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Article Summary

Abstract

Introduction. Spain is one of the countries with the lowest rates of revascularization and highest percutaneous coronary intervention (PCI) to coronary artery bypass grafting (CABG) rates.
Objectives. To investigate the changes and trends in the two revascularization procedures between 1998 and 2017 in our country.
Design. Retrospective cohort study. Analysis of in-hospital outcomes.
Setting. Large mandatory database from the Spanish National Department of Health collecting information of patients who are attended in Spanish public National Health System.
Participants. 596,810 patients who underwent isolated CABG or PCI in the Spanish National Health System. The study period was divided in 4 5-year intervals. Patients with acute myocardial infarction were excluded.
Primary and Secondary Outcomes: We investigated the volume of procedures nationwide, the changes in the risk profile of patients and in-hospital mortality of both techniques.
Results. We observed a 3-fold increase in the number of patients undergoing any type of myocardial revascularization: 14241(1998) to 39759(2017). 93,677 (15.7%) had a coronary surgery. PCI to CABG ratio rose from 2.2 (1998-2002) to 7.7 (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 209, while the volume of CABG was reduced from 137 to 72. 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 1.6%, p<0.001. Risk adjusted mortality rate was reduced for both CABG (1.55 Vs 0.44, p<0.001), and PCI (1.72 Vs. 0.85, p<0.001).
Conclusion. We detected a significant increase in the volume of revascularizations (particularly PCI) in Spain. Risk-adjusted in-hospital mortality has been significantly reduced

Strengths and limitations.

- This is the first study to investigate the nationwide changes and trends in coronary revascularization 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 NHS hospital between 1998-2017.
- Follow up information is not available
- The analysis might be biased by administrative information coding errors.
- However, no other source of information allows to perform a long-term nationwide investigation like this.

INTRODUCTION

Surgical and percutaneous myocardial revascularization 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 syndrome, the choice between PCI and coronary surgery 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 analyzed 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 OECD(6), one of the European countries with the lowest revascularization rates and the one with the highest ratio of PCI to CABG among patients with coronary artery disease. 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, and the risk profile of CABG and PCI patients in the Spanish National Health System (NHS).

In our country, there are no patient-level clinical registries specifically dedicated to patients with coronary artery disease undergoing myocardial revascularization. The Spanish Society of Thoracic and Cardiovascular Surgery and the Spanish Society of Cardiology annually report the volume and outcomes of CABG and PCI in Spain(7,8). However, these reports are based on voluntary, aggregated and unaudited information submitted by hospitals. On the other hand, the healthcare centers of the Spanish NHS have to report the administrative information of all admitted patients to a mandatory nationwide registry: The Minimum Basic Dataset (MBDS) from the Department of Health. The MBDS stores individual and anonymized data from all discharge reports from all the NHS episodes, coded according to the International Classification of Diseases (ICD) in its 9th and 10th edition. 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 analyze 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 of the Department of Health of our country. Specifically, we analyzed the volume of CABG and PCI, the changes in the risk profile of patients and hospital mortality in the two revascularization 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 was 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. This study was approved by the Institutional Review Board and Ethics Committee at Hospital Clínico San Carlos (Madrid,Spain).

The patient selection algorithm can be seen in Figure 1. We investigated all the outpatient or hospitalization episodes of the Spanish NHS from 1998 to 2017 in which a CABG or PCI procedure had been carried out. Those patients undergoing concomitant procedures were excluded (See supplemental Table 1 ICD9 and ICD10 codes).

Likewise, all episodes with an acute myocardial infarction/acute coronary syndrome with ST segment elevation as the primary diagnosis (See supplemental Table 1) were excluded, as those who received both types of revascularization in the same episode. In addition, to avoid possible coding errors, patients younger than 18 or older than 100-year-old, patients operated on CABG in centers without CABG or who underwent PCI in centers without PCI were also discarded. Patients discharged alive earlier than two days after the procedure were also considered as coding errors. The episodes corresponding to patients who were transferred to another center and consecutive planned revascularization episodes were consolidated into a single episode(14). 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 deidentified from the Spanish Department of Health

National volume of revascularization 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. To estimate the nationwide population, data was extracted from the National Institute of Statistics(15).

Healthcare centers 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 & ≤70,>70 & ≤80, and >80-year-old). We analyzed the evolution of the prevalence of various comorbidities (see Table 1). Age-modified Charlson´s Index was calculated (16,17). In addition, the individual components of this score (myocardial infarction, kidney disease, diabetes, ...) and other procedural variables were analyzed throughout the study period.

Mortality

We analyzed 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 chi-squared test. The normality of the quantitative variables was analyzed with PP- plots, and they were expressed with mean and standard deviation or median and interquartile range. 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 odds ratio (OR) were used to represent the strength of association between different variables and mortality.

We investigated factors associated to mortality for each type of revascularization. For this purpose, we created multivariate models including variables with theoretical value and variables related to mortality (statistical significance $p<0.1$) in an univariate analysis. The best models were selected based on the value of the Akaike information criterion, R^2 and their area under the curve. Using the mortality risk estimated by these models, we calculated the risk- adjusted mortality rate (RAMR) by dividing the observed and expected mortality (14).

Statistical analysis was performed with Stata v 15.0 (StataCorp. 2017. Stata Statistical Software:Release 15.College Station,TX: StataCorp LLC.)

RESULTS

Study Population

Almost one million (977,797) patients underwent CABG or PCI in the study period. Thirty nine percent (381,167) were excluded and 596,810 patients were considered for the purpose of this study. Of these, 93,677(15.7%) had CABG and 503,133(84.3%) PCI. There was a linear increase (p_{TL}<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 2013-2017:7.7(88.5% PCI Vs. 11.5% CABG) (Table 1). In the global series, an increase in the number of revascularizations was observed with an increase in the number of PCI and a reduction in the number of CABG (Figure 2). Given the national population in Spain, in 1998, 357 revascularizations per million inhabitants were carried out, while in 2017 it was 855. In the same interval, the number of CABG per million decreased from 138 to 102, and the number of PCI increased from 219 to 752 per million inhabitants (Figure 2).

The risk profile of patients worsened throughout the study period (table 1). In PCI and CABG groups, we observed an increase in the mean age and in the prevalence of risk factors such as previous myocardial infarction, heart failure, peripheral vascular disease, diabetes or COPD. Consequently, Charlson´s Index rose up from 2.7 to 3.5(p_{TL}<0.001) among CABG patients and from 2.6 to 3.6 (p_{TL}<0.001) in PCI .

The proportion of patients who were revascularized electively decreased in the two groups(p_{TL}<0.001). We detected an increase in PCI activity in centers without CABG: in 1998-2002, only 17.4% of patients underwent PCI in a center without CABG, while between 2013 and 2017, the proportion increased to 41.1%(p_{TL}<0.001).

The proportion of patients who had three or more coronary arteries revascularized was higher in the CABG group (40.5% Vs 8.4%,p<0.001). We observed a linear increase in the use of bilateral internal thoracic arteries (8% Vs. 23.6 %,p_{TL}<0.001), and off-pump CABG (31.3% Vs. 34.2% p_{TL} <0.001) from the first to the last period.

Mortality

Among patients undergoing CABG, a decrease in non-adjusted in-hospital mortality was observed between 1998 and 2017: 6.5% Vs. 2.6% (p_{TL}<0.001; RRR -0.6, 95%CI -0.67;-0.53). Mortality among patients undergoing PCI increased slightly from 1.2% to 1.6% (p_{TL}<0.001; RRR +1.33, 95%CI 0.31;0.35)(Figure 3A).

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 revascularization (COPD, age, previous infarction, heart failure, etc.…). The effect of some variables changed depending on the type of revascularization such as the hospital volume of procedures. PCI mortality in centers without CABG was lower than in centers with CABG on site (OR 0.87,95%CI 0.81; 0.93,p<0.001). Mortality was independently reduced by the study period.

Information regarding the estimation of RAMR is shown in Table 2 in the supplementary material. A decrease in RAMR was detected in both CABG and PCI patients. In the case of coronary surgery, the RAMR decreased from 1.55 to 0.44(p_{TL}<0.001), and in the case of PCI from 1.72 to 0.85(p_{TL}<0.001) between 1998 and 2017 respectively (see Figure 3B).

Volume of activity and mortality by center

The number of centers with CABG and PCI on site increased from 37 (1998-2002) to 48 (2013-2017)(p_{TL}<0.001)(table 3 and supplementary Figure 1). The number of centers with PCI but without CABG on site increased from 25 (1998) to 96 (2017) (see Table 3). We observed an increase in the median volume of PCI per center from 136 to 209(p_{TL}<0.001) and a decrease in CABG from 137 to 72 CABG(p_{TL}<0.001) between 1998 and 2017. (Supplementary figure 1). The volume of interventions was independently associated to a lower in-hospital mortality for CABG and a higher mortality after PCI (see table 3)

DISCUSSION

Between 1998 and 2017, in Spain, the volume of revascularizations/million inhabitants in patients with stable angina or acute coronary syndromes without ST elevation increased to 852 (See Figure 2). However, these rates are very low as compared to other countries. For example, in the United States, the number of CABG per million inhabitants in 2007-2008 was 1,081/year, while that of PCI was 3,667/year(18). In Germany, in 2013, the proportion of revascularizations 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 our country, 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 revascularization.

In addition, there was, over the past 20 years, a 13.5% reduction in the volume of CABG (5509 in 1998 Vs 4756 in 2017) and a 178.7% increase of PCI volume (14245 in 1998 Vs 39636 in 2017). The PCI/CABG ratio in the last period of the study was 7.7. In the 2015 "*Health at a Glance*" report, the PCI/CABG ratio was 7.3 in Spain, very similar 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 reduction in CABG volume of 116% between 1998 and 2015(19) and 14% between 2001 and 2007 with a stabilization of the volume of PCI procedures(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 revascularizations 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.

A significant worsening of the risk profile has been observed for both PCI and CABG patients: 14% increase in the prevalence of diabetes, proportion of patients with severe chronic kidney disease has multiplied by 6 and that of COPD by 2 (see Table 1)… In general, the increased risk of patients is consistent with a progressive aging of patients and an increase in the prevalence and severity of cardiovascular risk factors observed in Spain and other countries(20- 22). Despite the conflicting evidence on the benefit of off pump CABG or multiple arterial grafts revascularization, 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_{TL}<0.001)) or off pump (31.3% Vs 34.2% in the first and last period respectively, p_{TL}<0.001)(23,24).

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 (21). The strong reduction of mortality is a common finding too: for example, the registry for New South Wales detected a decrease in hospital mortality after CABG of 30% between 2000 and 2013(26). Beyond the reduction in non-adjusted mortality, a significant reduction in risk-adjusted mortality was observed too. Between 1998 and 2017, the risk-adjusted death rate decreased in CABG almost 4 times (1.55 to 0.44(p_{TL}<0.001)).

Hospital mortality after PCI in Spain was similar to that of other developed countries(26,27), and slightly increase throughout the series. However, when adjusting for patient comorbidities and other confounding factors, the RAMR was reduced by almost half (1.72 to 0.85(p_{TL}<0.001)). In Spain, we have detected a fourfold increase in the number of centers that perform PCI without CABG (see Table 3). Between 2013 and 2017, 41.1% of the patients treated with PCI were revascularized in a center without coronary surgery. On addition, there has been a very significant decrease in the median number of CABG procedures per center between the first and last period of the study (130.5 Vs 74.5,p_{TL}<0.001). This volume of interventions per center is different from that reported by Goicolea et al.(15) who detected a mean number of CABG procedures of 95/year between 2013 and 2015. Goicolea et al. misclassified procedures such as combined surgery of the aorta, pericardium, ventricular remodeling or cardiac arrhythmias as isolated coronary surgery interventions, which can explain the differences. In any case, the volume of CABG or PCI per center in Spain is very low. For example, in Europe, hospitals with an intermediate volume of CABG perform between 125 and 450 procedures per year(28) and the EACTS/ESC Myocardial Revascularization Guidelines recommend a minimum of 200 isolated CABG interventions to maintain viable coronary surgery programs(1).

