate (29.03 %) being the most frequently observed malformations. A higher incidence of congenital malformations was detected in puppies from dams with incomplete sanitary health and from inbreeding cross. Overall, the study provides valuable insights into the complex interplay between maternal characteristics and cesarean outcomes. Appropriate genetic selection, good sanitary health conditions, and the age of the reproducers, are pivotal factors in planning for gestation and improving the survival of neonates.

1. Introduction

Parturition represents the end of pregnancy, and it is essential to identify situations where veterinary intervention is necessary. When parturition cannot proceed in a physiological way, a dystocic birth occurs, which may be due to maternal factors such as uterine inertia, fetal factors such as malpresentation, malformations, or fetal oversize, or a combination of both [1]. The number of previous births, the age of the mother [2] and the nature of the crossbreeding (inbreeding/outbreeding) have also been cited as causes that may predispose to dystocia in the canine species [3]. Once dystocia is detected, medical or surgical treatment can be performed based on the type of dystocia. Cesarean section is a common procedure performed in bitches and is often recommended in brachycephalic breeds due to the high risk of complications during birth [4]. Approximately 16 % of bitches experience dystocia, and 60 % of those with dystocia require a cesarean section [5].

Neonatal viability is a critical aspect in the study of the health and survival of puppies during their initial weeks of life. Neonatal mortality varies significantly depending on whether the delivery is natural or via cesarean section. In natural deliveries, the transition of neonates from the intrauterine to the extrauterine environment is particularly delicate [6]. Overall, neonatal mortality in puppies following a natural delivery range between 20 and 40 %, including an 11 % stillbirth rate and neonatal death2s comprising 8–31 % [7]. Cesarean sections are often associated with different rates of neonatal mortality, influenced by factors such as the urgency of the surgery [3] and the condition of the bitch and puppies at the time of delivery [4]. Neonatal mortality rates across all breeds from cesarean sections range from 2.3 % to 8 % [7]. However, in brachycephalic breeds such as English Bulldogs or French Bulldogs, the neonatal mortality rate is usually higher, approximately 11.6 %–14.9 % [4]. Understanding these differences is crucial for improving care strategies and outcomes for both mothers and their

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Table 1
Distribution of programmed C-sections and emergency C-sections in brachycephalic and non-brachycephalic bitches.

	Brachycephalic	Non-brachycephalic	Total
Programmed C-sections	64.42%[a] (67/104)	35.58%[b] (37/104)	74.28 %[1] (104/140)
Emergecy C-sections	19.44%[a] (7/36)	80.56%[b] (29/36)	25.71 %[2] (36/140)

[ab] Different letters in the same file denote significant differences ($P < 0.01$).
[12]Different numbers in the same row and category denote significant differences ($P < 0.05$).

Table 2
The distribution of programmed and emergency C-sections based on different maternal parameters.

Maternal parameters		Programmed C sections	Emergency C- sections
Age	<2 years	2.8 % (3/104)[1]	22.2 % (8/36)[1]
	2–4 years	54.8 % (57/104)[2]	50.0 % (18/36)[2]
	4–6 years	28.8 % (30/104)[3]	22.2 % (8/36)[1]
	>6 years	12.5 % (13/104)[4]	9.3 % (3/36)[3]
Number of births	No previous births	11.5 % (12/104)[1]	77.7 % (28/36)[1]
	≥1 birth	88.4 % (92/104)[2]	22.2 % (8/36)[2]
Sanitary status	Complete	67.3 % (70/104)[1]	5.5 % (2/36)[1]
	Incomplete	28.8 % (30/104)[2]	38.9 % (14/36)[2]
	Unknow	3.84 % (4/104)[3]	55.5 % (20/36)[3]
Litter size	<3	25.0 % (26/104)[1]	30.5 % (11/36)[1]
	3–6	42.3 % (44/104)[2]	22.2 % (8/36)[1]
	>6	32.7 % (34/104)[1]	47.2 % (17/36)[2]

[123]: Different numbers in the same row and category (age, number of births, sanitary status, litter size) denote significant differences ($P < 0.05$).

Table 3
Neonatal mortality in emergency and scheduled cesarean sections in the brachycephalic and non-brachycephalic breeds.

