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The Impact of Medical Technology on Health: A Longitudinal Analysis of Ischemic Heart Disease

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ABSTRACT

Objectives: This article estimates the costs and benefits of changes in ischemic heart disease (IHD) care in Spain from 1980 to 2003.

Methods: We use joinpoint regression to identify trends in the standardized rates of mortality and hospitalization for IHD in general and acute myocardial infarction (AMI) in particular. We estimate also logistic regression models for the probability of in-hospital death of patients admitted for AMI. To measure costs and benefits between 1980 and 2003 we use the microdata from Spanish Hospital Morbidity Survey, and the reports of the Cardiac Catheterization and Coronary Intervention Registry of the Spanish Society of Cardiology.

Results: Mortality from IHD in Spain has been substantially reduced in the past 25 years. Medical advances have saved lives of many patients admitted to hospitals. If the patients with AMI admitted in 2003 had been treated with 1980 procedures the rate of hospital mortality for AMI would have doubled. The estimated benefits in 2003 are the lives of the 5326 patients saved. The unit real costs have increased from €2143 to €4550 per AMI admission. If this cost increase is applied to the 57,842 Spanish AMI inpatients admitted in 2003, one could say that advances in medical technology from 1980 to 2003 carry a cost of €26,140 per life saved.

Conclusions: In Spain advances in hospital technology for the treatment of IHD since 1980 are well worth the cost.

Keywords: costs and benefits, ischemic heart disease treatment, longitudinal analysis, technological change.

Introduction

Over the years, technological changes have transformed medical treatment leading to significant improvements in the length and quality of lives. In 1975 life expectancy in Spain was 70.4 years for men and 76.2 years for women; by 2003 these numbers had increased by 7 and 7.5 years, respectively. These gains in the quantity of life have led to interest in assigning an economic value to the means employed to achieve them and in identifying the role of technological innovation, both pharmaceutical and nonpharmaceutical.

This interest is not easy to satisfy. A number of US health economists have addressed it starting in 1996 [1,2]. In particular for the acute myocardial infarction (AMI), the overall conclusion of these analyses is that in the US technological advances in the treatment of AMI "are worth more than they cost." But these improvements in effectiveness may be slowing in recent years [3].

There are no comparable studies for other countries. It would be especially useful to have studies for Europe, particularly for those countries with national health systems, which generally have low mortality rates for ischemic heart disease (IHD). This study addresses the question for Spain, which after France has the lowest mortality rates for this disease in Europe, in spite of quite moderate levels of expenditure when compared with other Western European countries [4].

In this article we estimated the costs and benefits of changes in AMI care from 1980 to 2003. We compare improvements in health between 1980 and 2003 in terms of decrease in mortality in hospitals and increase in longevity with the costs entailed. IHD is the most common cause of death in most industrialized countries. In Spain it causes more than 10% of all deaths annually, and it is the most important cause of death for men and the third most important for women [5]. The most common manifestation of IHD is AMI, which accounts for 64% of cases (67% for men and 60% for women). In Spain in the year 2002 it is estimated that there were 68,500 cases of AMI, of which about two-thirds were hospitalized, the rest dying before they could be treated [6]. In the last 30 years mortality from IHD in general and AMI in particular have declined.

No one in the scientific community doubts the importance of lifestyle for altering cardiac risk factors and hence IHD, but it is no simple task to know how

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to apportion effectiveness and responsibility between individuals and the health system in the reduction of the incidence and the mortality of IHD and AMI. Furthermore, an AMI is just one point in a latent and chronic heart disease. Because medical and surgical treatment reduces the incidence of AMI, we will analyze trends for IHD in general, and estimate the number of deaths avoided and years gained because of medical and surgical treatment for the specific case of AMI.

Our study is organized as follows: After a presentation of data sources and statistical methods we analyze trends in IHD and AMI mortality rates by joinpoint loglinear regression. We also present data of years of life lost because of these diseases in 1980 and 2003, and estimate the hospital deaths avoided in 2003 as a result of improvements in technology since 1980. We them compare these results with comparable studies and consider the possible attribution of improvements in mortality to the decline of risk factors in the population, to improvements in emergency services and to medical treatment.