There is an important relationship between the volume of CABG per center and in-hospital mortality, such that as the volume of the centers increases, mortality decreases. (Table 2 and

3). On the contrary, mortality after PCI increases as the volume of interventions increases (Table 2 and 3). The latter can be explained by the fact that patients referred to centers with greater activity may have anatomical characteristics or comorbidities that confer a greater risk, and which have not been contemplated in this study.

Conclusions

In the last 20 years there has been a significant increase in the volume of revascularizations in Spain. This increase has been uneven, with a significant increase in PCI and a gradual reduction in CABG. Risk-adjusted mortality has been significantly reduced in both arms, although the intensity of the reduction has been particularly intense among surgically revascularized patients. Finally, there is a significant atomization of revascularization in Spain, with centers with a low volume of CABG and a large number of hospitals that have PCI programs in their service portfolio but not CABG.

Limitations

These conclusions have to be taken with caution due to possible coding biases and others inherent to administrative databases analyses. We could not estimate operative risk according to validated scales in cardiac surgery (such as EuroSCORE). The MBDS does not contain information on private activity in Spain, which account for 10% of healthcare delivery in Spain.

Footnotes:

Author Contributions: MCA, DHV, LCMC and JLM contributed to developing the design of the study. MCA and LCMC requested the information from the Spanish Department of Health. MCA, MP, JAM, CV and GCC contributed to interpreting the data. MCA, JCC, DVH performed the statistical analysis. AF and LCMC contributed to the critical review of the paper. MCA is the guarantor of this work and assumes full responsibility for the conduct of the study

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Patient consent for publication: Not required

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Data availability statement: Data was provided deidentified by the *Unit of Health Care Information and Statistics* (Spanish Department of Health), which stores securely the information in their remote servers. This information is public and was provided only for investigation purposes.

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	CABG					PCI					GLOBAL		
	1998-2002	2003-2007	2008-2012	2013-2017	p(TL)	1998-2002	2003-2007	2008-2012	2013-2017	p(TL)	CABG	PCI	p
n(%)[a]	27146(31)	24522(16.7)	21594(11.7)	20415(11.5)	<0.001	60451(69)	122350(83.3)	163342(88.3)	156990(88.5)	<0.001	93677(15.7)	503133(84.3)	<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*			
≤60	7635(28.1)	6498(26.5)	5797(26.9)	5354(26.2)	<0.001	20890(34.6)	36811(30.1)	45328(27.8)	42679(27.2)	<0.001	25284(27)	145708(29)	<0.001
60-70	10295(37.9)	8073(32.9)	7212(33.4)	7222(35.4)	<0.001	19448(32.2)	34787(28.4)	45310(27.7)	43708(27.8)	<0.001	32802(35)	143253(28.5)	<0.001
70-80	8685(32)	9078(37)	7437(34.4)	6573(32.2)	<0.001	17402(28.8)	40412(33)	51540(31.6)	45195(28.8)	<0.001	31773(33.9)	154549(30.7)	<0.001
>80	531(2)	873(3.6)	1148(5.3)	1266(6.2)	<0.001	2711(4.5)	10340(8.5)	21164(13)	25408(16.2)	<0.001	3818(4.1)	59623(11.9)	<0.001
Female sex	5380(19.8)	4768(19.5)	3778(17.5)	3345(16.4)	<0.001	13192(21.8)	29707(24.3)	39883(24.4)	37652(24)	<0.001	17271(18.4)	120434(23.9)	<0.001
High blood pressure	12266(45.2)	14540(59.3)	14169(65.6)	13800(67.6)	<0.001	26009(43)	68911(56.3)	100988(61.8)	98855(63.1)	<0.001	54775(58.5)	294763(58.6)	0.057
Previous MI[b]	3472(12.8)	3944(16.1)	3330(15.4)	4119(20.2)	<0.001	11383(18.8)	29619(24.2)	46776(28.6)	54703(34.8)	<0.001	14865(15.9)	142481(28.3)	<0.001
NSTEACS	8291(30.2)	6085(24.8)	4541(21)	4228(20.7)	<0.001	25498(42.2)	44829(36.6)	53406(32.7)	49946(31.8)	<0.001	23045(24.6)	173679(34.5)	<0.001
CHF[b]	1599(5.5)	1737(7.1)	2102(9.7)	2104(10.3)	<0.001	2745(4.5)	9474(7.7)	17725(10.9)	20199(12.9)	<0.001	7442(7.9)	50143(10)	<0.001
PVD[b]	1751(6.5)	2240(9.1)	2239(10.4)	2181(10.7)	<0.001	4430(7.3)	10382(8.5)	12585(7.7)	11587(7.4)	<0.001	8411(9)	38984(7.8)	<0.001
CVD[b]	746(2.8)	1122(4.6)	1223(5.7)	1360(6.7)	<0.001	897(1.5)	2566(2.1)	4420(2.7)	4619(2.9)	<0.001	4451(4.8)	124502(2.5)	<0.001
Diabetes[b]	7494(27.6)	8799(35.9)	8510(39.4)	8797(43.1)	<0.001	13131(21.7)	3783(31)	55318(33.9)	54629(34.8)	<0.001	33600(35.9)	1609719(32)	<0.001
CKD[b]	423(1.6)	701(2.9)	1442(6.7)	1946(9.5)	<0.001	1066(1.8)	3688(3)	12219(7.5)	15107(9.6)	<0.001	4512(4.8)	32080(6.4)	<0.001
COPD[b]	961(3.5)	1396(5.7)	1322(6.1)	1518(7.4)	<0.001	2241(3.7)	6279(5.1)	10273(6.3)	11717(7.5)	<0.001	5196(5.6)	30510(6.1)	<0.001
Liver failure[b]	241(0.9)	331(1.4)	410(1.9)	560(2.7)	<0.001	460(0.8)	1392(1.1)	2499(1.5)	3455(2.2)	<0.001	1542(1.7)	7806(1.6)	0.101
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	1088(4)	1070(4.4)	130(0.6)	132(0.7)	<0.001	1691(2.8)	3255(2.7)	4128(2.5)	4686(3)	<0.001	2421(2.6)	13760(2.7)	0.007
Previous PCI	1517(5.6)	1895(7.7)	2555(11.8)	3014(14.8)	<0.001	7835(13)	21700(17.7)	38928(23.8)	43158(27.5)	<0.001	8981(9.6)	111621(22.2)	<0.001
Non-elective Procedure	10474(38.6)	8951(36.7)	7990(37.2)	5014(40.1)	<0.001	32980(54.8)	75290(62.1)	102762(64.1)	66459(66.7)	<0.001	32428(37.9)	277491(66.7)	<0.001
Hospital without CABG on site	-	-	-	-	-	10151(17.4)	36428(30.7)	65011(40.9)	62398(41.1)	<0.001	-	173988(35.7)	-
Revascularization +3 vessels	9321 (40.3)	8558(40.7)	7514(40.3)	7456(40.6)	0.071	-	-	12322(8.5)	12333(8.4)	<0.001	32849(40.5)	24655/292945 (8.4)	0.053
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)	3457(16)	4814(23.6)	<0.001	-	-	-	-	-	13657(14.6)	-	-
Off Pump CABG	8497(31.3)	8709(35.5)	7182(33.3)	6977(34.2)	<0.001	-	-	-	-	-	31365(33.5)	-	-
Hospital Volume					<0.001 *					<0.001*			<0.001
Low	3971(15.1)	3053(12.6)	2406(11.2)	2077(10.7)	<0.001	3260(5.6)	6006(5.1)	7575(4.8)	7628(5)	<0.001	11407(12.6)	24459(5)	<0.001
Low- Intermediate	5511(21.5)	4671(19.3)	4276(19.9)	3680(18.9)	<0.001	8159(14)	17227(14.5)	21343(13.4)	21522(14.2)	<0.001	18138(20)	68351(14)	<0.001
Intermediate-High	7149(27.8)	6984(28.8)	6449(30)	5495(28.2)	<0.001	15955(27.4)	33550(28.3)	45385(28.6)	45144(29.7)	<0.001	26077(28.7)	140034(28.7)	0.128
High	9157(35.7)	9525(39.3)	8377(39)	8232(42.3)	<0.001	30872(53)	61926(52.2)	84660(53.3)	77549(51)	<0.001	35291(38.8)	255007(52.3)	<0.001

Table 1. Baseline and procedural characteristics of PCI (percutaneous coronary intervention) or CABG (Coronary artery bypass grafting). Data is expressed with n(%) or mean SD. $p_{(TL)}$ contrast test for linear trend. *No contrast for linear trend. a. Number of CABG or PCI divided by the volume of revascularizations. b. according to Charlson´s index definition(17,18). MI: Myocardial infarction. CHF: Congestive heart failure. PVD: peripheral vascular disease. CKD: Chronic kidney disease. CVD: Cerebrovascular disease. COPD Chronic obstructive pulmonary disease: ITA: internal thoracic artery.

CABG			PCI		
Variable	OR CI 95%	p	Variable	OR CI 95%	p
Region of Spain	Not Shown	<.001	Region of Spain	Not Shown	<0.001
Hospital Volume of CABG (as compared to Low Volume centers)			Hospital Volume of PCI (as compared to Low Volume centers)		
Low-Intermediate	0.87(0.77;0.96)	0.001	Low-Intermediate	1.36(1.14;1.63)	<0.001
Intermediate-High	0.8(0.72;0.89)	<0.001	Intermediate-High	2(1.68; 2.37)	<0.001
High	0.76(0.68;0.85)	<0.001	High	1.94 (1.62;2.31)	<0.001
COPD	1.36(1.2;1.54)	<0.001	COPD	1.29(1.18;1.39)	<0.001
Age (as compared to <60)			Age (as compared to <60)		
60-70	1.74(1.57;1.93)	<0.001	60-70	1.67(1.52;1.84)	<0.001
70-80	3.08(2.79;3.39)	<0.001	70-80	2.63(2.41;2.87)	<0.001
>80	5.23(4.51;6.05)	<0.001	>80	3.85(3.5;4.23)	<0.001
Female sex	1.14(1.06;1.23)	0.001	Female sex	1.08(1.02;1.15)	0.016
Previous MI	2.81(2.62;3.01)	<0.001	Previous MI	2.63(2.5;2.77)	<0.001
NSTE ACS as primary diagnosis	1.19(1.11;1.28)	<0.001	NSTE ACS as primary diagnosis	0.96(0.9;1.02)	0.151
CHF	3.21(2.96;3.49)	<.001	CHF	4.68(4.43;4.94)	<0.001
PVD	1.43(1.3;1.59)	<.001	PVD	1.24(1.15;1.34)	0.002
CVD	1.74(1.54;1.96)	<.001	CVD	2.33(2.11;2.57)	<0.001
CKD	1.77(1.56;2.01)	<.001	CKD	1.56(1.46;1.69)	<0.001
Previous PCI	1.09(0.96;1.23)	0.176			
Previous CABG	1.27(1;1.6)	0.053			
On pump CABG	1.1(1.02;1.19)	0.009			
Period of study (as compared to 1997-2002)			Period of study (as compared to 1997-2002)		
2003-2007	0.66(0.61;0.71)	<0.001	2003-2007	0.9(0.81;0.1)	0.041
2008-2012	0.41(0.37;0.45)	<0.001	2008-2012	0.83(0.75;0.91)	<0.001
2013-2017	0.28(0.25;0.32)	<0.001	2013-2017	0.7(0.64;0.78)	<0.001
			Hospital without CABG on site	0.87(0.81;0.93)	<.001
			Diabetes	1.54(1.4;1.7)	<.001

Table 2. Factors associated to in-hospital mortality. Stepwise logistic regression. CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. COPD: chronic obstructive pulmonary disease. MI: myocardial infarction. NSTEACS: non-ST elevation acute coronary syndrome. PVD: peripheral vascular disease. CHF: congestive heart failure. CVD: cerebrovascular disease. CKD: chronic kidney disease.