	C-sections	Brachycephalic	Non-brachycephalic	Total
After delivery	Programmed	2.97 %[1](9/303)	2.91 %[1] (7/240)	2.94 %[1] (16/543)
	Emergency	8.97 %[2,a] (7/78)	19.11 %[2,b] (13/68)	13.70 %[2] (20/146)
First h. after birth	Programmed	1.98 %[1] (6/303)	2.8 %[1] (5/240)	2.02 %[1] (11/543)
	Emergency	11.53 %[2] (9/78)	13.53 %[2] (9/68)	12.32 %[2] (18/146)
Fisrt 48 h after birth	Programmed	2.97 % (9/303)	2.50 % (6/240)	2.76 % (15/543)
	Emergency	2.56 % (2/78)	2.94 % (2/68)	2.73 % (4/146)
Total		11.02 % (42/381)	13.63 % (42/308)	12.19 % (84/689)

[12]:Different numbers in the same row and category (immediately after delivery, first h after birth, first 48 h after birth) denote significant differences ($P < 0.05$).
[ab] Different letters in the same file denote significant differences ($P < 0.01$).

offspring, especially in breeds that are predisposed to higher risks.

Among the causes of neonatal mortality, congenital defects and malformations are significant factors. These defects cause structural and functional abnormalities across various organs and can result in the death of neonates [8]. The prevalence of these malformations generally ranges from 1 to 3 % [1], although some authors have reported rates as high as 6.7–6.9 % [9]. The development of these anomalies can be attributed to genetic factors or teratogenic influence, such as nutritional deficiencies, exposure to irradiation, toxins, or infectious agents during pregnancy. Consanguinity is another contributing factor [10], and while direct associations have not been extensively documented, an increased incidence of malformations has been reported in cases of close kinship [11]. Additionally, maternal age plays a crucial role, with older dogs over 7 years more likely to produce offspring with malformations compared to younger mothers [2]. Cleft palate, abdominal wall defects, and anasarca are more common in brachycephalic breeds, indicating a strong genetic influence [2]. Specific malformations like hydrocephalus are responsible for 11.3 % of neonatal deaths within the first 4 weeks of life, while cleft palate accounts for 50 % of such mortality during the same period [12].

The Apgar score is a crucial tool used to assess neonatal viability immediately after birth, evaluating five key parameters: mucous membrane color, heart rate, reaction to irritability, neonatal motion, and respiratory rate [12]. Scores range from 0 to 10, with neonates scoring 0–3 classified as critical, 4–6 as moderate viability, and 7–10 as normal viability [7,12,13]. The Apgar score has been specially adapted for brachycephalic breeds like English Bulldogs and French Bulldogs due to their unique physiological characteristics [14]. Studies indicate that neonates born via cesarean section generally score lower on the Apgar scale compared to those born natural [1], highlighting the importance of immediate and effective resuscitation to reduce neonatal mortality [12].

The objective of this study was to determine the distribution of the type of cesarean sections (scheduled cesarean sections, emergency cesarean sections) based on the breed type, as well as the influence of different maternal parameters. Likewise, neonatal mortality and the incidence of congenital malformations based on the type of cesarean section, breed, and different maternal parameters were recorded.

2. Material and methods

2.1. Animals

One hundred and forty (140) privately owned bitches and 689 puppies were enrolled in this study. The bitches were classified as either brachycephalic ($n = 74$) or non-brachycephalic ($n = 66$). Data on their age, reproductive history, potential for inbreeding (endogamy) or outbreeding, health status, and dietary habits were recorded prior to surgery. Furthermore, the bitches were categorized into two groups: scheduled cesarean section and emergency cesarean section. All cesarean sections were performed by a board-certified surgeon at a private clinic from 2016 to 2021. Neonatal assessments were conducted by a Spanish neonatology specialist. This study adhered to the European

Table 4
Influence of maternal parameters over the percentage of neonatal mortality in programmed and emergency C-sections.

Maternal parameters		Scheduled C-sections	Emergency C- sections
Age	<2 years	6.8%[a,1] (3/44)	50.0%[b,1] (6/12)
	2–4 years	9.8%[a,1] (32/327)	39.65%[b,1] (23/58)
	4–6 years	4.47%[a,2] (6/134)	21.73%[b,2] (10/46)
	>6 years	2.63%[b,3] (1/38)	10.00%[b,2] (3/30)
Number of births	No previous births	12.79%[a,1] (11/86)	31.13%[b,1] (33/106)
	>1 birth	6.78%[a,2] (31/457)	22.25%[b,2] (9/40)
Sanitary status	Complete	3.25%[a,3] (11/338)	13.3%[b,3] (10/75)
	Incomplete	14.89%[a,1] (21/141)	51.28%[b,1] (20/39)
	Unknow	3.12%[a,2] (2/64)	28.57%[b,2] (12/42)
Litter size	<3	6.97%[a] (3/43)	28.57%[b] (4/14)
	3–6	8.09%[a] (17/210)	28.00%[b] (7/25)
	>6	7.58%[a] (22/290)	29.90%[b] (32/107)

[ab] Different letters in the same file denote significant differences ($P < 0.01$).
[123]Different numbers in the same row and category (age, number of births, sanitary status, litter size) denote significant differences ($P < 0.05$).