Materials and Methods

Data Sources and Reliability

Our mortality data come from statistics compiled by the National Center of Epidemiology (NCE) of the Spanish Ministry of Health [7]. Since 1992, the NCE maintains an IHD morbidity/mortality database. In turn, the NCE uses as its primary data source the records of natural movement of the Spanish population prepared by the Spanish Statistical Office.

The reliability of this information has slowly improved over the years. Deaths assigned to the residual category "Other unspecified causes" have fallen 75% from 1975 to 2003. The validity of the basic cause of death matches the overall level of development of the health system. Studies indicate that in 10% to 15% of death certificates the cause of death is in error [8,9]. Our analysis suggests that diagnostic errors have decreased over time and are likely to have been quite significant up to the 1980s.

The category "ischemic heart disease" used in this study corresponds to code 420 in the World Health Organization's Sixth and Seventh International Classifications of Diseases (ICD) used in the years 1952 to 1960 and 1961 to 1967, respectively, and codes 410 and 414 in the Eighth and Ninth versions used in 1968 to 1979 and 1980 to 2003, respectively. In spite of the effort to keep the different codes comparable, there are problems when analyzing long series, principally because of errors in diagnosis of the cause of death. From the 1950s through the 1970s, mortality rates for both men and women are irregular, with a high interannual variability [7]. The variance for percent change for the male series is 80.46 for the first half (1951–1975) and falls to 6.25 for the second (1976–2003). For women the variance falls from 139.78 to 9.62. In the series of interannual increments, one notes that the mid-1970s marks an inflection point in the variance, which suggests that major improvements in the reliability of the data started then. This sharp decline in the percent changes for men and women, as well as the high correlation between the two ($r = 0.862$) suggests one should treat the data with caution, particularly that of the first 25 years. We chose to analyze the series from 1980 on for the reasons mentioned above and because in that year mortality rates for AMI began to be available. Hence, the time span analyzed is 1980 to 2003.

To analyze hospital utilization we have made use of the microdata in the Hospital Morbidity Survey (HMS) [10], and the reports of the Cardiac Catheterization and Coronary Intervention Registry of the Spanish Society of Cardiology [11]. Another database, the Minimum Basic Data Set [12], would have been a preferable alternative, because it contains more detailed diagnostic and intervention information, but it has come into use only in the last years. The advantage of the HMS is that it has been maintained annually since 1979 using a consistent method. It provides information on the intensity of hospital use. We have analyzed the microdata of patients hospitalized from 1980 to 2003 for all IHD and, separately, those for AMI. The HMS is obtained by sampling, and the sample sizes have increased as patient records in hospitals have become digital. In 1980 each patient in the sample represented an average of 13 admissions; by 2003 the relation was almost one-to-one. The great advance came between 1990 (10,183 IHD cases in the HMS) and 1995 (38,262 cases) and between 1995 and 2000 (105,728 cases).

Hence, the HMS has increased in precision and reliability since the 1980s. Over time, the proportion of cases of angina has decreased, and that of AMI has increased, possibly because of improvements in diagnosis. In 1990 more than a quarter of IHD admissions were for angina (30% if weighed by the raising factor), but by 2003 this proportion was down to 12%. In a longitudinal study, change over time in the variance of errors of measurement can seriously skew the results. This is an inevitable limitation of this study.

Methods

The Calculation of Mortality Trends and Life Expectancy

The NCE provides mortality rates standardized by age and sex. Rate adjustment is calculated using the direct estimation method and taking as a reference the standard European population, to allow for easier comparisons with the rest of the European Union countries. The mortality adjusted rates and absolute interannual differences depend, in theory, on the reference population used. Nevertheless, the annual percent change in the IHD standardized mortality rates in Spain appears very stable when a variety of reference populations is used (1971 Spanish population, 1991 Spanish population, standard World population and standard European population) [13]. The Spanish IHD mortality rates seem to be an example of constant stratum-specific rate ratio [14], even though the absolute value rates appear to be very sensitive to the reference population used in the standardization process.