	1998-2002	2003-2007	2008-2012	2013-2017	p(TL)
Median number of hospitals/year					
(+)CABG(+)PCI	37(36;40)	44(42;44)	47(47;47)	48(45;50)	<0.001
(-)CABG(+)PCI	25(19;32)	61(54;62)	93(88;96)	96(70;99)	<0.001
Median number of procedures/center-year					
CABG	130.5(102;163)	103(73;145)	89(58;120)	74.5(49;109)	<0.001
PCI	148(58;249)	195(77;334)	185.5(71;344)	198(79;350)	<0.001
Mortality according to hospital volume of procedures					
Hospital Volume of CABG					
Low Volume	331/3871(8.6)	206/3053(6.8)	87/2406(3.6)	72/2077(3.5)	<0.001
Low-Intermediate	411/5511(7.5)	322/4671(6.9)	172/4276(4)	106/3680(2.9)	<0.001
Low-High	530/7149(7.4)	345/6984(4.9)	226/6449(3.5)	161/5495(2.9)	<0.001
High	469/9157(5.1)	352/9525(3.7)	265/8377(3.2)	217/8232(2.6)	<0.001
Hospital Volume of PCI					
Low Volume	18/3260(0.6)	31/6006(0.5)	45/7575(0.6)	61/7628(0.8)	0.049
Low-Intermediate	67/8159(0.8)	155/17227(0.9)	201/21343(0.9)	237/21622(1.1)	0.014
Low-High	172/15955(1.1)	426/33550(1.3)	685/45385(1.5)	700/45053(1.6)	<0.001
High	296/30872(1)	745/61926(1.2)	1226/84660(1.5)	1189/77549(1.5)	<0.001

Table 3. Number of hospitals and volume of procedures/hospital in each study period. Data is shown as n(%) or median and IQR. CABG: “Coronary Artery Bypass Grafting”. PCI: “Percutaneous Coronary Intervention. (+)CABG(+)PCI: Hospitals with CABG and PCI: (-)CABG(+)PCI. Hospitals without CABG but with PCI.

Figure 1. Flow diagram. Selection of patients.

Figure 2. Number of procedures.

Figure 3. Non adjusted and adjusted in-hospital mortality. RAMR: Risk adjusted mortality rate.

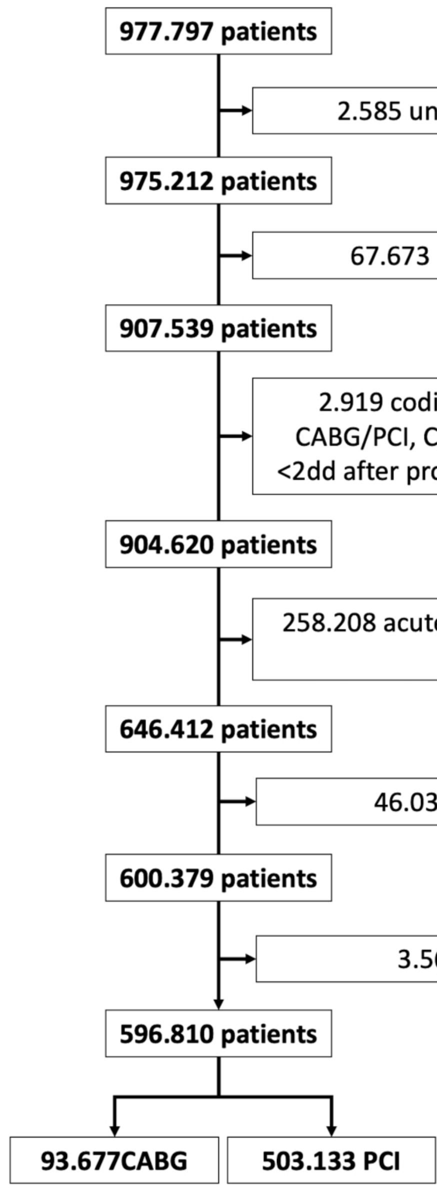


Figure 1. Flow diagram. Selection of patients.

187x265mm (300 x 300 DPI)

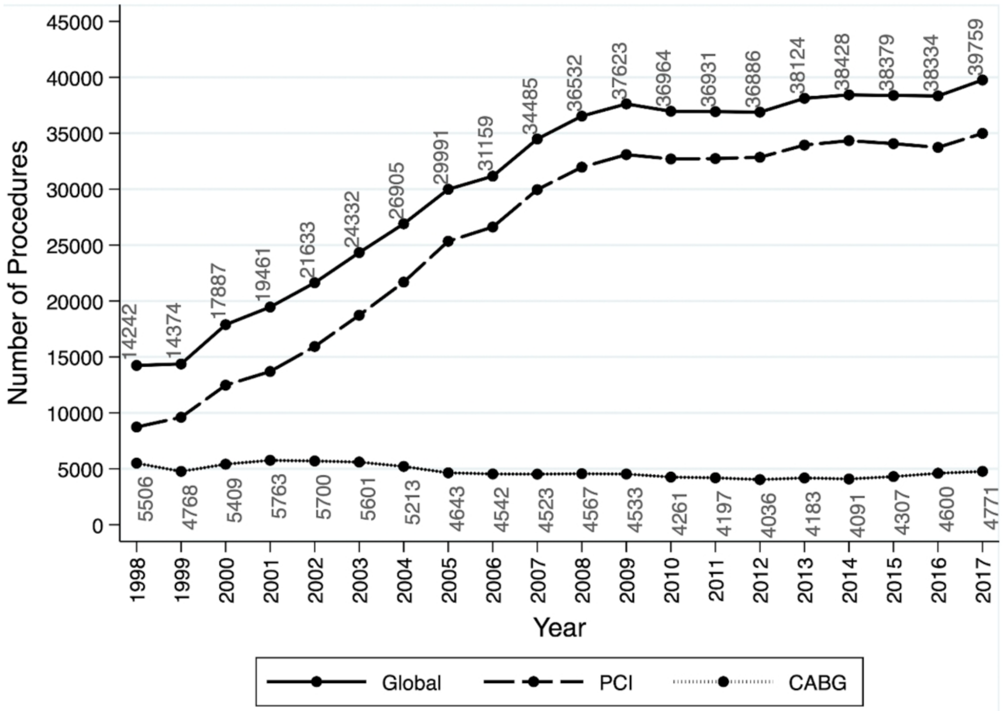
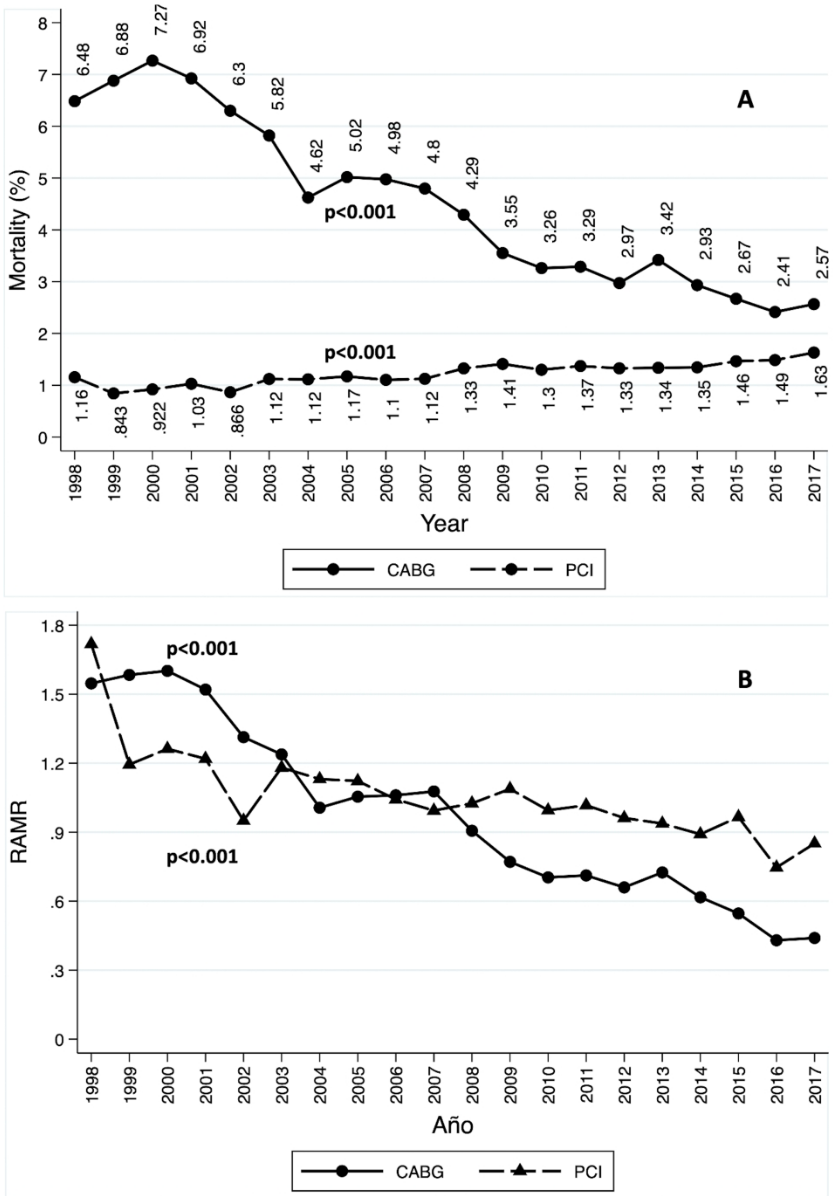


Figure 2. Number of procedures.

189x143mm (300 x 300 DPI)



. Non adjusted and adjusted in-hospital mortality. RAMR: Risk adjusted mortality rate.

189x273mm (300 x 300 DPI)

Supplemental Material

Table 1. ICD9 and ICD10 codes

	ICD9	ICD10
CABG	36.1x	0210xxx,0211xxx,0212xxx,0213xxx
PCI	00.66, 36.03, 36.06, 36.07, 36.09	0270xxx, 0271xxx,0272xxx,0273xxx
Excluded Concomitant procedures	35.xx, 37.3x, 37.51, 38.44, 38.45, 39.1x, 39.2x, 39.3x and 37.90	027Fxxx, 027Gxxx, 02NFxxx, 02NGxxx, 02Vxxxx, 027Jxxx, 02NJxxx, 02Nxxxx, 02Rxxxx, 02Qxxxx, 028xxxx, 02Bxxxx, 02Cxxxx, 02Fxxxx, 02Hxxxx, 02Jxxxx, 02Kxxxx, 02Nxxxx, 02Pxxxx, 02Uxxxx, 02Wxxxx, 02Yxxxx, 025xxxx
AMI/STEACS	410.x1	I21.x9, I21.x1, I21.x, I21.4, I21.3, I21.9

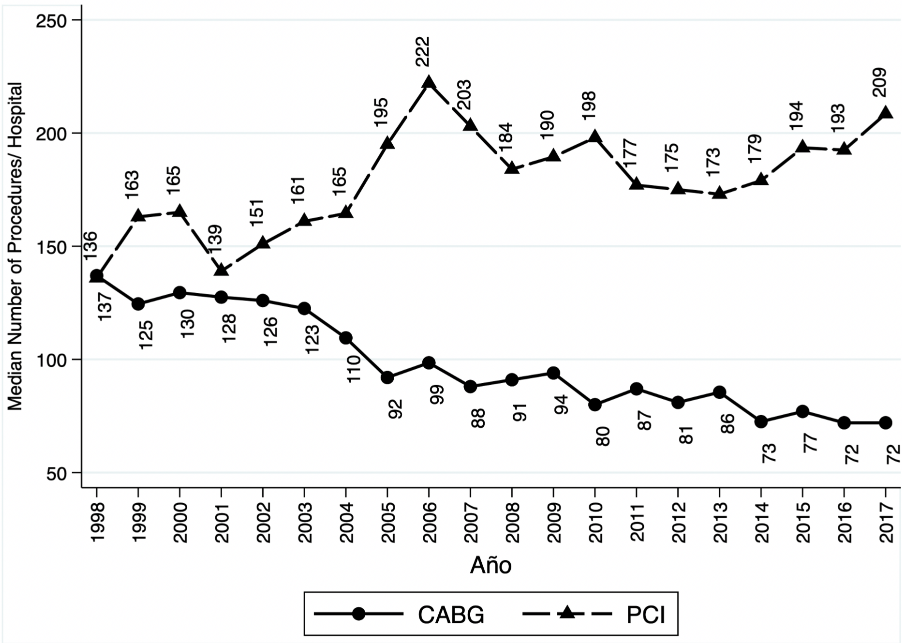
CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. AMI: acute myocardial infarction STEACS: ST elevation acute coronary syndrome

Table 2. Variables included in the model to predict risk adjusted mortality rates for CABG and PCI.

