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Retrospective cohort analysis of Spanish national trends of coronary artery bypass grafting and percutaneous coronary intervention from 1998 to 2017

Manuel Carnero Alcazar [iD],[1] Daniel Hernandez-Vaquero [iD],[2]
Hector Cubero-Gallego,[3] Jose Lopez Menendez,[4] Miguel Piñon,[5]
Jose Albors Martin,[6] Gregorio Cuerpo Caballero,[7] Javier Cobiella Carnicer,[1]
Cristina Villamor,[8] Alberto Forteza,[9] Isaac Pascual,[10]
Luis Carlos Maroto Castellanos[1]

Correspondence to
Dr Manuel Carnero Alcazar;
mcarneroalcazar@gmail.com

ABSTRACT

Introduction Spain is one of the countries with the lowest rates of revascularisation and highest ratio of percutaneous coronary intervention (PCI) to coronary artery bypass grafting (CABG).

Objectives To investigate the changes and trends in the two revascularisation procedures between 1998 and 2017 in Spain.

Design Retrospective cohort study. Analysis of in-hospital outcomes.

Setting Minimum basic data set from the Spanish National Department of Health: mandatory database collecting information of patients who are attended in the Spanish public National Health System.

Participants 603 976 patients who underwent isolated CABG or PCI in the Spanish National Health System. The study period was divided in four 5-year intervals. Patients with acute myocardial infarction on admission were excluded.

Primary and secondary outcomes We investigated the volume of procedures nationwide, the changes of the risk profile of patients and in-hospital mortality of both techniques.

Results We observed a 2.2-fold increase in the rate of any type of myocardial revascularisation per million inhabitants-year: 357 (1998) to 776 (2017). 93 682 (15.5%) had a coronary surgery. PCI to CABG ratio rose from 2.2 (1998–2002) to 8.1 (2013–2017). Charlson's index increased by 0.8 for CABG and 1 for PCI. The median annual volume of PCI/hospital augmented from 136 to 232, while the volume of CABG was reduced from 137 to 74. In the two decades, we detected a significant reduction of CABG in-hospital mortality (6.5% vs 2.6%, p<0.001) and a small increase in PCI (1.2% vs 1.5%, p<0.001). Risk adjusted mortality rate was reduced for both CABG (1.51 vs 0.48, p<0.001), and PCI (1.42 vs 1.05, p<0.001).

Conclusion We detected a significant increase in the volume of revascularisations (particularly PCI) in Spain. Risk-adjusted in-hospital mortality was significantly reduced.

Strengths and limitations of this study

► This is the first study to investigate the nationwide changes and trends in coronary revascularisation in Spain during the past two decades.

► It was based on a very large and detailed administrative database which included most of the episodes of patients who have been admitted to any public National Health Service hospital between 1998 and 2017.

► Follow-up information is not available.

► The analysis might be biased by administrative information coding errors and missings.

► However, no other source of information allows to perform a long-term nationwide investigation like this.

INTRODUCTION

Surgical and percutaneous myocardial revascularisation have demonstrated to improve symptoms and life expectancy in patients with advanced coronary artery disease. In the vast majority of patients with ST-elevation acute coronary syndrome, percutaneous coronary intervention (PCI) is the preferred strategy.[1] However, in chronic stable angina or non-ST elevation acute coronary syndromes, the choice between PCI and coronary artery bypass grafting (CABG) depends on multiple factors. In this scenario, the best therapeutic option for each patient must be decided[1 2] by a multidisciplinary 'Heart Team'.

Many authors have investigated large national registries and analysed the changes of both techniques over time and the distribution of CABG and PCI across different regions and countries.[3–6] Spain is, according to the Organisation for Economic Co-operation and Development (OECD),[6] one of

the European countries with the lowest rates of revascularisation and the one with the highest ratio of PCI to CABG. The causes of the magnitude of this disbalance have never been studied in depth. Moreover, there is no robust evidence on the evolution of the two techniques in terms of their results and variability, nor the risk profile of patients with CABG and PCI in the Spanish National Health System (NHS).

In Spain, there are no patient-level clinical registries specifically dedicated to patients with coronary artery disease undergoing myocardial revascularisation. The Spanish Society of Thoracic and Cardiovascular Surgery and the Spanish Society of Cardiology annually report the national volumes and outcomes of CABG and PCI.[7 8] However, these reports are based on voluntary, aggregated and unaudited information submitted by hospitals. On the other hand, the healthcare centres of the Spanish NHS have to report the administrative information of all admitted patients to a mandatory nationwide registry: The minimum basic data set (MBDS) from the Department of Health. The MBDS is a public open access database which stores individual and anonymised data from all discharge reports from all the NHS episodes, coded according to the International Classification of Diseases (ICD). Despite the fact that the use of non-specific administrative sources, such as this one, for the analysis of clinical indicators in the field of cardiology is controversial,[9] different studies based on the MBDS have validated its usefulness to analyse the results of clinical processes in Spain.[10–14]

We set out to study the evolution of CABG and PCI in Spain between 1998 and 2017 with the information obtained from the MBDS from the Department of Health of Spain. Specifically, we analysed the volume of CABG and PCI, the changes in the risk profile of patients and hospital mortality in the two revascularisation strategies. It was not the objective of this study to compare the results of both techniques, taking into account that they have different indications and that follow-up information is not available.