Using joinpoint loglinear regression we analyzed trends in standardized death rates (men and women) from IHD and AMI using annual series from 1980 to 2003. Given the loglinear nature of the model, the exponential parameters that provide the regression may be presented as percentages of annual change (PAC) of the standardized rates for each period or segment. Each joinpoint is accompanied by a corresponding confidence interval (CI) [15]. For the joinpoint analysis Joinpoint Regression Program, Version 3.0 was used [16].

To measure the increase in healthiness over the last quarter-century, we also analyzed changes in potential years of life lost (PYLL) because of IHD between 1980 and 2003. The OECD database Health Data [17] contains long series of PYLL for the most deadly diseases. The OECD calculates PYLL as standardized rates per 100,000 inhabitants. They take as their base of reference the population of the OECD countries in 1980, and cut off their calculation of PYLL at 70 years of age. For the purpose of our study, cutting off at 70 the upper limit for the calculation of PYLL will underestimate the gains in life expectancy between 1980 and 2003, because the number of years gained over 70 has been increasing, and this increase is not reflected in the OECD formula with age limit fixed at 70. We calculate the increase in years of life gained between 1980 and 2003 with the limit in the age 80 years.

Hospital Use and the Estimation of Hospital Treatment Effectiveness

To better measure effectiveness between 1980 and 2003 in the reduction of in-hospital mortality, we estimated logistic regression models for the probability of in-hospitals death of patients admitted for AMI in the years 1980, 1985, 1990, 2000, and 2003 (n = 210,139), controlling for age, sex, province of hospital, kind of admission (scheduled or emergency), standardized rates of hospital admissions for AMI and year of admission. The odds ratio of the year 2003 relative to 1980 estimates the reduction in the in-hospital mortality rates since 1980 after adjusting for the confounding variables. The standardized rate of admissions is defined as number of AMI-diagnosed hospital admissions per 1000 population and it was calculated for each year and sex. The rate is included in the model to account for the possibility of a gradual decline in the seriousness of the condition of AMI patients at the time of admission between 1980 and 2003, potentially because of improvements in health education and lifestyles.

Cost Calculations

In Spain there is no register of treatment costs for individuals. In 1980 cost accounting was not available in hospitals in Spain and risk-based classification and adjustment systems (Diagnosis Related Groups, etc.) were yet to be designed. Private hospitals billed the National Health system per day of hospital stay. The average unit cost for hospital admission for AMI in 1980 was estimated from overall data on the cost of hospitalization from the statistical series of Public Health Expenditures [18], accounting for the weight of private provision in inpatient care (data from the OECD health database [17]). We multiplied the unit average cost by the number of admissions for AMI, weighting the admissions with the current weights (for AMI, the average of diagnostic group categories 121 (2.7677) and 122 (1.8758). For 2003, we have used the disaggregated average costs of treatment for every group of patients with AMI (including ambulatory care provided to the patient before reaching the hospital: ECG, fibinolysis, primary angioplasty, etc.). To calculate the hospital total cost, we multiplied the average cost by the respective total numbers of the different treatments applied. These latter numbers were obtained from the HMS [10], the Minimum Basic Data Set for Hospitals [12], and the Cardiac Catheterization and Coronary Intervention Registry of the Spanish Society of Cardiology [11]. The average costs for 2003 were taken from the standard public prices listed in Decree 1247/2002 [19]. The number of ambulatory and emergency procedures to patients with AMI was based on published figures for 2002 [20], around 55% of the cases reach the hospital through the prehospital health-care system, but only a 2.9% of these received a prehospital thrombolysis or primary angioplasty. Valuation of resources for services and procedures was performed from the standard public prices listed [19]. The General Consumer Price Index was used to adjust for general price inflation. All costs are presented in 2003 euros. Because we are computing short-term health-care costs, discounting is not necessary.