	Model to estimate RAMR after CABG	Model to estimate RAMR after PCI
Variables	Spanish region, Groups of hospitals according to the volume of CABG/year-center, COPD, Age ranges, Sex, Previous MI, NSTEACS, PVD, CVD, Diabetes, CKD, Previous CABG, Previous PCI, Off-Pump, CHF	CABG on site Spanish region, Groups of hospitals according to the volume of PCI/year-center, COPD, Age ranges, Sex, Previous MI, NSTEACS, PVD, CVD, Diabetes, CKD, Previous CABG, CHF
AUC	0.76 (95%CI 0.75;0.77)	0.8 (95%CI 0.8;0.81)

CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. COPD: chronic obstructive pulmonary disease. MI: myocardial infarction. NSTEACS: non-ST elevation acute coronary syndrome. PVD: peripheral vascular disease. CHF: congestive heart failure. CVD: cerebrovascular disease. CKD: chronic kidney disease. AUC Area Under the Curve.

Figure 1. Median Number of Procedures/Hospital- year.



Reporting checklist for quality improvement study.

Based on the SQUIRE guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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		Reporting Item	Page Number
Title			
	#1	Indicate that the manuscript concerns an initiative to improve healthcare (broadly defined to include the quality, safety, effectiveness, patientcenteredness, timeliness, cost, efficiency, and equity of healthcare)	2,3
Abstract			
	#02a	Provide adequate information to aid in searching and indexing	2
	#02b	Summarize all key information from various sections of the text using the abstract format of the intended publication or a structured summary such as: background, local problem, methods, interventions, results, conclusions	2
Introduction			
Problem description	#3	Nature and significance of the local problem	3

Available knowledge	#4	Summary of what is currently known about the problem, including relevant previous studies	3
Rationale	#5	Informal or formal frameworks, models, concepts, and / or theories used to explain the problem, any reasons or assumptions that were used to develop the intervention(s), and reasons why the intervention(s) was expected to work	3-4
Specific aims	#6	Purpose of the project and of this report	3
Methods			
Context	#7	Contextual elements considered important at the outset of introducing the intervention(s)	3
Intervention(s)	#08a	Description of the intervention(s) in sufficient detail that others could reproduce it	4
Intervention(s)	#08b	Specifics of the team involved in the work	1,7
Study of the Intervention(s)	#09a	Approach chosen for assessing the impact of the intervention(s)	3,4
Study of the Intervention(s)	#09b	Approach used to establish whether the observed outcomes were due to the intervention(s)	3,4
Measures	#10a	Measures chosen for studying processes and outcomes of the intervention(s), including rationale for choosing them, their operational definitions, and their validity and reliability	3,4
Measures	#10b	Description of the approach to the ongoing assessment of contextual elements that contributed to the success, failure, efficiency, and cost	3,4
Measures	#10c	Methods employed for assessing completeness and accuracy of data	3,4
Analysis	#11a	Qualitative and quantitative methods used to draw inferences from the data	4
Analysis	#11b	Methods for understanding variation within the data, including the effects of time as a variable	4
Ethical considerations	#12	Ethical aspects of implementing and studying the intervention(s) and how they were addressed, including, but not limited to, formal ethics review and potential conflict(s) of interest	3
Results			

	#13a	Initial steps of the intervention(s) and their evolution over time (e.g., time-line diagram, flow chart, or table), including modifications made to the intervention during the project	4, 5
	#13b	Details of the process measures and outcome	4,5, 10, 12
	#13c	Contextual elements that interacted with the intervention(s)	4,5, 10, 12
	#13d	Observed associations between outcomes, interventions, and relevant contextual elements	4,5, 10,12
	#13e	Unintended consequences such as unexpected benefits, problems, failures, or costs associated with the intervention(s).	4,5,10,12
	#13f	Details about missing data	7
Discussion			
Summary	#14a	Key findings, including relevance to the rationale and specific aims	5
Summary	#14b	Particular strengths of the project	2,5
Interpretation	#15a	Nature of the association between the intervention(s) and the outcomes	5,6
Interpretation	#15b	Comparison of results with findings from other publications	5,6
Interpretation	#15c	Impact of the project on people and systems	5,6
Interpretation	#15d	Reasons for any differences between observed and anticipated outcomes, including the influence of context	5,6
Interpretation	#15e	Costs and strategic trade-offs, including opportunity costs	n/a
Limitations	#16a	Limits to the generalizability of the work	7
Limitations	#16b	Factors that might have limited internal validity such as confounding, bias, or imprecision in the design, methods, measurement, or analysis	7
Limitations	#16c	Efforts made to minimize and adjust for limitations	7
Conclusion	#17a	Usefulness of the work	5,6
Conclusion	#17b	Sustainability	5,6
Conclusion	#17c	Potential for spread to other contexts	5,6

Conclusion	#17d	Implications for practice and for further study in the field	5,6
Conclusion	#17e	Suggested next steps	6
Other information			
Funding	#18	Sources of funding that supported this work. Role, if any, of the funding organization in the design, implementation, interpretation, and reporting	7

Notes:

- 13b: 4,5, 10, 12
- 13c: 4,5, 10, 12 This checklist was completed on 20. October 2020 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

BMJ Open

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

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

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Structured abstract & article summary: 358
Abstract: 270
Text: 3340
References: 971
Tables and Figures: 922

Article Summary

Abstract

Introduction. Spain is one of the countries with the lowest rates of revascularization and highest ratio of percutaneous coronary intervention (PCI) to coronary artery bypass grafting (CABG).
Objectives. To investigate the changes and trends in the two revascularization procedures between 1998 and 2017 in our country.
Design. Retrospective cohort study. Analysis of in-hospital outcomes.
Setting. Minimum Basic Dataset 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 revascularization/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 revascularizations (particularly PCI) in Spain. Risk-adjusted in-hospital mortality was significantly reduced

Strengths and limitations.

- This is the first study to investigate the nationwide changes and trends in coronary revascularization 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 NHS hospital between 1998-2017.
- 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 revascularization 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 analyzed 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 OECD(6), one of the European countries with the lowest rates of revascularization 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 CABG and PCI patients in the Spanish National Health System (NHS).

In our country, there are no patient-level clinical registries specifically dedicated to patients with coronary artery disease undergoing myocardial revascularization. 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 centers of the Spanish NHS have to report the administrative information of all admitted patients to a mandatory nationwide registry: The Minimum Basic Dataset (MBDS) from the Department of Health. The MBDS is a public open access database which stores individual and anonymized 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 analyze 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 of the Department of Health of our country. Specifically, we analyzed the volume of CABG and PCI, the changes in the risk profile of patients and hospital mortality in the two revascularization 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 was 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. This study was approved by the Institutional Review Board and Ethics Committee at Hospital Clínico San Carlos (Madrid,Spain).

The patient selection algorithm can be seen in Figure 1. We investigated all the outpatient or hospitalization 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 supplementary Table 1 ICD9 and ICD10 codes).

Likewise, all episodes with an acute myocardial infarction/acute coronary syndrome with ST segment elevation as the primary diagnosis on admission (See supplementary Table 1) were excluded, as those with both types of revascularization. In addition, to avoid possible coding errors, patients younger than 18 or older than 100-year-old, patients operated on CABG in centers without CABG or who underwent PCI in centers without PCI were also discarded. Patients discharged alive earlier than two days after CABG were also considered as coding errors. The episodes corresponding to patients who were transferred to another center and consecutive planned revascularizations 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 analyzed 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 deidentified from the Spanish Department of Health

National volume of revascularization 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 was extracted from the National Institute of Statistics(15).

Healthcare centers 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 & ≤70,>70 & ≤80, and >80-year-old). We analyzed 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 other procedural variables were analyzed throughout the study period (see Table 1).

Mortality

We analyzed 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 chi-squared test. The normality of the quantitative variables was analyzed with PP- plots, and they were expressed with mean and standard deviation or median and interquartile range. 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 odds ratio (OR) were used to represent the strength of association between different variables and mortality.

We investigated factors associated to mortality for each type of revascularization. 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, R^2 and their area under the curve.

Subsequently, we estimated 2 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 analyzed the evolution of risk- adjusted mortality rate (RAMR) over time. (14).

Statistical analysis was performed with Stata v 15.0 (StataCorp. 2017. Stata Statistical Software:Release 15.College Station,TX: StataCorp LLC.)

RESULTS

Study Population)

Almost one million (977,797) episodes of CABG or PCI were included in the study. Thirty eight percent (373,831) were excluded, and 603,967 were considered for the purpose of this study (Supplementary Table 2 and Figure 1). Of these, 93,682(15.5%) had CABG and 5103,294(84.5%) 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 revascularizations 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 over 70 years of age and experienced a slight decrease in the younger population strata (Figure 3). Absolute number of procedures and according to type of coronary syndrome is shown in supplementary 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 Supplementary Figure 4).

We detected a significant growth of PCI in centers without CABG: 1998-2002 (17.4%) 2013-2017 (41.1%) (p_{LT} <0.001). The proportion of patients who had three or more coronary arteries revascularized 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 PCI patients (p_{LT}<0.001). The number of outpatient percutaneous procedures was small, but increased in the las two periods (see table 1).

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 Supplementary 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%; -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%;27.6%) (Figure 4A).

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 revascularization (COPD, age, previous infarction, heart failure, etc.…). The effect of some variables changed depending on the type of revascularization such as the hospital volume of procedures and period of study. PCI mortality in centers without CABG was lower than in centers with CABG on site (OR 0.86,95%CI 0.8; 0.92, p<0.001) (more information can be found in Supplementary material)

Information regarding the estimation of RAMR is shown in Supplementary tables 4 and 5. A decrease in RAMR was detected in both CABG and PCI patients. 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 center

The number of centers with CABG and PCI on site grew from 37 (1998-2002) to 48 (2013-2017)(p_{LT}<0.001)(Supplementary Material : Table 6 and Figure 5). The number of centers with PCI but without CABG on site increased from 25 (1998) to 96 (2017). We observed a higher median volume of PCI per center from 136 to 232(p_{LT}<0.001) and a decrease in CABG from 137 to 74 CABG(p_{LT}<0.001) between 1998 and 2017. (Supplementary material). The 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 revascularizations in patients without ST elevation myocardial infarction increased to 776/million inhabitants (See Figure 2). However, these rates are very low as compared to other countries. For example, in the United States, the number of CABG per million inhabitants in 2007-2008 was 1,081/year, while that of PCI was 3,667/year(18). In Germany, in 2013, the proportion of revascularizations 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 our country, 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 revascularization.