MATERIALS AND METHODS
Sources of information and patient selection
Data were obtained from the MBDS from the Department of Health of Spain. This research was carried out according to the STROBE (Strengthening the Reporting of OBservational studies in Epidemiology) recommendations.

The patient selection algorithm can be seen in figure 1. We investigated all the outpatient or hospitalisation episodes of the Spanish NHS from 1998 to 2017 in which a CABG or PCI procedure had been carried out. Those episodes during which patients underwent concomitant procedures were excluded (see online supplemental table 1 ICD-9 and ICD-10 codes).

Likewise, all episodes with an acute myocardial infarction/acute coronary syndrome with ST-segment elevation as the primary diagnosis on admission (see online
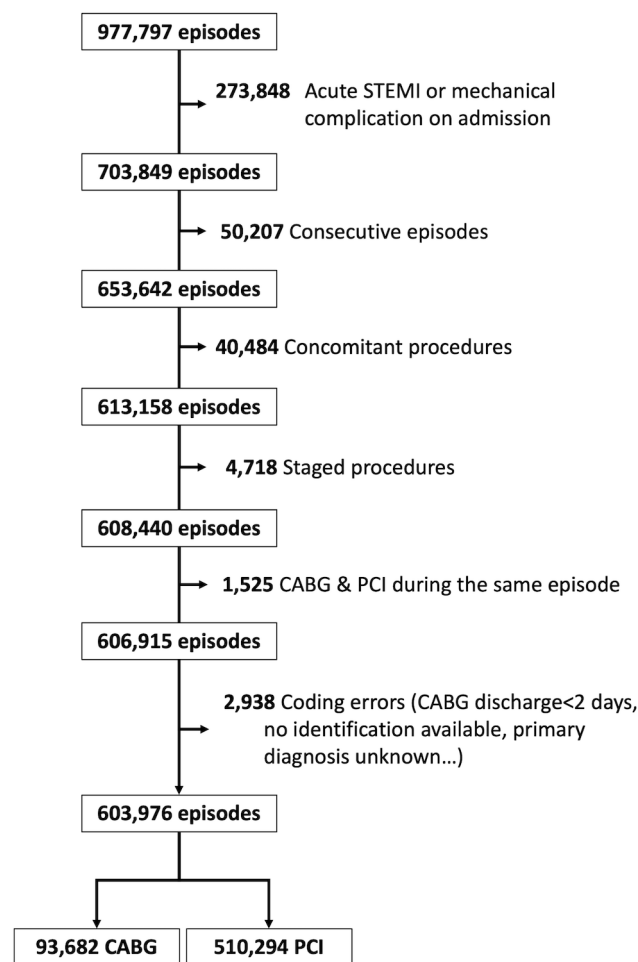

Figure 1 Flow diagram. Selection of episodes. CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention.

supplemental table 1) were excluded, as those with both types of revascularisation. In addition, to avoid possible coding errors, patients younger than 18 years of age or older than 100 years of age, patients operated on CABG in centres without CABG or who underwent PCI in centres without PCI were also discarded. Patients discharged alive earlier than 2 days after CABG were also considered as coding errors. The episodes corresponding to patients who were transferred to another centre and consecutive planned revascularisations episodes were consolidated into a single episode.[14] Each episode corresponds to a single patient, but a patient might have more than one episode. Given that we analysed in-hospital outcomes, different consolidated episodes will be considered as different patients for the purpose of this study.

The full period of time (1998–2017) was divided in four 5-year intervals (1998–2002, 2003–2007, 2008–2012 and 2013–2017).

Patient and public involvement
No patient was actively involved in the study. Information regarding the delivered healthcare to the patients included in this investigation was obtained de-identified from the Spanish Department of Health

National volume of revascularisation procedures and risk profile of the patients

We investigated the absolute number of CABG and PCI per year, the number of procedures per million of inhabitants and the changes in the PCI/CABG ratio. Further analyses to investigate the trends in the indexed volume of each type of procedure were also performed according to sex and age. To estimate the nationwide population, data were extracted from the National Institute of Statistics.[15]

Healthcare centres were classified according to the volume of procedures per year. Thus, for both CABG and PCI, hospitals were divided into four groups according to the quartile of the volume of PCI or CABG interventions that they performed in each year: low volume (quartile 1), low–intermediate volume (quartile 2), high–intermediate volume (quartile 3) and high volume (quartile 4).

Patients were classified into four groups according to their age (≤60, >60 and ≤70, >70 and ≤80 and >80-year-old). We analysed the evolution of the prevalence of various comorbidities age-modified Charlson's index was calculated.[16 17] In addition, the individual components of this score (previous history of myocardial infarction, kidney disease, diabetes and so on) and other procedural variables were analysed throughout the study period (see table 1).

Mortality

We analysed in-hospital non-adjusted and adjusted mortality for PCI and CABG and its changes over the study period.

Statistical analysis

Categorical variables were represented with absolute and relative frequencies (%) and were compared with the χ^2 test. The normality of the quantitative variables was analysed with P–P plots, and they were expressed with mean and SD or median and IQR. Imputation was not made for missing values. Statistics were estimated using available data. Quantitative variables were compared among the periods of the study with an analysis of variance or non-parametric comparison of medians. Contrasts were performed to investigate the presence of a linear trends (LT). The relative risk reduction (RRR) and OR were used to represent the strength of association between different variables and mortality.