Table 5
Percentage of females showing neonatal mortality based on the type of C-section and breed.

	Breed			Type of C-section		
	Brachycephalic	Non-brachycephalic	Total	Scheduled	Emergency	Total
Immediately after C-section	12.16%[a] (9/74)	22.72%[b] (15/66)	17.14 %[1] (24/140)	5.09%[a] (8/104)	44.44%[b] (16/36)	17.14 %[1] (24/140)
First hour after birth	8.11 % (6/74)	7.57 % (5/66)	7.86 %[2] (11/140)	7.69 % (8/104)	8.33 % (3/36)	7.85 %[2] (11/140)
First 24 h after birth	12.16%[a] (9/74)	7.57%[b] (5/66)	10.0 %[2] (14/140)	9.61 % (10/104)	11.11 % (4/36)	10.00 %[2] (14/140)
Total	33.78 % (25/74)	36.36 % (24/66)	35.0 % (49/140)	24.04%[a] (25/104)	66.66%[b] (24/36)	35.0 % (49/140)

[ab] Different letters in the same file and category (breed/type of C-section) denote significant differences ($P < 0.01$).
[12] Different numbers in the same row denote significant differences ($P < 0.05$).

animal welfare laws and was conducted following the guidelines of the Bioethics Committee at the University Veterinary Hospital of Las Palmas.

2.2. Experimental design

In the experimental design of our study, we evaluated multiple maternal characteristics in dogs and their potential influence on birth outcomes. The bitches included were classified as either brachycephalic or non-brachycephalic breeds. Regarding the delivery procedure, we distinguished between scheduled and emergency cesarean sections. A total of 104 bitches underwent scheduled cesareans, with 67 being brachycephalic and 37 non-brachycephalic. In contrast, 36 bitches underwent emergency cesareans, with 7 brachycephalic and 29 non-brachycephalic. Furthermore, the bitches were categorized by age into four groups: <2, 2–4, 4–6 and >6 years old. We also considered the number of previous births, differentiating between primiparous (first birth) and multiparous (more than one birth) bitches. The health plan for each animal was assessed and classified into three categories: complete, incomplete, or unknown, which included aspects such as vaccinations and deworming. The size of the litters was another factor, classified into three categories: fewer than 3 puppies, between 3 and 6 puppies, and more than 6 puppies. Lastly, consanguinity in the breeding was evaluated to determine the presence of any consanguinity between the parents. This comprehensive experimental design was aimed at thoroughly addressing the factors that could influence the health and well-being of both the mothers and the puppies.

2.3. Cesarean sections classification

Cesarean sections were classified as either programmed or emergency. Programmed C-sections were scheduled for 59–61 days after ovulation, defined when plasma progesterone levels reached 6–8 ng/ml. C-sections were scheduled for bitches from breeds predisposed to dystocia, such as brachycephalic breeds, owners who preferred cesarean delivery over natural birth, or females that had previously undergone cesarean sections. During gestation, three ultrasound evaluations were conducted: the first between 25 and 30 days after insemination/mating, assessing the total number of embryos and their viability (heartbeat); the second between 43 and 46 days, where fetal heartbeat, size, congenital anomalies, and placental status were evaluated; the final ultrasound, conducted between 57 and 59 days of gestation, determined the biparietal diameter and heartbeat in approximately 50 % of the fetuses. All ultrasound evaluations were performed by the same veterinarian using a GE Medical Systems Ultrasound scanner (GE Medical Systems Ultrasound scanner LOGIQ™, Model MWA150019A, GE HealthCare, United Kingdom).

Emergency C-sections were indicated when parturition commenced (first stage of labor) and complications arose that impeded normal birth (dystocia) or when fetal distress was diagnosed. Prior to the cesarean sections, a comprehensive clinical evaluation of the bitches was conducted, including heart rate, blood pressure, temperature, mucosa examination, plasma progesterone levels, and hematological (Procyte dx, IDEXX Laboratorios S.L., Spain) and biochemical (Catalyst Dx, IDEXX Laboratorios S.L., Spain) analyses. Additionally, thorax radiography and electrocardiograms were performed.

2.4. Premedication, anesthetic and surgical procedures

Initially, premedication was administered to the dogs. Premedication protocols included administering a microdose of IV dexmedetomidine (1 μg/kg, Dexdomitor® 0.5 mg, Zoetis Spain S.L.U., Madrid, Spain) and metoclopramide (0.1 mg/kg, Primepran® 1 mg/ml, Zoetis Spain S.L.U., Madrid, Spain). Bitches were then oxygenated using a face mask, and an intravenous catheter was inserted into the cephalic vein. Induction of anesthesia was completed with fentanyl (2 μg/kg, Fentanest® 0.05 mg/ml, Kern Pharma, Barcelona, Spain) and propofol (2 mg/kg, Propovet® 10 mg/ml, Esteve, Barcelona, Spain), followed by endotracheal intubation. The females were then connected to an automatic respirator delivering 3–4 % oxygen, with 2–3 % isoflurane administered for

Table 6
Congenital anomalies recorded in brachycephalic and non-brachycephalic females and malformations distribution.