Results

Estimation of Mortality Trends for IHD by Joinpoint Analysis

For IHD as a whole and for AMI the results of the joinpoint regression are presented in Figure 1. The

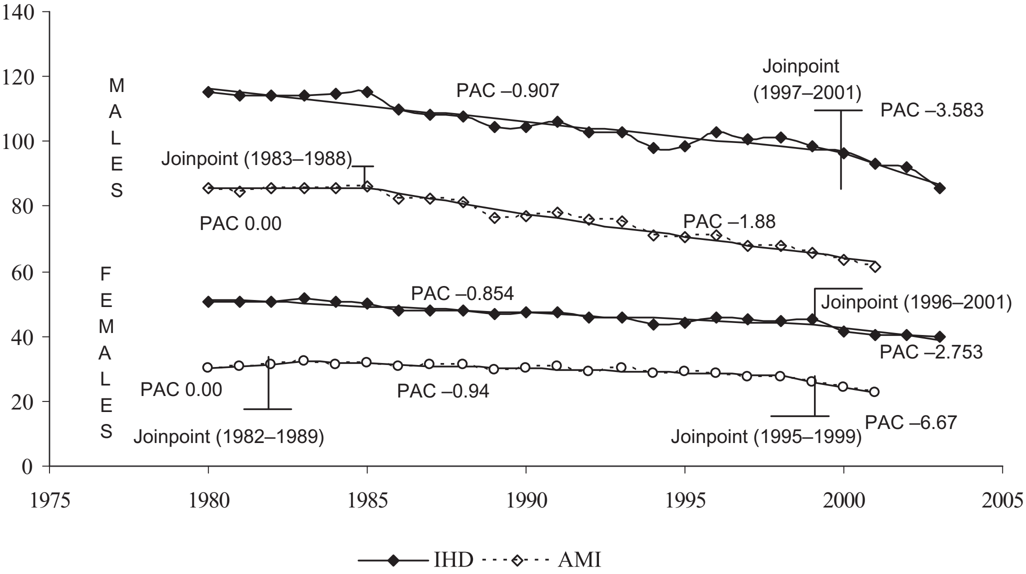

Figure 1 Joinpoint analysis of trends in mortality rates for ischemic heart disease (IHD) and acute myocardial infarction (AMI) in Spain from 1980 to 2003. Note: PAC, percentage of annual change estimated ($P < 0.05$). In brackets, joinpoint confidence intervals at 95%.

analysis divides the series of men into two clearly distinguishable periods, 1980 to 2000 and 2000 to 2003, with PAC of –0.907% and –3.58%, respectively. For women the periods differentiated were similar, 1980 to 1999 and 1999 to 2003 and in fact coincide with that of the men if one takes account of CIs, with PAC of –0.85% and –2.75%. Both in men and women the trends for each interval are statistically significant. The joinpoint regression for AMI identifies significant trends only beginning in 1985 for men and 1983 for women, which is the same period since the CIs overlap. In other words, in the first years under examination, there was neither a significant increase nor decrease in the death rate. Subsequently, mortality from AMI decreased steadily for men at an annual change of –1.88%. For women this kind of mortality decreased in two stages, first more slowly at an –0.94% annual change until 1998, and then more rapidly at a rate of –6.67%.

The specific mortality rates from IHD have been reduced since 1980 for all age groups except for those over 75 years, in accordance with the increase in life expectancy.

Using data from the HMS and from death certificates we have estimated for every year since 1980 deaths from AMI in hospitals as a percentage of total AMI deaths. This percentage remains quite stable, about 14%, until 2001. In the 3 years thereafter it was higher, at 17.9% on average, suggesting that emergency services had improved and that many persons who previously died before reaching the hospital were arriving there alive. It is probable therefore that patients with AMI have been arriving at hospitals since the year 2000 in a more serious condition than previously.

Reduction in Years of Life Lost from IHD from 1980 to 2003

Since standardized mortality from IHD has been reduced and the death of persons with heart disease postponed, the number of PYLL from premature death by IHD has been reduced in Spain, according to the OECD database, even more than the IHD mortality rates themselves. Taking as base 100 deaths from IHD per 100,000 inhabitants and the years lost in 1980, in the year 2000 mortality rates had dropped to 84 for men and 82 for women, whereas PYLL had dropped to 67 for men and 60 for women. Our calculations show that between 1980 and 2003 48,152 potential years of life have been saved for men and 20,214 for women, for a total of 68,366 years.