We investigated factors associated to mortality for each type of revascularisation. For this purpose, we created multivariable models including variables with theoretical value and variables related to mortality (statistical significance p<0.1) in an univariable analysis. The best models were selected based on the value of the Akaike information criterion, adjusted R^2 and their area under the curve.

Subsequently, we estimated two new models to predict mortality after PCI and CABG, respectively, excluding the time period. We divided the observed mortality in each year for PCI and CABG by that expected according to the corresponding model. In this way, we analysed the evolution of risk-adjusted mortality rate (RAMR) over time.[14]

Statistical analysis was performed with Stata V.15.0 (StataCorp, College Station, Texas, USA).

RESULTS

Study population

Almost one million (977 797) episodes of CABG or PCI were included in the study. Thirty-eight per cent (373 831) were excluded, and 603 967 were considered for the purpose of this study (see figure 1 and online supplemental figure 1 and table 2). Of these, 93 682 (15.5%) had CABG and 510 294 (84.5%) had PCI. There was a linear increase (p_{LT}<0.001) in the PCI/CABG ratio: 1998–2002: 2.2 (69% PCI vs 31% CABG), 2003–2007: 5 (83.3% PCI vs 16.7% CABG), 2008–2012: 7.6 (88.3% PCI vs 11.7% CABG) and 2013–2017: 8.1 (89% PCI vs 11% CABG) (table 1). In the general sample, an increase in the number of revascularisations was observed, mainly due to a higher number of PCI and a drop in CABG (figure 2A). We observe relevant differences in the volume of procedures by sex. Overall, more PCI and CABG were performed in men than in women, but the difference increased more markedly in PCI (figure 2B). Regarding the type of procedure by age range, PCI increased in all age ranges, although the increase was more pronounced in those over 60 years of age. On the contrary, CABG significantly decreased among those between 60 and 80 years of age and experienced a slight decrease in the the youngest population group (figure 3). Absolute number of procedures and according to type of coronary syndrome is shown in online supplemental figures 2 and 3.

The risk profile of patients worsened throughout the study period (table 1). In PCI and CABG groups, we observed a higher mean age and a greater prevalence of risk factors such as previous myocardial infarction, heart failure, peripheral vascular disease, diabetes or chronic obstructive pulmonary disease (COPD). Consequently, Charlson's index rose up from 2.7 to 3.5 (p_{LT}<0.001) in CABG and from 2.6 to 3.6 (p_{LT}<0.001) in PCI (table 1 and online supplemental figure 4).

We detected a significant growth of PCI in centres without CABG: 1998–2002 (17.4%) and 2013–2017 (41.1%) (p_{LT}<0.001). The proportion of patients who had three or more coronary arteries revascularised was higher in the CABG group (40.5% vs 7.1%, p<0.001). We observed a linear increase in the use of bilateral internal thoracic arteries (8% vs 23.6%, p_{LT}<0.001), and off-pump CABG (31.3% vs 34.2%, p_{LT}<0.001) from the first to the last period. Similarly, an increase in drug eluting stents and a decrease of bare metal stents was observed among patients with PCI (p_{LT}<0.001). The number of outpatient percutaneous procedures was small but increased in the last two periods (see table 1). The proportion of patients with previous

Table 1 Baseline and procedural characteristics of percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG)