Congenital anomalies	Breed		Total
	Brachycephalic	Non-brachycephalic	
Anasarca	1.83 % (7/381)	1.62 % (5/308)	1.74 %[1] (12/689)
Cleft palate	1.31 % (5/381)	1.30 % (4/308)	1.31 %[2] (9/689)
Cleft lip	0.78 % (3/381)	0.32 % (1/308)	0.58 %[3] (4/689)
Hernia	0.26 % (1/381)	0.32 % (1/308)	0.29 %[4] (2/689)
Missing limbs	0.26 % (1/381)	0.32 % (1/308)	0.29 %[4] (2/689)
Monster	0.0 % (0/381)	0.32 % (1/308)	0.14 %[4] (1/689)
Eviscerated	0.26 % (1/381)	0.00 % (0/308)	0.14 %[4] (1/689)
Total	4.72 % (18/381)	4.22 % (13/308)	4.50 % (31/689)

[1234]:Different numbers in the same row denote significant differences ($P < 0.05$).

Table 7
Percentage of congenital malformations and bitches showing puppies with anomalies based on different maternal parameters.

Maternal parameters		Litters showing malformations	Percentage of neonates with malformations
Age	<2 years	18.18 %[12] (2/11)	6.81 % (3/44)
	2–4 years	12.00 %[1] (9/75)	4.58 % (15/327)
	4–6 years	21.05 %[2] (8/38)	7.46 % (10/134)
	>6 years	18.75 %[12] (3/16)	7.89 % (3/38)
Number of births	No previous births	17.50 % (7/40)	4.68 % (9/192)
	>1 birth	14.00 % (14/100)	4.42 % (22/497)
Sanitary status	Complete	12.50 %[1] (9/72)	2.90 %[1] (12/413)
	Incomplete	25.00 %[2] (11/44)	9.44 %[2] (17/180)
	Unknow	8.33 %[3] (2/24)	3.77 %[1] (4/106)
Litter size	<3	10.81 %[1] (4/37)	7.01 %[1] (4/57)
	3–6	13.46 %[1] (7/52)	3.83 %[2] (9/235)
	>6	21.57 %[2] (11/51)	4.53 %[2] (18/397)
Mating	Inbreeding	21.74 %[1] (5/33)	11.72 %[1] (17/145)
	Outbreeding	8.24 %[2] (8/97)	2.40 %[2] (12/499)
	Unknow	20.0 %[1] (2/10)	4.44 %[1] (2/45)

[123]Different numbers in the same row and category (age, number of births, sanitary status, litter size, mating) denote significant differences ($P < 0.01$).

maintenance [5,13].

To stabilize blood pressure before and after the procedure, crystalloid fluids (3–4 ml/kg/h Ringer Lactate®, Braun, Rubí, Spain) were administered. Continuous monitoring during the surgery was ensured using a Ventilator GE Datex Ohmeda Anesthesia Machine (Ventilator GE Datex Ohmeda Anesthesia Machine, Vetmat, Bizkaia). Throughout the surgical procedure, vital signs such as heart rate, respiratory rate, oxygen saturation, carbon dioxide levels, and pressures were monitored using a cuff system. Additional analgesia was provided with intravenous fentanyl (2 μg/kg, Fentanest® 0.05 mg/ml, Kern Pharma, Barcelona, Spain) if any signs of pain were observed during the procedure [5,13].

Local anesthesia at the surgical site was achieved with lidocaine (Lidocaína B. Braun 20 mg/ml, Braun, Rubí, Spain), followed by a 6–12 cm incision through the skin and subcutaneous tissue to access the linea alba [14]. Upon entering the abdominal cavity, the uterine horns were exposed, and a 6–10 cm incision was made in the uterine body to extract the neonates, who were then immediately transferred to the neonatal resuscitation area. The duration from propofol induction to neonate extraction ranged between 10 and 15 min.

If an ovariohysterectomy was indicated, it was performed following standard procedures. Alternatively, if the uterus was preserved, closure was achieved using a double inverting pattern (Cushing) with a monofilament absorbable suture (Monosyn® 3/0, B. Braun Surgical, Rubí, Spain). The abdominal wall and subcutaneous tissues were also closed using Monosyn® in a discontinuous pattern, and the skin was closed with an intradermal suture (Monosyn® 3/0, B. Braun Surgical, Rubí, Spain) to facilitate postoperative care [1].