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 32272 in 2017). During such a long period of time, the indications for CABG and PCI have varied, mainly in patients with stable 1 or 2-vessel coronary artery disease, with percutaneous revascularization 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 optimization 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 2015 "*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 stabilization 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 revascularizations 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 our country may be due to several factors such as difficulties in accessing one of the therapies, poor adherence to therapeutic recommendations, underindication of revascularization, 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 revascularization (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 both PCI and CABG patients: 14% raise in the prevalence of diabetes, 6-fold 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 aging 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 revascularization, 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, revascularizations with drug eluting stents grew as bare metal stents less became less frequently used.

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 4- fold 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 centers that perform PCI without CABG (see Supplementary Table 6). Between 2013 and 2017, 41.1% of the patients treated with PCI were revascularized in a center without coronary surgery. In addition, there has been a very significant reduction in the median number of CABG procedures per center between the first and last period of the study (130.5 Vs 75.5, p_{LT} <0.001). This volume of interventions per center is different from that reported by Goicolea et al. (15) who detected a mean number of CABG procedures of 95/year between 2013 and 2015. Goicolea et al. misclassified procedures such as combined surgery of the aorta, pericardium, ventricular remodeling or cardiac arrhythmias as isolated coronary surgery interventions, which can explain the differences. In any case, the volume of CABG or PCI per center 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 Revascularization Guidelines recommend a minimum of 200 isolated CABG interventions to maintain viable coronary surgery programs(1).

There is an important relationship between the volume of CABG per center and in-hospital mortality, such that as the volume of the centers increases, mortality decreases. On the contrary, mortality after PCI increases as the volume of interventions increases (Table 2 and Supplementary Material). The latter can be explained by the fact that patients referred to centers with greater activity may have anatomical characteristics or comorbidities that confer a greater risk, and which have not been adequately contemplated in this study (i.e.: left man disease, severely calcified coronary arteries, poor left ventricular function…).

Conclusions

From 1998 to 2017 there has been a significant increase in the volume of revascularizations 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 revascularized patients. Finally, in Spain, there is not an adequate balance between the volume of revascularizations and the number of hospitals, with centers with a low number of CABG procedures and a great proportion of hospitals with PCI programs but without CABG onsite.

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 de study period. Surgical turndowns are known to have higher risk despite risk adjustment, but they could not be identified in this dataset. 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.

Footnotes:

Author Contributions: MCA, DHV, HCG, LCMC, JLM, contributed to developing the design of the study. MCA and LCMC requested the information from the Spanish Department of Health. MCA, MP, JAM, CV, IP and GCC contributed to interpreting the data. MCA, JCC, DVH performed the statistical analysis. AF and LCMC contributed to the critical review of the paper. MCA is the guarantor of this work and assumes full responsibility for the conduct of the study

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Competing interests: None.

Patient consent for publication: Not required

Ethics approval: This study was approved by the Institutional Review Board and Ethics Committee at Hospital Clínico San Carlos (Madrid)

Data availability statement: Data was provided deidentified by the *Unit of Health Care Information and Statistics* (Spanish Department of Health), which stores securely the information in their remote servers. This information is public and was provided only for investigation purposes.

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º	CABG					PCI					TOTAL		
	1998-2002	2003-2007	2008-2012	2013-2017	$p_{(TL)}$	1998-2002	2003-2007	2008-2012	2013-2017	$p_{(TL)}$	CABG	PCI	p
n(%)[a]	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*			
≤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[b]	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[b]	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[b]	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[b]	**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[b]	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[b]	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[b]	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[b]	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)	
Revascularization 3+ vessels	11326 (41.7)	9206(37.5)	7947(36.8)	7357(36)	<0.001	-	-	11312(7)	11792(7.2)	<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)	
DES							34873(28.5)	89198(54.8)	115643(70.2)	<0.001		239714/449843(53.3)	
IVUS							1037(0.9)	6104(3.8)	4517(2.7)	<0.001		11658/449843 (2.6)	
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- Interm	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
Interm- 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

Table 1. Baseline and procedural characteristics of PCI (percutaneous coronary intervention) or CABG (Coronary artery bypass grafting). Data is expressed with n(%) or mean SD. $p_{(TL)}$ contrast test for linear trend. *No contrast for linear trend. a. Number of CABG or PCI divided by the volume of revascularizations. b. according to Charlson´s index definition(16,17). MI: Myocardial infarction. CHF: Congestive heart failure. PVD: peripheral vascular disease. CKD: Chronic kidney disease. CVD: Cerebrovascular disease. COPD Chronic obstructive pulmonary disease. BMS: bare metal stent, DES: drug eluting stent ITA: internal thoracic artery.

CABG			PCI		
Variable	OR CI 95%	p	Variable	OR CI 95%	p
Region of Spain	Not Shown	<0.001	Region of Spain	Not Shown	<0.001
Hospital Volume of CABG (as compared to Low Volume centres)			Hospital Volume of PCI (as compared to Low Volume centres)		
Low-Intermediate	0.86(0.77;0.95)	0.004	Low-Intermediate	1.4(1.18;1.68)	<0.001
Intermediate-High	0.81(0.73;0.9)	<0.001	Intermediate-High	2.05(1.67;2.36)	<0.001
High	0.77(0.68;0.86)	<0.001	High	2.05(1.73;2.42)	<0.001
COPD	1.35(1.2;1.53)	<0.001	COPD	1.25(1.15;1.35)	<0.001
Age (as compared to <60)			Age (as compared to <60)		
60-70	1.72(1.55;1.91)	<0.001	60-70	1.69(1.54;1.85)	<0.001
70-80	3.02(2.73;3.33)	<0.001	70-80	2.6(3.38;2.84)	<0.001
>80	5.07(4.38;5.88)	<0.001	>80	3.58(3.26;3.93)	<0.001
Female sex	1.14(1.06;1.23)	0.001	Female sex	1.09(1.03;1.15)	0.004
Previous MI	2.81(2.62;3.01)	<0.001	Previous MI	2.62(2.49;2.76)	<0.001
NSTE ACS as primary diagnosis	1.2(1.12;1.28)	<0.001			
CHF	3.21(2.96;3.49)	<.001	CHF	4.63(4.39;4.9)	<0.001
PVD	1.43(1.29;1.57)	<.001	PVD	1.24(1.15;1.34)	<0.001
CVD	1.72(1.52;1-94)	<.001	CVD	2.29(2.08;2.52)	<0.001
CKD	1.75(1.55;1.99)	<.001	CKD	1.56(1.45;1.67)	<0.001
On pump CABG	1.09(1.02;1.17)	0.017			
Bilateral ITA	0.8 (0.71; 0.89)	0.042			
Period of study (as compared to 1997-2002)			Period of study (as compared to 1997-2002)		
2003-2007	0.66(0.61;0.72)	<0.001	2003-2007	1.09(0.99;1.21)	0.09
2008-2012	0.41(0.38;0.46)	<0.001	2008-2012	1.18(1.06;1.31)	0.002
2013-2017	0.29(0.26;0.32)	<0.001	2013-2017	1.18(1.06;1.32)	0.002
			Hospital without CABG on site	0.86(0.8;0.92)	<.001
			Diabetes	1.58(1.45;1.67)	<.001
			BMS	0.86(0.79;0.94)	<0.001
			DES	0.41(0.38;0.45)	0.001

Table 2. Factors associated to in-hospital mortality. CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. COPD: chronic obstructive pulmonary disease. MI: myocardial infarction. NSTEACS: non-ST elevation acute coronary syndrome. PVD: peripheral vascular disease. CHF: congestive heart failure. CVD: cerebrovascular disease. CKD: chronic kidney disease. ITA: Internal thoracic artery. BMS: Bare meta stent. DES: Drug eluting stent.

Figure 1. Flow diagram. Selection of episodes.

Figure 2. Number of procedures per million inhabitants and year. A) Volume of procedures per year. Number of total revascularizations and CABG are shown. B) number of procedures by sex and million inhabitants. The number of procedures of each type is represented by sex and million inhabitants of each sex throughout the study period.

Figure 3. Number of procedures per million inhabitants and year in age ranges. A: PCI B: CABG

Figure 4. Non adjusted and adjusted in-hospital mortality. RAMR: Risk adjusted mortality rate.

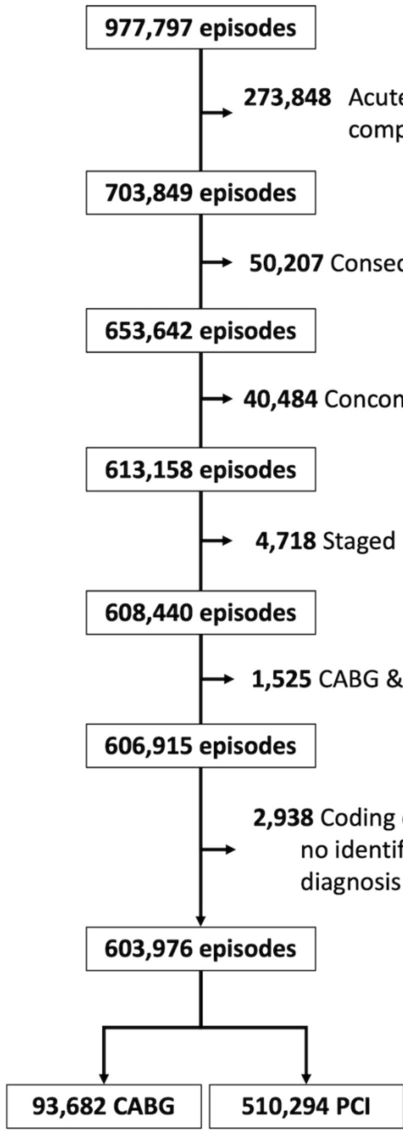

Figure 1. Flow diagram. Selection of episodes.

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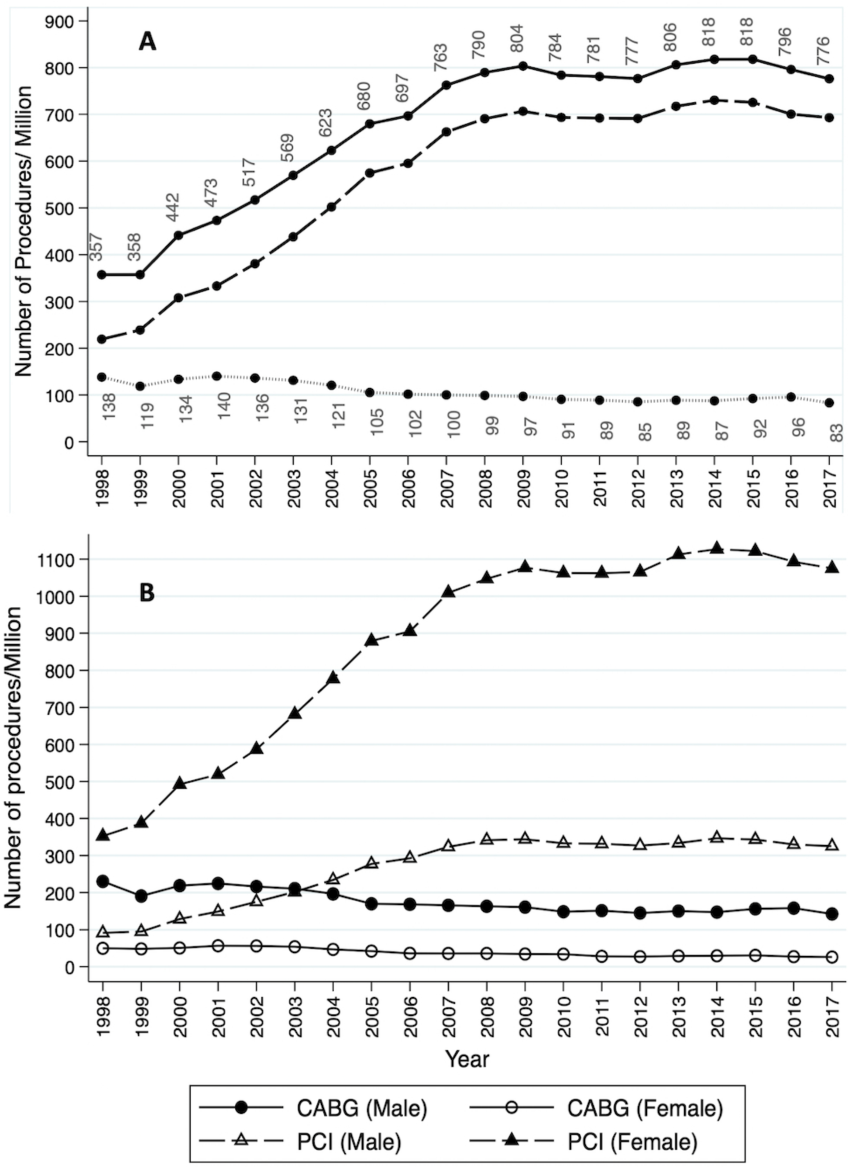

Figure 2. Number of procedures per million inhabitants and year. A) Volume of procedures per year. Number of total revascularizations and CABG are shown. B) number of procedures by sex and million inhabitants. The number of procedures of each type is represented by sex and million inhabitants of each sex throughout the study period.