	CABG					PCI					Total		
	1998–2002	2003–2007	2008–2012	2013–2017	p value(LT)	1998–2002	2003–2007	2008–2012	2013–2017	p(TL)	CABG	PCI	p
n (%)*	27141 (31)	24521 (16.7)	21584 (11.7)	20436 (11)	<0.001	60440 (69)	122310 (83.3)	162846 (88.3)	164698 (89)	<0.001	93682 (15.5)	5102294 (84.5)	<0.001
Age (years)	64.9±9.5	66±9.7	66.1±10	66.3±9.7	<0.001	64±11	65.9±11.1	67±11.5	67.6±11.6	<0.001	65.8±9.7	66.6±11.5	<0.001
Age (ranges)					<0.001†					<0.001†			<0.001†
≤60	7634 (28.1)	6498 (26.5)	5797 (26.8)	5360 (26.2)	<0.001	20883 (34.6)	36802 (30.1)	45210 (27.8)	44779 (27.2)	<0.001	25285 (27)	147674 (28.9)	<0.001
60–70	10292 (37.9)	8073 (32.9)	7209 (33.4)	7230 (35.4)	<0.001	19442 (32.2)	34783 (28.4)	451752 (27.7)	45878 (27.9)	<0.001	32805 (35)	145275 (28.5)	<0.001
70–80	8684 (32)	9077 (37)	7436 (34.4)	6579 (32.2)	<0.001	17406 (28.8)	40393 (33)	51357 (31.5)	46378 (28.8)	<0.001	31776 (33.9)	156540 (30.7)	<0.001
>80	531 (2)	873 (3.6)	1147 (5.3)	1267 (6.2)	<0.001	2711 (4.5)	10338 (8.5)	21096 (13)	26647 (16.2)	<0.001	3818 (4.1)	60794 (11.9)	<0.001
Female sex	5379 (19.8)	4768 (19.5)	3776 (17.5)	3353 (16.4)	<0.001	13191 (21.8)	29700 (24.3)	39773 (24.4)	39387 (23.9)	<0.001	17276 (18.4)	122046 (23.9)	<0.001
High blood pressure	12264 (45.2)	14540 (59.3)	14166 (65.6)	13896 (68)	<0.001	26005 (43)	68897 (56.3)	100802 (61.8)	103762 (63.1)	<0.001	54866 (58.6)	299466 (58.7)	0.05
Previous MI‡	3471 (12.8)	3944 (16.1)	3328 (15.4)	4132 (20.2)	<0.001	11383 (18.8)	29608 (24.2)	4669 (28.7)	58465 (35.5)	<0.001	14875 (15.9)	146150 (28.6)	<0.001
NSTEACS	8189 (30.2)	6085 (24.8)	4538 (21)	4236 (20.7)	<0.001	25495 (42.2)	44821 (36.6)	53322 (32.7)	54260 (33)	<0.001	23048 (24.6)	177898 (34.9)	<0.001
CHF‡	1498 (5.5)	1737 (7.1)	2101 (9.7)	2111 (10.3)	<0.001	2745 (4.5)	9475 (7.8)	17662 (10.9)	21218 (12.9)	<0.001	7447 (8)	51100 (10)	<0.001
PVD‡	1750 (6.5)	2240 (9.1)	2238 (10.4)	2182 (10.7)	<0.001	4431 (7.3)	10380 (8.5)	12581 (7.7)	12754 (7.7)	<0.001	8410 (9)	40146 (7.7)	<0.001
CVD‡	745 (2.7)	1122 (4.6)	1221 (5.7)	1361 (6.7)	<0.001	897 (1.5)	2566 (2.1)	4410 (2.7)	4911 (3)	<0.001	4449 (4.8)	12784 (2.5)	<0.001
Diabetes‡	7493 (27.6)	8799 (35.9)	8509 (39.4)	8804 (43.1)	<0.001	13131 (21.7)	37880 (31)	55245 (33.9)	57511 (34.9)	<0.001	33605 (35.9)	163767 (32.1)	<0.001
CKD‡	423 (1.6)	701 (2.9)	1441 (6.7)	1952 (9.6)	<0.001	1066 (1.8)	3689 (3)	12165 (7.5)	16094 (9.8)	<0.001	4517 (4.8)	33014 (6.5)	<0.001
COPD‡	959 (3.5)	1396 (5.7)	1322 (6.1)	1518 (7.4)	<0.001	2241 (3.7)	6276 (5.1)	10268 (6.3)	12677 (7.7)	<0.001	5195 (5.6)	31462 (6.2)	<0.001
Liver failure‡	241 (0.9)	331 (1.4)	410 (1.9)	560 (2.7)	<0.001	460 (0.8)	1392 (1.1)	2497 (1.5)	3496 (2.2)	<0.001	1541 (1.6)	8046 (1.6)	0.11
Charlson's index	2.7 (1.4)	3.1 (1.5)	3.3 (1.7)	3.5 (1.8)	<0.001	2.6 (1.5)	3 (1.7)	3.4 (1.9)	3.6 (2)	<0.001	3.1 (1.6)	3.3 (1.9)	<0.001
Previous CABG	1101 (4.1)	1085 (4.4)	146 (0.7)	146 (0.7)	<0.001	1727 (2.9)	3374 (2.8)	4359 (2.7)	5417 (3.3)	<0.001	2475 (2.6)	14877 (2.9)	<0.001
Previous PCI	1573 (5.8)	1990 (8.1)	2704 (12.5)	3204 (15.7)	<0.001	8163 (13.5)	23004 (18.8)	40898 (25.1)	47890 (29.1)	<0.001	9470 (10.1)	119955 (23.5)	<0.001
Hospital without CABG on-site						10151 (17.4)	36425 (30.7)	64882 (40.9)	65260 (40.9)	<0.001		173718 (35.7)	

Continued

Table 1 Continued

	CABG					PCI					Total		
	1998–2002	2003–2007	2008–2012	2013–2017	$p_{(LT)}$ value	1998–2002	2003–2007	2008–2012	2013–2017	$p_{(TL)}$	CABG	PCI	p
Revascularisation 3+ vessels	11326 (41.7)	9206 (37.5)	7947 (36.8)	7357 (36)	<0.001	–	–	–	–	<0.001	32849 (40.5)	23106/327528 (7.1)	<0.001
Outpatient PCI						–	1371 (1.1)	7200 (4.4)	6358 (3.9)	<0.001		14933/449843 (3.3)	
BMS						60107 (99.5)	91516 (74.8)	67018 (41.2)	34090 (20.7)	<0.001		252731 (49.5)	<0.001
DES							34873 (28.5)	89198 (54.8)	115643 (70.2)	<0.001		239714/449843 (53.3)	<0.001
IVUS						–	1037 (0.9)	6104 (3.8)	4517 (2.7)	<0.001		11658/449843 (2.6)	<0.001
ITA	19643 (72.3)	21635 (88.2)	19646 (90.9)	19928 (96.9)	<0.001	–	–	–	–	–	80852 (86.1)	–	–
Bilateral ITA	2168 (8)	3218 (13.1)	3454 (16)	4816 (23.6)	<0.001	–	–	–	–	–	13654 (14.6)	–	–
Off-pump CABG	8496 (31.3)	8708 (35.5)	7178 (33.3)	6984 (34.2)	<0.001	–	–	–	–	–	31365 (33.5)	–	–
Hospital volume					<0.001†					<0.001†			<0.001
Low	3868 (15.1)	3053 (12.6)	2404 (11.2)	2080 (10.2)	<0.001	3259 (5.6)	6004 (5.1)	7612 (4.8)	8002 (5)	<0.001	11405 (12.4)	24877 (5)	<0.001
Low-intermediate	5511 (21.5)	4671 (19.3)	4272 (19.9)	3901 (19.1)	<0.001	8150 (14)	17226 (14.5)	21447 (13.5)	23155 (14.2)	<0.001	18255 (20)	69988 (14.1)	<0.001
Intermediate–high	7149 (27.8)	6984 (28.8)	6446 (30)	5693 (27.9)	<0.001	15949 (27.4)	33545 (28.3)	45083 (28.5)	47527 (29.7)	<0.001	26272 (28.6)	142104 (28.7)	0.128
High	9156 (35.7)	9524 (39.3)	8377 (39)	8708 (42.7)	<0.001	30870 (53)	61902 (52.2)	84335 (53.2)	80730 (51)	<0.001	35765 (40)	257837 (52.1)	<0.001