After surgery, the bitches were monitored continuously in the post-surgery area and meloxicam (0.2 mg/kg SC, Inflacam® 5 mg/ml, Virbac, Barcelona, Spain), amoxicillin (20 mg/kg IM, Clamoxyl® 150 mg/ml, Zoetis, Madrid, Spain) and oxytocin (0.1 IU/kg IV, Oxiton® 10 UI/ml, Laboratorios Ovejero, León, Spain) were administered.

2.5. Neonatal care

Prior to the commencement of cesarean sections, a dedicated reanimation area was prepared, equipped with oxygenation facilities and electric blankets to maintain optimal temperature. The resuscitation team, comprising one person for every two puppies and a technician coordinating between the surgery and reanimation areas, was on standby.

The established protocol for managing newborns was the ABC (Airway, Breathing, Cardiac) sequence. Initially, the airways were cleared using a nasal aspirator to remove fluids and any remnants of the fetal membrane from the mouth and nose. Newborns were then vigorously dried with a towel, and their heads were positioned downward to facilitate further drainage of fluids from the airways. Respiratory rates were continuously monitored. Newborns exhibiting inadequate breathing were assisted with an oxygen mask and administered atipamezole (0.01 ml/100 g SC, Revazol® 5 mg/ml, Eurovet Animal Health BV, Handelsweg, Netherlands) and naloxone (0.05–0.1 mg/kg, SC, Naloxona Kern Pharma® 0.4 mg/ml, Kern Pharma, Barcelona, Spain). During this process, neonates were also auscultated to assess heart rate; if it fell below 100 beats per minute, emergency neonatal resuscitation procedures were initiated. This included the insertion of a jugular vein catheter for administering heptaminol (Vetecardiol® 100 mg/ml, Merck Sharp, Salamanca, Spain) to support blood pressure and heart rate, along with adrenaline to enhance cardiac output. If no heartbeat was detected, cardiac compressions at a rate of 2–3 per second were started, accompanied by subsequent doses of adrenaline administered intravenously. If neonatal viability did not improve, the steps of nasal aspiration, oxygenation, and drug administration were repeated. The ABC protocol was discontinued if there was no favorable response after 45 min [1].

Once stabilized, the puppies had the placenta removed, and the umbilical cord clamped. Neonatal temperatures were recorded and the puppies were weighed before placement in an incubator (Vetario© S40 Intensive Care Unit, Buckingham Road, Weston Industrial Estate, Weston-super-Mare) set at 33–34 °C under continuous supervision. Between 60 and 90 min post-delivery, puppies received 1–3 ml of reconstituted milk (Lacta diet®, Pharmadiet, Barcelona, Spain); those lacking a sucking reflex were fed via a nasogastric tube.

Puppies identified with congenital anomalies were assessed, and those with malformations deemed incompatible with life were humanely euthanized. For survival data analysis, newborns were categorized as follows: stillborn; born alive with severe birth defects; born alive but deceased within 4 h; or viable and alive after 4 h. Neonatal viability was further evaluated at 24 and 48 h post-birth.

2.6. Apgar test assessment

Neonatal viability was assessed using the Apgar test, applicable to all puppies whether they required neonatal reanimation [1]. The evaluation involved five parameters: heart rate, respiratory rate, mucous membrane color, neonatal mobility, and reflex/irritability status. The heart rate was determined using a stethoscope, while the respiratory rate was measured by recording the number of breaths per minute. Mucous membrane color was evaluated through direct visual inspection. Neonatal mobility was assessed based on the observation of spontaneous movement, and reflex/irritability was gauged by the response to external stimuli, such as compression of the tip of the paw.

Each parameter received a score of 0, 1, or 2, with the total possible score ranging from 0 to 10. Based on their final Apgar scores, puppies were classified into three categories: critical (score <3), moderate viability (score 3–7), and normal viability (score >7). The Apgar test was administered immediately after birth (Apgar 1) and again 60 min postpartum (Apgar 60) [1,12,15].