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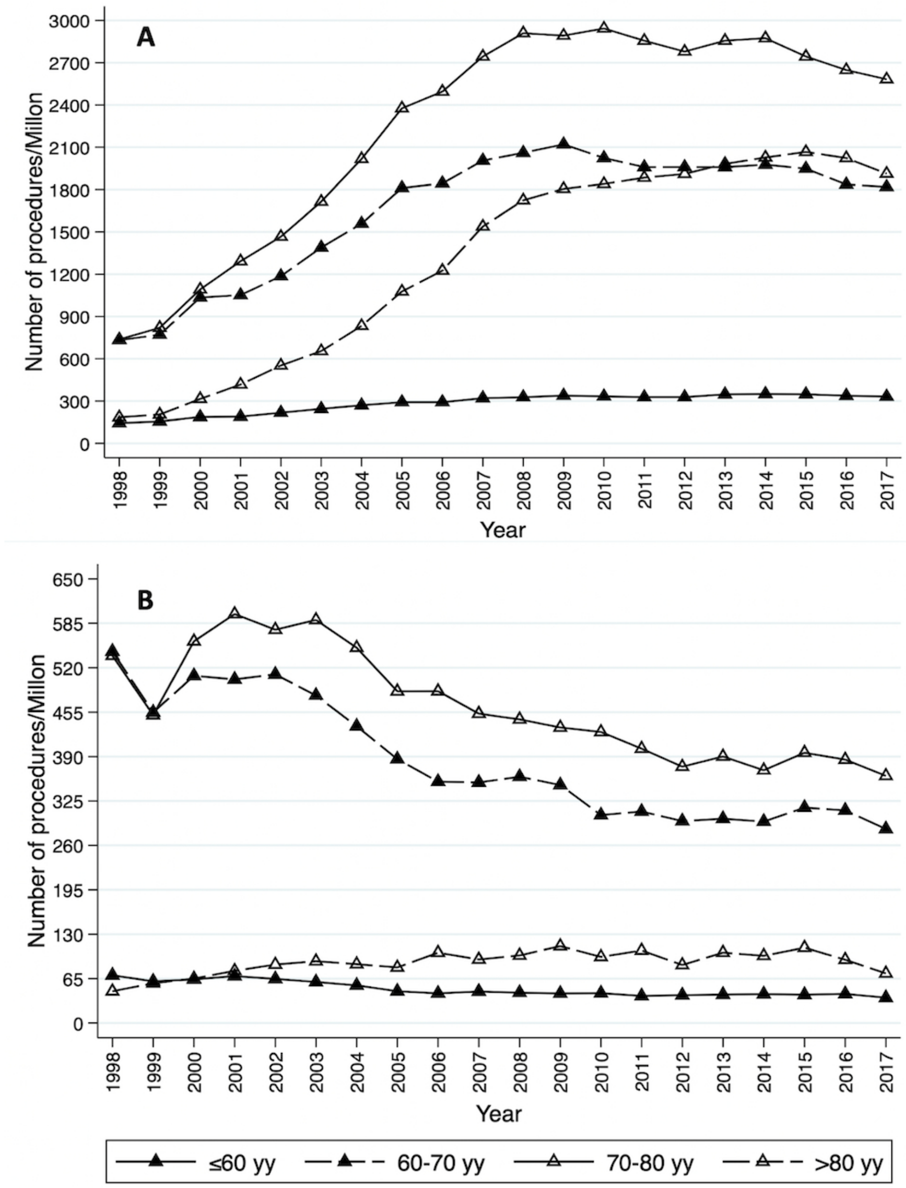


Figure 3. Number of procedures per million inhabitants and year in age ranges. A: PCI B: CABG

83x110mm (300 x 300 DPI)

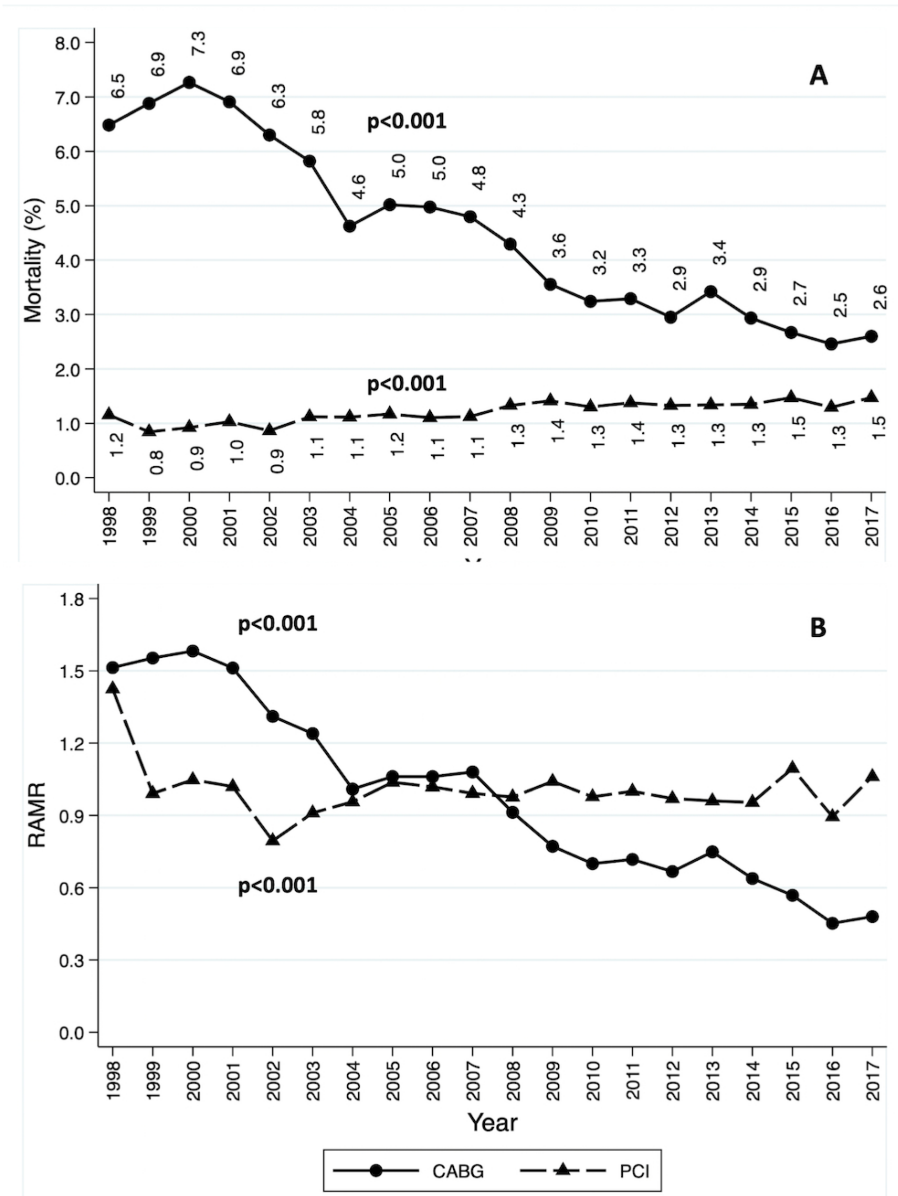


Figure 4. Non adjusted and adjusted in-hospital mortality. RAMR: Risk adjusted mortality rate.

83x111mm (300 x 300 DPI)

Supplementary Material

Table 1. ICD9 and ICD10 codes

	ICD9	ICD10
CABG	36.1x	0210xxx,0211xxx,0212xxx,0213xxx
PCI	00.66, 36.03, 36.06, 36.07, 36.09	0270xxx, 0271xxx,0272xxx,0273xxx, 02C0xxx, 02C1xxx, 02C2xxx, 02C3xxx, 02C4xxx
Excluded Concomitant procedures	35.xx, 37.3x, 37.51, 38.44, 38.45, 39.1x, 39.2x, 39.3x & 37.90	027Fxxx, 027Gxxx, 02NFxxx, 02NGxxx, 02Vxxxx, 027Jxxx, 02NJxxx, 02Nxxxx, 02Rxxxx, 02Qxxxx, 028xxxx, 02Bxxxx, 02Cxxxx (different from 02C0xxx, 02C1xxx, 02C3xxx and 02C4xxx), 02Fxxxx, 02Hxxxx, 02Jxxxx, 02Kxxxx, 02Nxxxx, 02Pxxxx, 02Uxxxx, 02Wxxxx, 02Yxxxx, 025xxxx
STEMI	410.x1	I21.x9, I21.x1, I21.x, I21.4, I21.3, I21.9

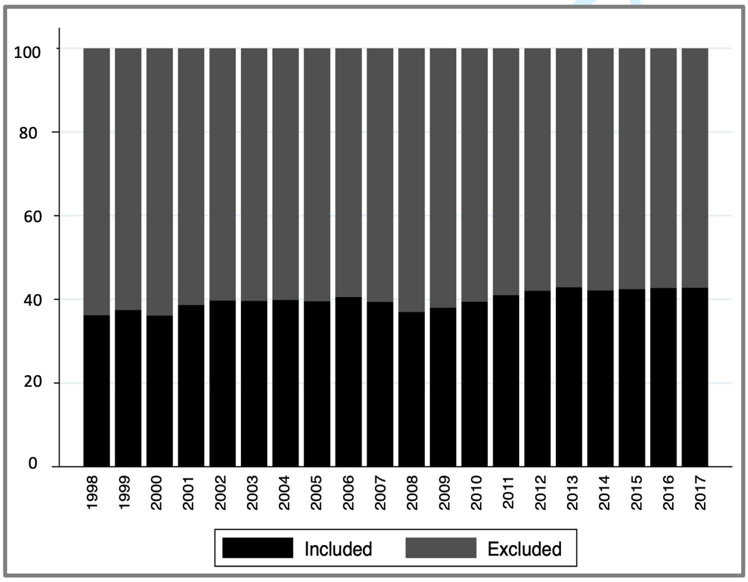
CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. AMI: acute myocardial infarction STEMI: ST elevation myocardial infarction

Table 2. Excluded volume and main reasons for exclusion throughout the study period.

	1997-2002	2003-2007	2008-2012	2013-2017	Total	p_{LT}
N	123593	229843	304095	320266	977797	
Acute STEMI	24316 (19.7)	60527 (26.3)	89136 (29.3)	99969 (31.2)	273948 (28)	<0.001
Coding *	7048 (5.7)	16264 (7.1)	28490 (9.4)	36700 (11.5)	88502 (9.1)	<0.001
Concomitant procedures	6319 (5.1)	11559 (5)	12603 (4.1)	15173 (4.7)	45654 (4.7)	<0.001
PCI & CABG in the same episode	447 (0.4)	580 (0.3)	777 (0.3)	781 (0.2)	2585 (0.3)	<0.001
Age <18 or >100	179 (0.1)	193 (0.1)	236 (0.1)	175 (0.1)	783 (0.1)	<0.001
Exclusion	36012 (29.1)	83012 (36.1)	119665 (39.4)	135132 (42.2)	373821 (38.2)	<0.001

PCI: Percutaneous coronary intervention. CABG: Coronary artery bypass grafting. LT: Linear trend. * Including coding errors, consolidated episodes, staged procedures..