Data are expressed with n (%) or mean SD. $P_{(LT)}$ contrast test for linear trend.
*Number of CABG or PCI divided by the volume of revascularisations.
†No contrast for linear trend.
‡According to Charlson's index definition.[16 17]
BMS, bare metal stent; ; CHF, congestive heart failure; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease; DES, drug eluting stent; ITA, internal thoracic artery; IVUS, IntraVascular UltraSound; MI, myocardial infarction; NSTEACS, non-ST elevation acute coronary syndrome; PVD, peripheral vascular disease.
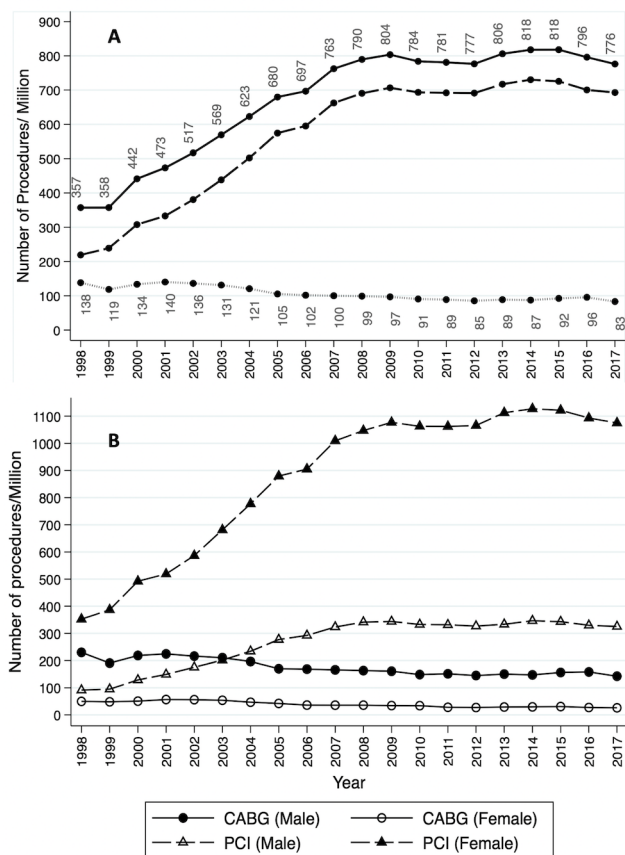
Figure 2 Number of procedures per million inhabitants and year. (A) Volume of procedures per year. Number of total revascularisations and CABG are shown. (B) Number of procedures by sex and per million inhabitants. The number of procedures of each type is represented by sex and per million inhabitants of each sex throughout the study period. CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention.

revascularisation increased linearly throughout the study: (1998–2002: 13.9%; 2003–2007: 19.4%; 2008–2012: 25.3%; 2013–2017: 29.4%; p_{LT}<0.001). Most of this increase was due to a growth of revascularised patients with previous PCI, while the number of patients undergoing CABG or PCI with a history of previous surgery decreased or increased minimally, respectively (table 1 and online supplemental figure 5).

We observed a growth of episodes of patients with diabetes and an increase of percutaneous procedures in this subset. Specific information on patients with diabetes can be found in online supplemental table 3.

Mortality

Among patients undergoing CABG, a reduction in non-adjusted in-hospital mortality was observed between 1998 and 2017: 6.5% vs 2.6% (p_{LT}<0.001; RRR −60%, 95% CI −64.8% to −55.2%). Mortality among patients undergoing PCI raised slightly from 1.2% to 1.5% (p_{LT}<0.001; RRR +25%, 95% CI 22.3% to 27.6%) (figure 4A).
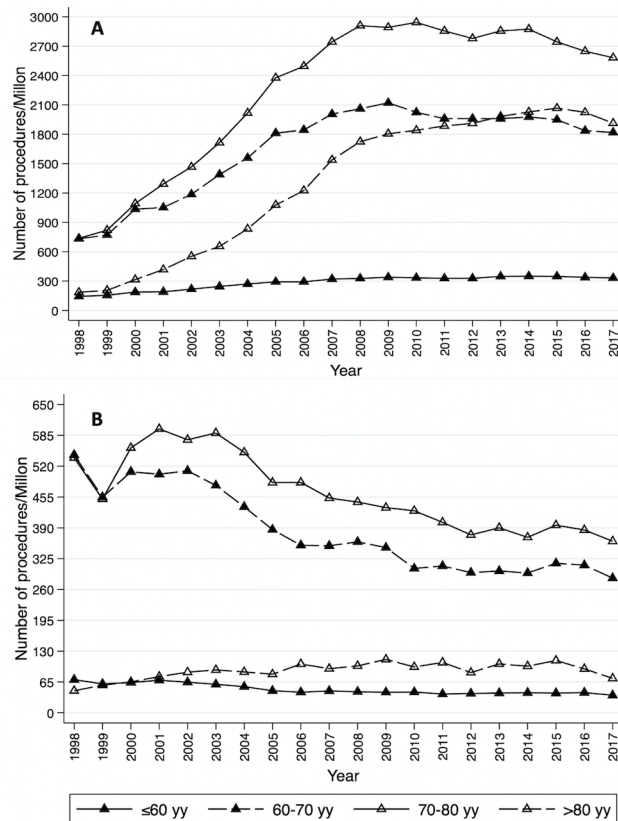