The Use of Hospitals by Inpatients Who Received a Diagnosis of IHD from 1980 to 2003

According to the HMS, the number of admissions for IHD quadrupled between 1980 and 2003, and cases of AMI have come to represent a smaller proportion of the total ischemic cardiopathies. Furthermore, in recent years the use of hospital day units and outpatient clinics has increased, so that real hospital use for IHD has increased even more than hospital admissions would indicate. In 2003 about 8.6% of IHD patients were hospitalized outside of the province of residence, whereas in 1980 this figure was 5%. Some cardiac surgery and treatments are not available in all hospitals, meaning that some patients have to travel for

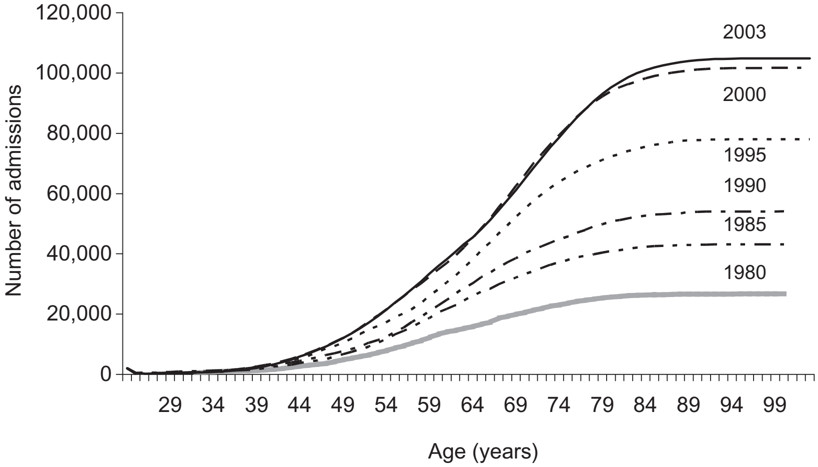

Figure 2 Hospital admissions of men for ischemic heart disease, Spain 1980–2003: number of admissions by age. Source: compiled by authors with data from Hospital Morbidity Survey.

treatment. This is why the percentage of admissions due to transfer from one hospital to another for AMI patients has also increased, from 2.7% of all admissions in 1980, to 8.3% in 2003. The percentage of emergency admissions for IHD as a whole has decreased from 77% to 71.6%, but has increased in the case of AMI from 80% to 85%.

Over the last 25 years there has been a significant change in the age of patients admitted (Fig. 2 gives information for men; that for women is similar). The average age at admission has increased from 61.7 years in 1980 to 67.4 years in 2003. Admissions of IHD patients older than 70 years increased from 28.2% in 1980 to 45.5% in 2003. At the other extreme, admissions for IHD of those younger than 40 years comprised 4.8% of the total in 1980, and only 1.8% of the total (and 2.5% of the AMI total) in 2003. The great leap of age at admission occurred after 1990 and above all after 1995. Between 2000 and 2003 it remained stable.

More Effective Treatment: A Logistic Model to Estimate Reduction in AMI Mortality in Hospitals Between 1980 and 2003

A rough indicator of improvements in effectiveness of hospital treatment are the gross rates of mortality in hospitals for patients admitted with AMI, which have been halved between 1980 and 2003, falling from 14.5% to 7.6%.

When a logistic regression model is applied to hospital deaths from AMI (n = 105,161), all the variables are significant, as is the overall fit (LR chi-square [59] = 5811.21, Pseudo $R^2 = 0.09$). Women admitted with AMI are more likely to die (odds ratio = 1.28, CI at 95% level = 1.22–1.34) and age is a very significant risk factor (odds ratio = 1.06, CI at 95% level = 1.058–1.062). For both women and men, geographic differences can be very striking. Emergency admissions have the worst prognosis (odds ratio = 1.39 CI at 95% level = 1.30–1.49). Scheduled admissions are those transferred between hospitals. Increased effectiveness of hospital care is reflected in the estimated coefficients for the time effect, with dummy variables for years (Table 1). The odds ratio for 2003 in relation to 1980 is 0.32 (CI at 95% level = 0.27–0.37).

With the logistic model, we found that 16% of the patients admitted for AMI would have died, more than twice the rate as in 2003. In absolute numbers, according to the model technology has saved the lives of 5326 Spaniards admitted with AMI in 2003; that is, if in 2003 the technology available was that of 1980, according to the model 5326 persons would not have survived.