Figure 1. Changes in the volume of excluded episodes.



Proportion (%) of excluded episodes per year

Figure 2. Absolute number of procedures per year.

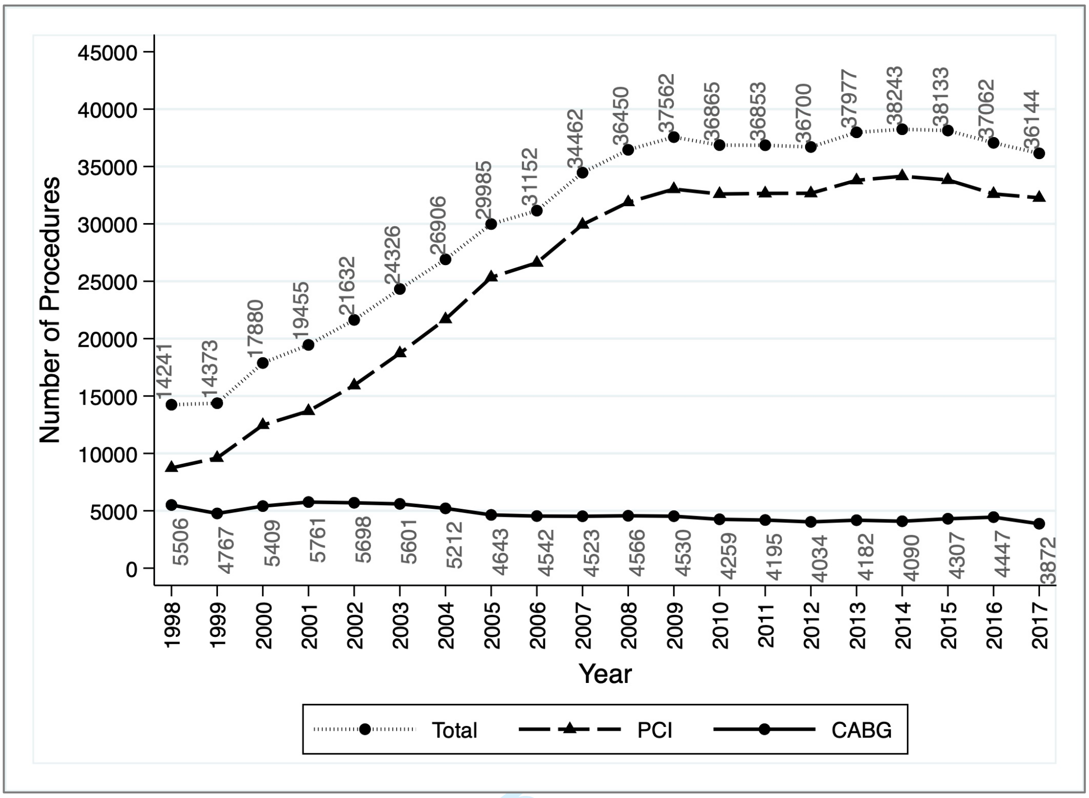
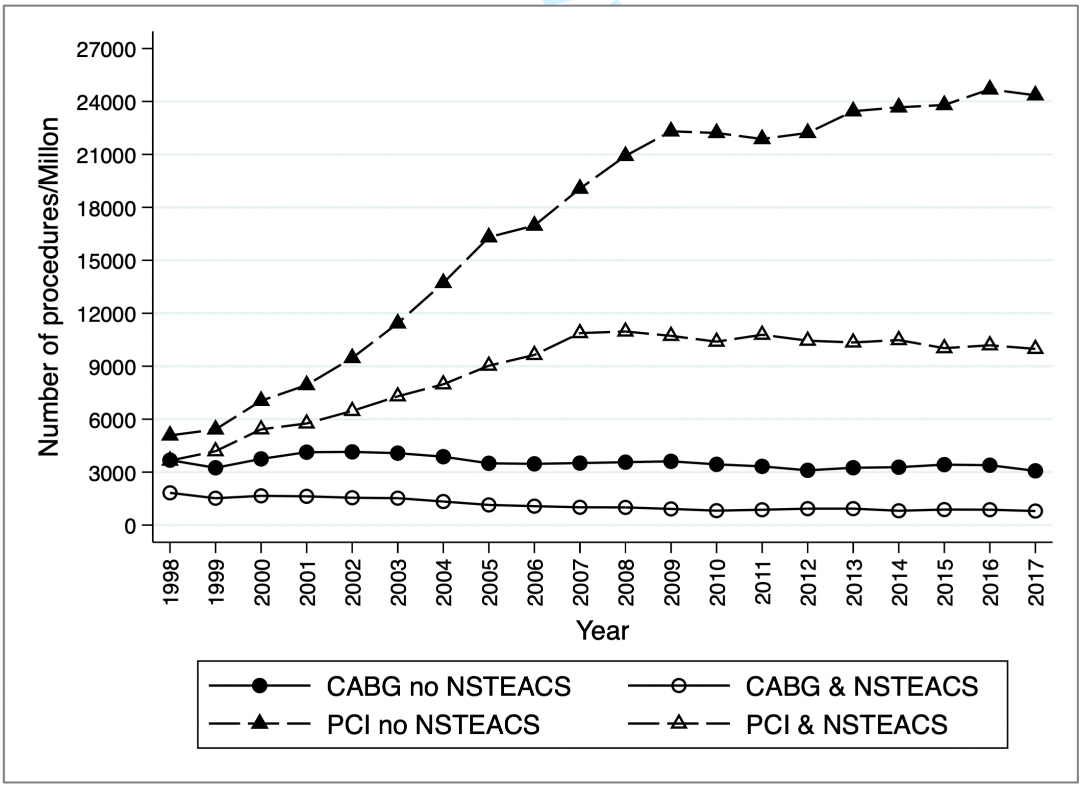
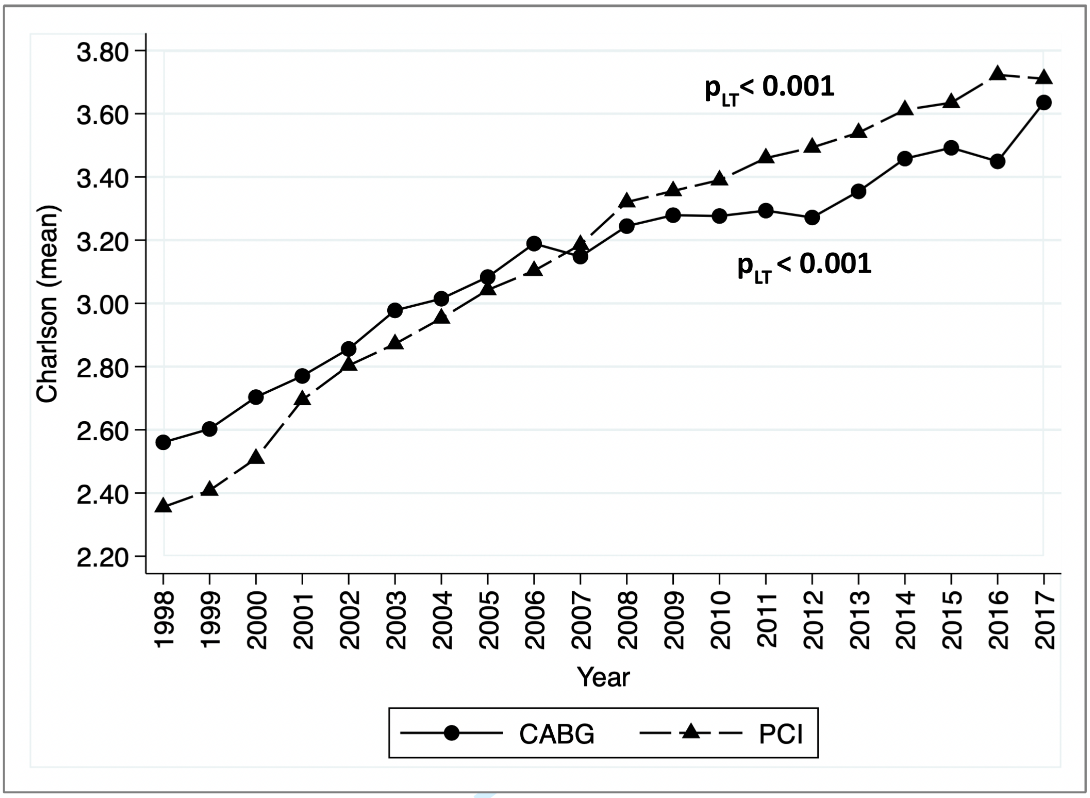


Figure 3. Absolute number of procedures depending on coronary syndrome.



It is observed that the proportion of CABG performed in patients with NSTEACS remained stable throughout the study period. However, there was a more marked increase in the number of PCI procedures in patients without NSTEACS. NSTEACS: non-ST elevation acute coronary syndrome.

Figure 4. Mean Charlson´s Index.



	CABG					PCI					TOTAL		
	1998-2002	2003-2007	2008-2012	2013-2017	$p_{(TL)}$	1998-2002	2003-2007	2008-2012	2013-2017	$p_{(TL)}$	CABG	PCI	p
n(%)[a]	7494 (36.3)	8799 (18.9)	8509 (13.4)	8805 (13.3)	<0.001	13131 (63.7)	37878 (81.2)	55246 (86.7)	57518 (86.7)	<0.001	33607 (17)	163773 (83)	<0.001
Revascularization 3+ vessels	2118(32.7)	2182(28.4)	2043(27.4)	1835(22.9)	<0.001	-	-	4853 (8.9)	4876 (8.5)	<0.001	8178 (27.6)	9729/112764 (8.6)	<0.001
Number of stents													
<3								44791 (81.1)	51306 (91.2)	<0.001		96097/112764 (85.2)	<0.001
≥3								10455 (18.9)	6212 (10.8)	<0.001		16667/112764(14.8)	<0.001
BMS						60440 (99.5)	91514 (74.8)	67011 (41.2)	34085 (20.7)	<0.001		252715(20.7)	<0.001
DES							34868 (28.5)	89196 (54.8)	115652 (70.2)	<0.001		239716 (47)	<0.001
Bilateral ITA	519 (6.9)	1037 (11.8)	1175 (13.8)	1844 (20.9)	<0.001	-	-	-	-	-	4575 (13.6)	-	-
Off Pump CABG	8496(31.3)	8708(35.5)	7178(33.3)	6984(34.2)	<0.001	-	-	-	-	-	31365(33.5)	-	-

Table 3. Procedural characteristics of PCI (percutaneous coronary intervention) or CABG (Coronary artery bypass grafting) among patients with diabetes. Data is expressed with n(%). $p_{(TL)}$ contrast test for linear trend. *No contrast for linear trend. a. Number of CABG or PCI divided by the volume of revascularizations in diabetic patients. BMS: bare metal stent, DES: drug eluting stent ITA: internal thoracic artery.

Table 4. Variables included in the model to detect factor associated to in-hospital mortality after CABG and PCI.