Figure 3 Number of procedures per million inhabitants and year in age ranges. (A) Percutaneous coronary intervention. (B) Coronary artery bypass grafting.

Table 2 shows factors independently associated to in-hospital mortality after CABG or PCI. Most of the factors increased mortality regardless of the type of revascularisation (COPD, age, previous infarction, heart failure and so on). The effect of some variables changed depending on the type of revascularisation such as the hospital volume of procedures and period of study. PCI mortality in centres without CABG was lower than in centres with CABG on-site (OR 0.86, 95% CI 0.8 to 0.92, p<0.001) (more information can be found in online supplemental material).

Information regarding the estimation of RAMR is shown in online supplemental tables 4 and 5. A decrease in RAMR was detected in patients with both CABG and PCI. In the case of coronary surgery, the RAMR decreased from 1.51 to 0.48 (p_{LT}<0.001), and in the case of PCI from 1.42 to 1.05 (p_{LT}<0.001) between 1998 and 2017, respectively (see figure 4B).

Volume of activity and mortality by centre

The number of centres with CABG and PCI on-site grew from 37 (1998–2002) to 48 (2013–2017) (p_{LT}<0.001) (online supplemental table 6 and figure 6). The number of centres with PCI but without CABG on-site increased from 25 (1998) to 96 (2017). We observed a higher median volume of PCI per centre from 136 to 232 (p_{LT}<0.001) and a decrease in CABG from 137 to 74 (p_{LT}<0.001) between 1998 and 2017 (online supplemental material). The
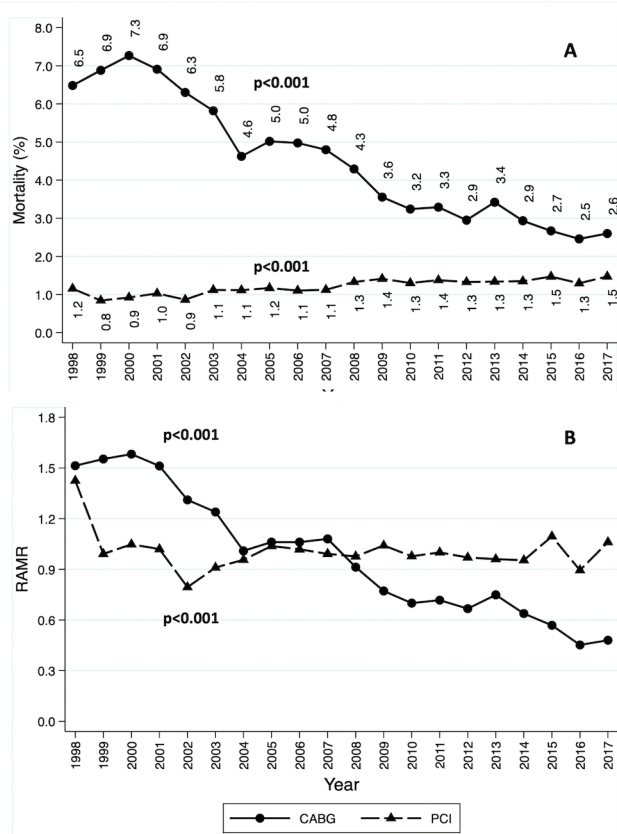
Figure 4 Non-adjusted and adjusted in-hospital mortality. CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention; RAMR, risk-adjusted mortality rate.

volume of interventions was independently associated to a lower in-hospital mortality for CABG and a higher mortality after PCI (see table 2).

DISCUSSION

Between 1998 and 2017, in Spain, the volume of revascularisations in patients without ST-elevation myocardial infarction increased to 776 per million inhabitants (see figure 2). However, these rates are very low as compared with other countries. For example, in the USA, the number of CABG per million inhabitants in 2007–2008 was 1081 per year, while that of PCI was 3667 per year.[18] In Germany, in 2013, the proportion of revascularisations per 100 000 inhabitants was three times higher than in Spain.[6] Although the differences can be explained by the lower prevalence of coronary heart disease in Spain, there are other factors that may influence such as a greater difficulty in accessing the healthcare system for patients or a less frequent indication for revascularisation.