Treatment Costs for IHD and AMI in 2003 and 1980

We have calculated the total health costs for the year 2003 and 1980 for hospital-related treatment of persons with AMI, including emergency critical care mobile facilities—which are in Spain a responsibility of the regional governments, aside from hospitals. The medical costs for AMI for the year 2003 (Table 2) are estimated to have been €263 million, with an average cost per admitted patient of €4550. This figure is somewhat higher than those estimated in other studies, no doubt because here we include all admissions coded

Table 1 Logistical regression model. Probability of death in hospital from acute myocardial infarction, Spain, 1980–2003

Temporal dummies effect, reference 1980		
Year	Odds ratio	CI at 95%
1985	1.07	0.88–1.31
1990	0.86	0.72–1.04
1995	0.62	0.53–0.73
2000	0.40	0.34–0.47
2003	0.32	0.27–0.37

CI, confidence interval.

Table 2 Cost estimates of hospital treatment of acute myocardial infarction (AMI) in Spain, 2003

Procedure	DRG*	Admissions	Unit price (2003 euros)	Total cost (2003 euros)
Percutaneous operations	808	6,080	5,617	34,151,360
Bypass (AMI patients)	106	37	10,884	402,708
	107	815	8,824	7,191,560
	109	14,712	8,824	12,984,516
Pacemakers, AMI	115	655	7,428	4,865,340
Admission in medical department (alive)	121	13,338	4,357	5,811,3666
	122	20,481	3,825	78,339,825
Admission in medical department (death)	123	5,207	4,035	21,009,294
Cost of prehospital care by ambulatory facilities and mobile emergency-care units		29,558	229	6,768,782
Total cost of admissions in medical departments				157,462,785
Total cost AMI (admissions plus procedures)				263,196,783
Average unit cost AMI				4,550

*Diagnoses Related Groups version AP 18.0.
Source: compiled from information from Minimum Basic Data Set, Survey of Morbidity in Hospitals, Cardiac Catheterization and Coronary Intervention Registry of the Spanish Society of Cardiology and unit prices from Decree 1247/2002.

410 (AMI), not just the emergency ones. The total hospital costs for AMI can be broken down to 75% for medical assistance, 13% for percutaneous surgical procedures, 9.5% for other surgical procedures (coronary bypass, pacemaker installation) and 2.5% for prehospital care.

We have estimated the equivalent cost of treating AMI in a hospital in 1980 as, €2143 (2003), less than half the cost in 2003. A patient admitted for AMI in 1980 had an average stay (15.14 days) practically equal to the average stay of all patients (15.35 days). Without the benefit of modern procedures, the treatment process was not complex, and so it does not appear sensible to apply to 1980 the present-day weights of diagnostic categories related to AMI. In 1980 a doctor faced with a patient with AMI had little alternative other than to reduce demands on the heart with rest, beta blockers, vasodilators, etc. At that time there was even doubt whether coronary thrombosis was the cause or the result of myocardial infarction [21]. After the introduction of fibrinolysis and direct angioplasty, mortality has been reduced considerably. The technique of cardiac revascularization was one of the most notable advances in heart treatment. There is evidence that proactive treatment of IHD brings marked benefits, especially in cases of high risk and early intervention [22,23]. Similarly, percutaneous treatment of AMI by primary angioplasty has been shown to be superior to fibrinolysis [24].

The Integrated Plan for IHD [8] calculates the cost of the disease in Spain as about €1.5 billion (1500 million) per year, about half of it indirect (from loss of productivity, etc.). A more recent study applying the same criteria to the 25 countries of the European Union calculates the cost of hospital treatment (excluding medicine) of heart disease as €395 million in 2003 [4].

Costs and Benefits

In an accounting exercise we can compare the "benefits" and the "costs" of technological change in this field. The estimated benefits in 2003 are the lives of the 5326 patients saved. The unit "costs" have increased from €2143 to €4550 per AMI admission. Applying this cost increment to the 57,842 patients admitted to Spanish hospitals for AMI in 2003, one could say that "saving a life" thanks to medical technology developed for the treatment of AMI since 1980 cost €26,140. This amount is lower even than that usually used as a reasonable cost limit for a quality-adjusted life-year gained through health intervention. The life expectancies of the AMI patients discharged from the hospital is more than a year, and hence we may conclude, as we expected, that the new technologies for treating AMI were worth it.