2.7. Statistical analysis

Frequency and proportion of categorical variables and mean and standard deviation of scale were calculated. Data of bitches and puppies represented as continuous variables were evaluated for normality using the Shapiro–Wilk test. To explore the homogeneity of baseline data, bitch data in continuous variables (age, health status, number of births) were compared between the type of cesarean section (programmed and emergency cesarean sections) using one-way analysis of variance with Bonferroni adjustment. Comparisons of discrete data (litter size, and number of puppies born following cesarean section) between groups were calculated using the Kruskal–Wallis test with Dunn's test for multiple comparisons. The number of bitches in each type of surgery (programmed and emergency) was analyzed using the Chi-square test with Pearson's correlation coefficient. Puppies' viability (puppies born alive, birth defects and neonatal mortality) were analyzed using the general linear models (GLM). The linear model included the effects of type of cesarean section (programmed and emergency), age (<2, 2–4, 4–6 and >6 years old), number of births, sanitary status (complete, incomplete, unknonw) and litter size (<3, 3–6, >6 puppies) as well as the interactions between them. Pairwise comparisons were adjusted for multiplicity using the Bonferroni test. All analyses were performed using the STATA software (Stata 18, StataCorp LLC, USA). Analysis with $p < 0.05$ was interpreted as statistically significant.

3. Results

A total of 140 cesarean sections were carried out and almost 75 % of which were previously scheduled (Table 1), with a higher frequency in brachycephalic breeds (90 %). Regarding emergency cesarean sections, a higher incidence ($p < 0.01$) was observed in non-brachycephalic breeds. Table 2 describes the distribution C-sections based on different maternal parameters; in scheduled cesarean section, females were mostly in 2–4 years old bitches (54.8 %), with more than one birth (88.4 %) and with a correct health status (67.3 %). Regarding emergency cesarean sections, they were carried out mainly in females under 4 years of age (72.2 %), without previous births (77.7 %), showing an incomplete or unknown health status (94.5 %) and with a large litter size (47.2 %).

Neonatal mortality immediately after cesarean section (Table 3) had a mean value of 5.22 % (36/689), being significantly higher in emergency cesarean sections, both in the number of newborns dead immediately after the cesarean section (13.70 % vs. 2.94 %, emergency vs. programmed C-sections; $p < 0.01$) and in the first hour after birth (12.32 % *vs* 2.94 %, emergency *vs* programmed C-sections; $p < 0.01$). When breeds were compared, the differences were only detected in the percentage of puppies dead before cesarean section, which was higher in non-brachycephalic breeds. Finally, neonatal mortality was similar in the first 48 h after birth, regardless of the breed and the type of cesarean section.

Table 4 shows the percentage of neonatal mortality based on maternal parameters in programmed and emergency C-sections. The highest incidence of neonatal mortality was recorded in young females (<2, 2–4 years) and when both types of cesarean sections were compared, a higher incidence of mortality was observed in emergency cesarean sections, regardless of the female's age. In addition, a higher incidence of neonatal mortality was found in primiparous females, exceeding 30 % of neonatal mortality in emergency cesarean sections and showing the lowest incidence in multiparous bitches with scheduled cesarean section. Bitches with a complete health status showed the lowest incidence of perinatal mortality and the highest values were recorded in females with an incomplete health status and more frequently (about 50 %) in emergency cesarean sections. Litter size did not show the influence on neonatal mortality, with very uniform values within each group of cesarean sections; however, in emergency cesarean sections, mortality was 4–5 times higher when compared to scheduled cesarean sections, within the same age range. The percentage of bitches that showed neonatal mortality is described in Table 5. Neonatal mortality was notably higher in emergency cesarean sections (66.6 % *vs* 24.04 %, emergency *vs.* scheduled C-sections, $p < 0.01$). A lower incidence of neonatal mortality was recorded in brachycephalic bitches just before cesarean sections (12.16 % *vs* 22.72 %, $p < 0.01$; brachycephalic *vs* non-brachycephalic, respectively), while in the first 24 h after birth, the mortality of puppies was slightly higher ($p < 0.05$) in brachycephalic bitches.

The total number of congenital anomalies showed a value of 4.5 % (31/689), with no significant differences between brachycephalic and non-brachycephalic breeds (Table 6). The most frequently malformations were anasarca and cleft palate, which represented 66.67 % (12/18) and 69.23 % (9/13) of the total congenital malformations, in brachycephalic and non-brachycephalic females, respectively. The percentage of litters with congenital anomalies and its distribution based on maternal parameters are described in Table 7. Bitches between 2 and 4 years old had the lowest incidence of litters (12 %) with congenital malformations, but the mother's age did not show influence over the percentage of congenital anomalies of puppies. In addition, Bitches with an incomplete health status had the highest number of litters with congenital anomalies (25 %) and about 21.5 % (11/51) of congenital anomalies were observed in bitches with large litters. Finally, pregnant bitches resulted from inbreeding showed an incidence of congenital malformations almost 3 times higher ($p < 0.01$) than bitches whose pregnancy was the result of outcrossing.

4. Discussion

This retrospective study has defined the percentage of scheduled and emergency cesarean sections in a private clinic, considering different maternal features such as breed, age, previous births, sanitary status, and litter size. In addition, neonatal mortality and congenital malformations were also registered, assessing the same factors previously described, as well as the inbreeding/outbreeding of the mating.