In addition, there was, over the past 20 years, a 27.7% reduction in the volume of CABG (5506 in 1998 vs 3872 in 2017) and a 3.7-fold increase of PCI volume (8735 in 1998 vs 32 272 in 2017). During such a long period of time, the indications for CABG and PCI have varied, mainly in patients with stable one-vessel or two-vessel coronary artery disease, with percutaneous revascularisation being the most

frequently indicated nowadays. In patients with left main or three-vessel disease, the indication for PCI has also gained strength, although with less intensity. These changes have been mainly due to the development of new percutaneous devices and the optimisation of medical treatment.[1 19] Even so, different studies have consistently continued to detect the benefit of CABG in patients with more complex coronary disease.[2 20]

The PCI/CABG ratio in the last period of the study was 8.1. In the 2016 'Health at a Glance' report, the PCI/CABG ratio was 7.3 in Spain, close to that observed in this study and more than double the average of the countries included in that report: 3.55.[6] Similar changes have happened in other countries. For example, the analysis of the US National Inpatient Sample registry found a decline in the volume of CABG of 116% between 1998 and 2015[21] and 14% between 2001 and 2007 with a stabilisation of the volume of PCI.[18] The New York State registry detected an increase in the PCI/CABG ratio between 1994 and 2008 from 1.12 to 5.14.[5] The ratio observed in the present study, however, is difficult to compare since we have excluded revascularisations among patients with acute myocardial infarction which were considered in other reports.[6] Therefore, the PCI to CABG ratio in Spain might be even higher. This large difference in Spain may be due to several factors such as difficulties in accessing one of the therapies, poor adherence to therapeutic recommendations, underindication of revascularisation or the characteristics of coronary heart disease in the Spanish population being different from those in other developed countries. Furthermore, we detected large and increasing differences between men and women depending on the type of revascularisation (see figure 2), which probably denotes a limited access of women to the healthcare system.

A significant worsening of the risk profile has been observed for patients with both PCI and CABG: 14% raise in the prevalence of diabetes, sixfold increase of patients with severe chronic kidney disease or COPD by 2 (see table 1). In general, the poorer risk profile of patients is consistent with a progressive ageing and a higher prevalence and severity of cardiovascular risk factors observed in Spain and other countries.[22–24] Despite the conflicting evidence on the benefit of off-pump CABG or multiple arterial grafts revascularisation, in Spain there has been an increase in the number of patients operated on with two or more internal thoracic arterial grafts (8% in the first period vs 23.6% between 2013 and 2017 (p_{LT}<0.001)) or off pump (31.3% vs 34.2% in the first and last period, respectively, p_{LT}<0.001).[25 26] Regarding PCI, revascularisations with drug eluting stents grew as bare metal stents became less frequently used.

The increase in the proportion of patients requiring a new revascularisation increased throughout the study (see table 1 and online supplemental material). This increase was more notable in PCI and, above all, at the expense of a previous percutaneous revascularisation. This finding is consistent with the sustained increase in revascularisations over time, the lower need for re-intervention after

Table 2 Factors associated to in-hospital mortality

CABG			PCI		
Variable	OR (95% CI)	P value	Variable	OR (95% CI)	P value
Region of Spain	Not shown	<0.001	Region of Spain	Not shown	<0.001
Hospital volume of CABG (as compared with low volume centres)			Hospital volume of PCI (as compared with low volume centres)		
Low–intermediate	0.86 (0.77 to 0.95)	0.004	Low–intermediate	1.4 (1.18 to 1.68)	<0.001
Intermediate–high	0.81 (0.73 to 0.9)	<0.001	Intermediate–high	2.05 (1.67 to 2.36)	<0.001
High	0.77 (0.68 to 0.86)	<0.001	High	2.05 (1.73 to 2.42)	<0.001
COPD	1.35 (1.2 to 1.53)	<0.001	COPD	1.25 (1.15 to 1.35)	<0.001
Age (as compared with <60)			Age (as compared with <60)		
60–70	1.72 (1.55 to 1.91)	<0.001	60–70	1.69 (1.54 to 1.85)	<0.001
70–80	3.02 (2.73 to 3.33)	<0.001	70–80	2.6 (3.38 to 2.84)	<0.001
>80	5.07 (4.38 to 5.88)	<0.001	>80	3.58 (3.26 to 3.93)	<0.001
Female sex	1.14 (1.06 to 1.23)	0.001	Female sex	1.09 (1.03 to 1.15)	0.004
Previous MI	2.81 (2.62 to 3.01)	<0.001	Previous MI	2.62 (2.49 to 2.76)	<0.001
NSTEACS as primary diagnosis	1.2 (1.12 to 1.28)	<0.001			
CHF	3.21 (2.96 to 3.49)	<0.001	CHF	4.63 (4.39 to 4.9)	<0.001
PVD	1.43 (1.29 to 1.57)	<0.001	PVD	1.24 (1.15 to 1.34)	<0.001
CVD	1.72 (1.52 to 1.94)	<0.001	CVD	2.29 (2.08 to 2.52)	<0.001
CKD	1.75 (1.55 to 1.99)	<0.001	CKD	1.56 (1.45 to 1.67)	<0.001
On-pump CABG	1.09 (1.02 to 1.17)	0.017			
Bilateral ITA	0.8 (0.71 to 0.89)	0.042			
Period of study (as compared with 1997–2002)			Period of study (as compared with 1997–2002)		
2003–2007	0.66 (0.61 to 0.72)	<0.001	2003–2007	1.09 (0.99 to 1.21)	0.09
2008–2012	0.41 (0.38 to 0.46)	<0.001	2008–2012	1.18 (1.06 to 1.31)	0.002
2013–2017	0.29 (0.26 to 0.32)	<0.001	2013–2017	1.18 (1.06 to 1.32)	0.002
			Hospital without CABG on-site	0.86 (0.8 to 0.92)	<0.001
			Diabetes	1.58 (1.45 to 1.67)	<0.001
			BMS	0.86 (0.79 to 0.94)	<0.001
			DES	0.41 (0.38 to 0.45)	0.001

BMS, bare metal stent; CABG, coronary artery bypass grafting; CHF, congestive heart failure; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease; DES, drug eluting stent; ; ITA, internal thoracic artery; MI, myocardial infarction; NSTEACS, non-ST elevation acute coronary syndrome; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease.