Discussion

Mortality from IHD in Spain has been substantially reduced in the past 25 years. In this respect Spain is similar to many of its neighboring countries.

Although we have established that mortality from IHD has been reduced and years of life have been gained in Spain in the last 25 years and that these improvements have accelerated in recent years, we cannot determine precisely and quantitatively what part medical attention has played [25–27].

Numerous epidemiological studies have identified factors associated with a higher rate of IHD, emphasizing high blood pressure, high cholesterol, smoking, diabetes and obesity, in addition to sedentary lifestyle and excess consumption of alcohol. IHD has multiple causes, and risk factors heighten one another and are frequently found together [28]. It is not clear whether the global prevalence of risk factors for IHD in Spain has increased or decreased between the 1980s and

2003, with the exception of smoking among men. The percentage of male smokers, 55.1% in 1987, fell to 34.2% by 2003. But smoking among women, on the other hand, increased from 1993 to 2001, and in 2003 the percentage of women smokers was the same as in 1987. There are only partial local evidences on the evolution of high pressure and high cholesterol in some groups of the population of Spain [29]. The National Health Surveys provide self-assessment of chronic conditions, but the changes in the thresholds for normal levels make comparisons difficult along time. Disparities in changes of lifestyles and risk factors between men and women can explain to a certain extent the observed differences in the dynamics of the standardized rates of mortality. Obesity, defined as a body mass greater that 30 kg/m^2, is the risk factor that has increased most rapidly. The percentage of obese persons in 2003 was double that in 1987 for both sexes.

If the risk of IHD has increased, we might admit the hypothesis that in the absence of technological advances in treatment mortality would have increased or at least would have stayed level at the rates of 1975 to 1980. But it may be that lifestyles are endogenous to medical technology, in the sense that there is a moral hazard such that people adopt unhealthy lifestyles and risk behavior more than before because new medical technologies can save them if they get sick.

The dynamic pattern of mortality rates of AMI in Spain is a delayed reflection of that in other countries that adopted earlier the new techniques (angioplasties, coronary bypasses, fribrinolytics). A recent study points out that post-AMI survival gains have stagnated, since 1996 in the United States, although spending has continued to increase [3]. In Spain, improvements in mortality and years of life on the contrary have accelerated in recent years, especially since the year 2000, for persons of all ages. Whether this improvement is a direct result of the exponential expansion of catheterization and interventional cardiology, the massive consumption of statins, or other medical or nonmedical interventions we cannot know with the data at hand.

Our logistic regression model estimates the hospital deaths due to AMI avoided in 2003 thanks to technological advances, in comparison with 1980. The model has the generic limitations of statistical artifacts, and some additional specific ones. The Survey of Morbidity in Hospitals has measurement errors (of diagnosis) that have improved over time; the sample sizes have multiplied, which implies that the estimations for 1980 are far less precise than those of recent years.

Our model does not take account of the risk or seriousness of inpatients, although this is critical for prognosis and for the decision whether or not to operate [30]. Because we did not adjust for AMI severity, the model might be biased toward overestimating or underestimating the benefits of technology. There is no evidence that at the population level AMI cases that result in hospital admissions may have been declining in severity, and some studies show that the severity at admission has increased [6,31,32]. Clearly, it would be ideal to be able to adjust for severity levels, as Gil and colleagues [33] do with data from case fatality at 28 days between 1978 and 1993 for patients with a first Q-Wave AMI admitted to a hospital of choice for that speciality in Catalonia. This is why Gil and colleagues [33] found that AMI admissions after 1989 involve older patients, more severe cases and comorbidity. In addition, from the 90 s, and even more so from 2000, some seriously ill AMI cases who in the past would have died before reaching the hospital now make it alive, thanks to medicalized ambulances and quick response of emergency services. In 2003 admitted patients are older than those in 1980, and the percentage of reinfarctions is also greater than in 1980. Because of that AIM survival rates improved, reinfarction (which has a poorer prognosis) has increased. The average age of AMI-admitted patients in 1980 was 61.1. In 2003 that average age was 67.9. In 1980, 26% was older than 70 years, in 2003, 49%.