Cesarean sections are a common procedure in veterinary clinics, especially in breeds with a higher predisposition to dystocia, as is the case with brachycephalic breeds [4]. The risk of dystocia is related to abnormal pelvic conformation, a narrow birth canal, and the long biparietal diameter, which predisposes to the inability of natural birthing to occur [4]. In the current study, a total of 75 % scheduled cesareans were performed, of which 90 % were brachycephalic breeds, while 80 % of the emergency cesareans involved non-brachycephalic breeds. This can be explained by scheduling cesareans for breeds known to be at risk of dystocia, thereby reducing the probability of them suffering from dystocia and needing emergency care. In contrast, owners of bitches with a lower predisposition to suffer from dystocia may be more likely to have been unaware of the pregnancy [16] and may not know how a birth occurs normally or when dystocia begins. About 53 % of the cesarean sections (scheduled and emergency C-sections) were performed in brachycephalic breeds, consistent with routine clinical practices and findings from other studies [4,16,15].

Different retrospective studies [4,16] reported an incidence between 34.4 and 50 % of primiparous females that underwent cesarean sections, with no differences between emergency and scheduled cesarean sections. In our study, about 71.4 % of females that underwent cesarean section were multiparous, although it was detected that in emergency cesarean sections, there were more primiparous females; likewise, bitches between 2 and 4 years old represented the highest percentage of females undergoing cesarean section, both in scheduled or emergency cesarean sections. Previous studies did not find a strong relationship between the age of the bitch and the incidence of cesarean sections, but Schrank et al. [17] reported a higher incidence of cesarean sections with advanced maternal age. On the other hand, the lowest incidence of emergency C-section was observed in bitches with a complete sanitary status and a litter size between 3 and 6 puppies, while in scheduled C-sections, bitches with a complete sanitary status and with a litter size between 1 and 6 puppies represented more than 66 % of the total females. No studies have assessed the influence of the sanitary status on the type of cesarean sections, and there were different results regarding the incidence of litter size over the presentation of cesarean sections [18–20].

Neonatal mortality, once excluded puppies with life-incompatible congenital malformations, was around 7.5 % immediately after birth, being notably higher in emergency C-section (15.7 %) compared with scheduled C-sections (1.84 %). Our results agree with those reported by Adams et al. [4] with values of neonatal mortality of 1.2 % and 19.6 % in scheduled C-sections and emergency C-sections, respectively, highlighting the critical impact of the type of cesarean on neonatal survival. Veronesi and Fusi [7] reported a neonatal mortality range of 20 %–40 % during the first three weeks of life, which includes 11 % of neonates born dead and 8–31 % dying within this period. Batista et al. [1] found a lower mortality rate (below 5 %) immediately after birth, although the range across studies varied from 8 to 14 % [21,22]. In our research, the overall neonatal mortality was 12.19 % (84/689), with higher rates observed in emergency cesareans (13.7 %) compared to scheduled ones (2.94 %). This trend was particularly evident in brachycephalic breeds [4], where the survival rate post-scheduled cesarean was 98.8 % (166/168 neonates), significantly better than the 80.4 % survival rate (37 out of 46 neonates) seen after emergency cesareans. Furthermore, our data suggest that most neonatal deaths occur in the first days of life, which can account for up to 67 % of all neonatal fatalities, often due to complications such as hypoxia, hypoglycemia, and hypothermia, which may subsequently lead to infectious diseases [6].

Our study assessed also the influence of maternal age, litter size and health status of the dam on neonatal mortality. Bitches <2 years old showed a particularly high mortality rate, especially during emergency cesareans (50 %) compared to scheduled cesareans (6.8 %). Some studies reported a mortality rate of 38.9 % in bitches over 7 years old [3] tend to have low birth weight and immature neonates, which favors higher mortality [3]. The size of the litter also plays a crucial role in neonatal outcomes; several studies have found a negative correlation between neonatal survival and larger litter size, with litters of more than 12 puppies experiencing a significant impact on survival [4,23]. Uteri from large litters are less able to contract, often leading to dystocia [23], and the increased number of fetuses reduces uterine space, potentially resulting in low-weight neonates. Low birth weight is a known risk factor for increased neonatal mortality due to associated lower glucose concentrations and temperatures [6]. However, in our study, we did not find significant differences in neonatal mortality based on litter size, with values very similar inside each type of cesarean sections (scheduled/emergency). The health status of the mother, encompassing vaccination, deworming, and nutrition, plays a vital role in breeding success. According to our findings, bitches that were well-vaccinated and dewormed exhibit significantly lower neonatal mortality rates. In contrast, bitches with incomplete health plans experienced much higher mortality rates, up to 48 %. This result highlights the critical need for thorough vaccination, deworming, and balanced nutrition to ensure fewer pregnancy complications and improved outcomes for neonates. It is acknowledged that certain pathogens are more likely to cause abortions and the development of congenital malformations [9,24], with these outcomes being considerably more prevalent in bitches with poor or nonexistent health care.