CABG and the preference for percutaneous approaches in the global series[1 2 6 8 19 20] (table 1 and online supplemental figure 5).

Mortality after CABG in Spain has decreased from 6.5% in 1998 to 2.6% in 2017 and is now similar to that of other countries.[22] The strong reduction of mortality is a common finding too: for example, the registry for New South Wales detected a reduction of in-hospital mortality after CABG of 30% between 2000 and 2013.[27] A significant fourfold reduction in risk-adjusted mortality was observed too between 1998 and 2017 (0.44) (1.55 to 0.44 (p_{LT}<0.001)).

Hospital mortality after PCI in Spain was similar to that of other developed countries,[28 29] and slightly grew throughout the series. When adjusting for patient comorbidities and other confounding factors, the RAMR was reduced by almost 40% (1.42 to 1.05 (p_{LT}<0.001)).

We have detected a fourfold growth of the number of centres that perform PCI without CABG on site (see online supplemental table 6). Between 2013 and 2017, 41.1% of the patients treated with PCI were revascularised in a centre without coronary surgery. In addition, there has been a very significant reduction in the median number of CABG procedures per centre between the first and last period of the study (130.5 vs 75.5, p_{LT}<0.001). This volume of interventions per centre is different from that reported by Goicolea et al[14] who detected a mean number of CABG procedures of 95 per year between 2013 and 2015. Goicolea et al misclassified procedures such as combined surgery of the aorta, pericardium, ventricular remodelling or cardiac arrhythmias as isolated coronary surgery interventions, which can explain the differences. In any case, the volume of CABG or PCI per centre in Spain is very low. For example, in Europe, hospitals with

an intermediate volume of CABG perform between 125 and 450 procedures per year[30] and the EACTS/ESC Myocardial Revascularisation Guidelines recommend a minimum of 200 isolated CABG interventions to maintain viable coronary surgery programmes.[1]

There is an important relationship between the volume of CABG per centre and in-hospital mortality, such that as the volume of the centres increases, mortality decreases. On the contrary, mortality after PCI increases as the volume of interventions increases (table 2 and online supplemental material). The latter can be explained by the fact that patients referred to centres with greater activity may have anatomical characteristics or comorbidities that confer a greater risk, and which have not been adequately contemplated in this study (ie, left main disease, severely calcified coronary arteries, poor left ventricular function and so on).

Conclusions

From 1998 to 2017 there has been a significant increase in the volume of revascularisations in Spain. This growth has been uneven, with more PCI and a gradual reduction in CABG. Risk-adjusted mortality has been significantly reduced in both arms, although the reduction has been particularly pronounced among surgically revascularised patients. Finally, in Spain, there is not an adequate balance between the volume of revascularisations and the number of hospitals, with centres with a low number of CABG procedures and a great proportion of hospitals with PCI programmes but without CABG on-site.

Limitations

These conclusions have to be taken with caution due to possible coding biases and others inherent to administrative databases analyses. Beyond a real change, the variation in the prevalence of comorbidities can be also partially explained by changes and errors in coding throughout the study period. Surgical turndowns are known to have higher risk despite risk adjustment, but they could not be identified in this data set. We could not estimate operative or cardiovascular risks according to validated clinical scores in cardiac surgery or cardiology (such as EuroSCORE, Framingham Risk Score or NCDR CathPCI Mortality risk) given that the items of these scores are not available in the MBDS. The MBDS does not contain information on private activity in Spain.

Author affiliations

[1]Cardiac Surgery, Hospital Clínico Universitario San Carlos Instituto Cardiovascular, Madrid, Comunidad de Madrid, Spain
[2]Cardiac Surgery, Hospital Universitario Central de Asturias, Oviedo, Asturias, Spain
[3]Cardiology, Unit of Interventional Cardiology, Hospital del Mar, Barcelona, Catalunya, Spain
[4]Cardiac Surgery, Hospital Ramon y Cajal, Madrid, Spain
[5]Cardiac Surgery, Alvaro Cunqueiro Hospital, Vigo, Galicia, Spain
[6]Cardiac Surgery, Hospital Universitario del Vinalopó, Elche, Alicante, Spain
[7]Cardiac Surgery, Hospital General Universitario Gregorio Marañón, Madrid, Spain
[8]Internal Medicine, Hospital Clinico Universitario San Carlos, Madrid, Spain
[9]Cadiac Surgery, Puerta del Hierro University Hospital of Majadahonda, Majadahonda, Madrid, Spain
[10]Cardiology, Unit of Interventional Cardiology, Hospital Universitario Central de Asturias, Oviedo, Asturias, Spain

Twitter Manuel Carnero Alcazar @manuel_carnero

ORCID iDs
Manuel Carnero Alcazar http://orcid.org/0000-0001-5045-5765
Daniel Hernandez-Vaquero http://orcid.org/0000-0003-3518-6629

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