But on the other hand it can happen that an overall healthier population is now being admitted, thanks to the use of statins as primary prevention and the improvement of risk factors, particularly smoking. Severity of the disease among those admitted in 2003 could be lower than among those admitted in 1980 resulting from improvements in the health education of the population.

The diagnosis of AMI has changed over time. With the use of cardiac tropinins and assays for creatine kinase isoforms, the ability to detect small infarcts has increased. In the 1980s some infarctions (ICD 410) might have been registered as angina pectoris (ICD 413), with the result that the classification itself was misleading (with angina defined as an infarction that the patient survives). In this case, the model would in fact underestimate the beneficial effects of technological improvements.

Another limitation is that the dependent variable is in-hospital mortality. It would be better to model short-term mortality (28 days), like in other studies [33]. Stays were longer in 1980 than in 2003, so the "exposure" time to death in 1980 was also higher than in 2003.

In the treatment of IHD one may expect in Spain yet more improvements in health (gains in years of life) as a result of medical technology, because the rates of use of these techniques are still rather reduced compared with other countries, adjusting for "need" (mortality). There are important geographic differences as to the application of these techniques [34]. The number of diagnostic cardiological studies, in particular of coronary angiography diagnoses, doubled in 10 years. Diagnostic studies went from 50,000 in 1993 to 105,939 in 2003, and coronary angiographies increased from 37,501 to 90,939. Not only has the use of percutaneous procedures expanded exponentially in Spain, but there has been a strong upward trend in intensity and cost: the average number of stents per procedure is increasing (an average of 1.26 in 2003), as well as the percentage of coated stents (20.2% in 2003). Only 14.9% of the percutaneous procedures were performed on patients with AMI (although this is a considerable increase from 3.3% in 1994). In Europe there are great differences among countries in the use of high-technology procedures, in part as a result of an absence of standards and protocols because of lack of dissemination or lack of evidence as to cost effectiveness [35]. Nevertheless, those who suffer AMI do not usually die in the hospital. According to published estimates [6], more than two-thirds die out of hospital. A quarter of patients admitted with AMI die within 28 days and 6% more within a year.

It may be that the fall in mortality from IHD has been caused by a decline in the incidence of the disease and by a decline in its lethality. In the former, the principal causes are related to the activities of primary prevention (reduction in risk factors in and outside of the health system), whereas in the second instance, the reason for the decline would be the appearance of new treatments specific to the disease. Another kind of intervention that may have affected the years of live gained is the use of statins by patients known to have coronary disease (there is a strong evidence of its effectiveness) and by nonpatients as primary prevention. Between 1987 and 2003, the cost of statins in the social security system went up from €26 to €600 million, that is, by a factor of 23 (12 in real terms). The majority of deaths from coronary disease occur in the prehospital phase and most victims do not survive long enough to receive medical help. Emergency services with mobile coronary units have helped to reduce the lethality of heart attacks.

Our results are not easily comparable with other studies. For example, Cutler and McClellan [2] found that in 1984, $3 billion was spent on heart attack patients; by 1998 the total was near $5 billion, 3.4% annual growth in real terms, and that the treatment costs about $10,000 more in 1998 than in 1984. The cost increase in Spain between 1980 and 2003 was more moderate than in the United States (about €2400 of 2003). Our results are not directly comparable to Cutler's because Spain has a lower incidence of IHD than the United States. AMI mortality rates in Spain remain among the lowest in Europe. Nevertheless, we reached the same conclusion as Cutler: technology increases spending, but the health benefits more tan justify the added costs.

Conclusion

We hope that this study sheds new light on the long-term relations between medical technologies, costs, and health. The case of IHD is a classic one and our results for Spain match those made in other contexts. Medical technology for treatment of AMI is worth. Spain is still far from the "flat portion of the Preston curve" [36] that associate health-care expenditure and health gains for the hospital treatment of AMI, because effective technologies of treatment are still in the diffusion phase.

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