In our study, the 4.5 % of the total neonates exhibited congenital malformations, with a significant prevalence in brachycephalic breeds, which accounted for over 60 % of these abnormalities. The incidence of congenital anomalies has been reported in different studies, with values ranging between 2.8 and 14 % [1,2,4,9,21,25,26] but the influence of maternal factors over the presentation of congenital malformations has not been described deeply. Congenital malformations were slightly less common in bitches aged 2–4 years compared to those under 2 years and over 6 years, with rates ranging from 18 to 21 %, though the differences were not statistically significant Furthermore, neonates born from mothers lacking adequate health care displayed a 9.34 % incidence of malformations. This higher incidence of malformations may be connected to deficiencies in prenatal care, such as insufficient folic acid supplementation, which is crucial for reducing malformation risks and managing conditions that can complicate pregnancies, like hypothyroidism and diabetes mellitus [21]. Overall, our research underscores the importance of comprehensive health management for breeding bitches. This highlights the critical need for thorough vaccination, deworming, and balanced nutrition to ensure fewer pregnancy complications and improved outcomes for neonates [27]. Proper maternal healthcare not only decreases the risk of congenital malformations but also enhances neonatal survival rates. Moreover, congenital malformations can arise from genetic factors or from inbreeding, with inbreeding seen more commonly in large breeds than in small breeds [10,21]. This could explain the higher incidence observed in brachycephalic breeds which tend to involve large-breed dogs [1]. Breeders often select individuals for breeding based on phenotypic characteristics and behavior, which can create genetic bottlenecks. This selection, particularly prevalent in brachycephalic dogs, tends to reduce fertility, increase reproductive issues, and contributes to the occurrence of dystocia due to anatomical disproportion in some breeds [21]. This observation is consistent with the patterns noted in our study, highlighting a critical area for intervention to improve canine breeding outcomes. Finally, litters with 6 or more puppies showed a higher incidence of congenital malformations in agreement with Batista et al. [1] that proposed a predisposition to the development of congenital malformations when the uterus is subjected to an overuse of its functional capacity.

The most common malformations identified were anasarca and cleft palate, representing more than 60 % of the total congenital anomalies, as reported in previous studies [1,2,26,28]. Some studies have reported a higher incidence of anasarca and clef palate in brachycephalic breeds, suggesting the influence of genetic factors in the development of anasarca in the English bulldog [9,29] and a 30 % risk factor for the development of cleft palate in puppies of brachycephalic breeds [30,31]. However, in our study, non-brachycephalic and brachycephalic bitches showed a similar incidence of puppies with anasarca and clef palate and these findings may be due to the low number of inbreeding mating recorded in our study, since inbreeding practices tend to increase the occurrence of congenital malformations [3,29,32]. In addition, hydrocephalus is other congenital malformations usually described in puppies, but this alteration was not observed in our study; this may be related to the breeds involved in each study, with some malformations being more common in large breeds, whereas in small breeds, the appearance of hydrocephalus is more common [9].

5. Conclusion

The present study confirmed the influence of maternal factors over the type of cesarean sections and the incidence of neonatal mortality. Scheduled cesareans were more frequent in bitches with a complete health status, multiparous and a litter size between 4 and 6 puppies, while the higher incidence in emergency C-sections was recorded in bitches without previous birth, with incomplete health status and a big litter size (>6 puppies). Neonatal mortality was notable higher in emergency C-sections, in bitches without previous births and with a not proper sanitary management. Finally, inbreeding and incomplete sanitary health conditions were factors that could favor a higher incidence of congenital malformations. The comprehensive analysis of the study indicates that proper reproductive management is crucial for gestation and the safe delivery of neonates. Appropriate genetic selection of breeders, maintaining good sanitary health conditions, and considering the age of the reproducers, are pivotal factors in planning for gestation. Moreover, owners should be counseled to implement strict control and monitoring during gestation to prevent conditions that could lead to dystocia, which would necessitate emergency cesarean sections and potentially result in higher neonatal mortality rates.

CRediT authorship contribution statement

Raquel Rodríguez: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Dácil Alemán:** Methodology, Investigation, Formal analysis. **Miguel Batista:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Carla Moreno:** Methodology, Investigation, Formal analysis. **Melania Santana:** Methodology, Formal analysis. **Kseniia Iusupova:** Writing – review & editing, Formal analysis. **Desirée Alamo:** Writing – review & editing, Validation.

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