	Model to detect factors associated for in hospital mortality after CABG	Model to detect factors associated for in hospital mortality after PCI
Variables	Spanish region, Groups of hospitals according to the volume of CABG/year-center, COPD, Age ranges, Sex, Previous MI, NSTEACS on admission, PVD, CVD, Diabetes, CKD, Previous CABG, Previous PCI, Off-Pump, CHF, bilateral ITA, Period of study	CABG on site, Spanish region, Groups of hospitals according to the volume of PCI/year-center, COPD, Age ranges, Sex, Previous MI, NSTEACS on admission, PVD, CVD, Diabetes, CKD, Previous CABG, Previous PCI, BMS, DES, CHF, Period of study
AUC	0.76 (95%CI 0.76;0.77)	0.81 (95%CI 0.81;0.82)

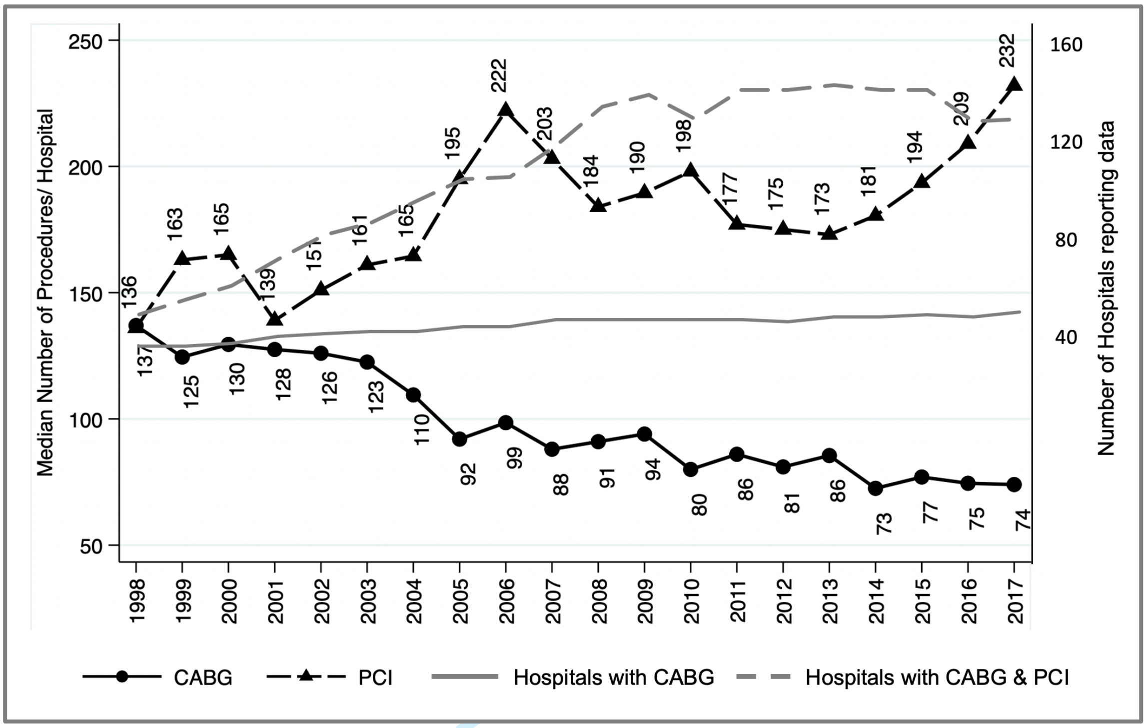
CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. COPD: chronic obstructive pulmonary disease. MI: myocardial infarction. NSTEACS: non-ST elevation acute coronary syndrome. PVD: peripheral vascular disease. CHF: congestive heart failure. CVD: cerebrovascular disease. CKD: chronic kidney disease. ITA: Internal thoracic artery. BMS: implantation of bare metal stent. DES: Implantation of drug eluting stent. AUC Area Under the Curve.

Table 5. Variables included in the model to estimate expected in-hospital mortality after CABG and PCI.

	Model to detect factors associated for in hospital mortality after CABG	Model to detect factors associated for in hospital mortality after PCI
Variables	Spanish region, Groups of hospitals according to the volume of CABG/year-center, COPD, Age ranges, Sex, Previous MI, NSTEACS on admission, PVD, CVD, Diabetes, CKD, Previous CABG, Previous PCI, Off-Pump, CHF, bilateral ITA, High blood pressure	CABG on site, Spanish region, Groups of hospitals according to the volume of PCI/year-center, COPD, Age ranges, Sex, Previous MI, NSTEACS on admission, PVD, CVD, Diabetes, CKD, Previous CABG, Previous PCI, BMS, DES, CHF, high blood pressure.
AUC	0.74 (95%CI 0.73;0.75)	0.81 (95%CI 0.81;0.82)

CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. COPD: chronic obstructive pulmonary disease. MI: myocardial infarction. NSTEACS: non-ST elevation acute coronary syndrome. PVD: peripheral vascular disease. CHF: congestive heart failure. CVD: cerebrovascular disease. CKD: chronic kidney disease. ITA: Internal thoracic artery. BMS: implantation of bare metal stent. DES: Implantation of drug eluting stent. AUC Area Under the Curve.

Figure 5. Median Number of Procedures/Hospital- year and Number of Hospitals reporting data to MBDS.



Left axis: median procedures/hospital. Right axis: number of hospitals reporting data to MBDS

Table 6. Number of hospitals and volume of procedures/hospital in each study period

	1998-2002	2003-2007	2008-2012	2013-2017	p(LT)
Median number of hospitals/year					
(+)CABG(+)PCI	37(36;40)	44(42;44)	47(47;47)	48(45;50)	<0.001
(-)CABG(+)PCI	25(19;32)	61(54;62)	93(88;95)	96(77;99)	<0.001
Median number of procedures/center-year					
CABG	130.5(102;163)	103(73;145)	89(58;120)	75.5(50.5;114)	<0.001
PCI	148(58;249)	195(77;334)	186(71;340)	198(80.5;350.5)	<0.001
Mortality according to hospital volume of procedures					
Hospital Volume of CABG					
Low Volume	330/3866(8.5)	206/3053(6.8)	87/2406(3.6)	74/2079(3.6)	<0.001
Low-Intermediate	411/5511(7.5)	322/4671(6.9)	170/4272(4)	108/3901(2.8)	<0.001
Low-High	530/7149(7.4)	345/6984(4.9)	226/6446(3.5)	172/5694(3)	<0.001
High	469/9156(5.1)	352/9524(3.7)	265/8376(3.2)	222/8708(2.6)	<0.001
Hospital Volume of PCI					
Low Volume	18/3259(0.6)	31/6004(0.5)	45/7613(0.6)	65/8052(0.8)	0.04
Low-Intermediate	67/8160(0.8)	155/17226(0.9)	204/21446(1)	264/23081(1.1)	0.003
Low-High	172/15950(1.1)	426/33545(1.3)	682/45088(1.5)	758/47881(1.6)	<0.001
High	296/30869(1)	745/61896(1.2)	1225/84334(1.5)	1140/80415(1.4)	<0.001

Table 3. Data are shown as n(%) or median and IQR. CABG: “Coronary Artery Bypass Grafting”. PCI: “Percutaneous Coronary Intervention. (+)CABG(+)PCI: Hospitals with CABG and PCI: (-)CABG(+)PCI. Hospitals without CABG but with PCI.

The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	Title	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	**Article Summary** Title **Article Summary** NA
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction		
Objectives	3	State specific objectives, including any prespecified hypotheses	Introduction		
Methods					
Study Design	4	Present key elements of study design early in the paper	**Article Summary**		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Materials and Methods		

Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case	Materials and Methods	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	Materials and Methods and Supplemental material NA NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	Materials and Methods and Supplemental Material	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Materials and Methods and supplemental material
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Materials and Methods and Supplemental Material		

Bias	9	Describe any efforts to address potential sources of bias	Materials and Methods (Statistical Analysis)		
Study size	10	Explain how the study size was arrived at	Materials and Methods & Figure 1		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	Materials and Methods		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses	Materials and Methods (Statistical Analysis)		
Data access and cleaning methods		..	Materials and Methods	RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	Materials and Methods and Introduction

				RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	Materials and Methods. Figure 1.
Linkage		..	NA	RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram	Results. Section: 2 *Study Population*". Figure 1.	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	Results. Section: 2 *Study Population*". Figure 1.
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)	Results. Section: "*Study Population"* Table 1. Supplemental material.		
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure	Results. Section "Mortality"		

		category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Results. Table 2. Section: "Mortality"		
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	NA		
Discussion					
Key results	18	Summarise key results with reference to study objectives	Discussion. Par 1.		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion. Par 1 "Limitations" section	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	Discussion. Par 1 "Limitations" section
Interpretation	20	Give a cautious overall interpretation of results considering objectives,	Discussion. Par 1 "Conclusion" section		

		limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA		
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Footnotes		
Accessibility of protocol, raw data, and programming code		..	Footnotes	RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	Footnotes

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.

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

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

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Abstract: 270
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Article Summary

Abstract

Introduction. Spain is one of the countries with the lowest rates of revascularization and highest ratio of percutaneous coronary intervention (PCI) to coronary artery bypass grafting (CABG).
Objectives. To investigate the changes and trends in the two revascularization procedures between 1998 and 2017 in our country.
Design. Retrospective cohort study. Analysis of in-hospital outcomes.
Setting. Minimum Basic Dataset 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 revascularization/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 revascularizations (particularly PCI) in Spain. Risk-adjusted in-hospital mortality was significantly reduced

Strengths and limitations.

- This is the first study to investigate the nationwide changes and trends in coronary revascularization 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 NHS hospital between 1998-2017.
- 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 revascularization 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 analyzed 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 OECD(6), one of the European countries with the lowest rates of revascularization 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 CABG and PCI patients in the Spanish National Health System (NHS).

In our country, there are no patient-level clinical registries specifically dedicated to patients with coronary artery disease undergoing myocardial revascularization. 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 centers of the Spanish NHS have to report the administrative information of all admitted patients to a mandatory nationwide registry: The Minimum Basic Dataset (MBDS) from the Department of Health. The MBDS is a public open access database which stores individual and anonymized 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 analyze 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 of the Department of Health of our country. Specifically, we analyzed the volume of CABG and PCI, the changes in the risk profile of patients and hospital mortality in the two revascularization 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 was 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. This study was approved by the Institutional Review Board and Ethics Committee at Hospital Clínico San Carlos (Madrid,Spain).

The patient selection algorithm can be seen in Figure 1. We investigated all the outpatient or hospitalization 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 supplementary Table 1 ICD9 and ICD10 codes).

Likewise, all episodes with an acute myocardial infarction/acute coronary syndrome with ST segment elevation as the primary diagnosis on admission (See supplementary Table 1) were excluded, as those with both types of revascularization. In addition, to avoid possible coding errors, patients younger than 18 or older than 100-year-old, patients operated on CABG in centers without CABG or who underwent PCI in centers without PCI were also discarded. Patients discharged alive earlier than two days after CABG were also considered as coding errors. The episodes corresponding to patients who were transferred to another center and consecutive planned revascularizations 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 analyzed 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 deidentified from the Spanish Department of Health

National volume of revascularization 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 was extracted from the National Institute of Statistics(15).

Healthcare centers 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 & ≤70,>70 & ≤80, and >80-year-old). We analyzed 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 other procedural variables were analyzed throughout the study period (see Table 1).

Mortality

We analyzed 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 chi-squared test. The normality of the quantitative variables was analyzed with PP- plots, and they were expressed with mean and standard deviation or median and interquartile range. 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 odds ratio (OR) were used to represent the strength of association between different variables and mortality.

We investigated factors associated to mortality for each type of revascularization. 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, R^2 and their area under the curve.

Subsequently, we estimated 2 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 analyzed the evolution of risk- adjusted mortality rate (RAMR) over time. (14).

Statistical analysis was performed with Stata v 15.0 (StataCorp. 2017. Stata Statistical Software:Release 15.College Station,TX: StataCorp LLC.)

RESULTS

Study Population

Almost one million (977,797) episodes of CABG or PCI were included in the study. Thirty eight percent (373,831) were excluded, and 603,967 were considered for the purpose of this study (See Figure 1, Supplementary Table 2 and Supplementary Figure 1). Of these, 93,682(15.5%) had CABG and 5103,294(84.5%) 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 revascularizations 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 over 70 years of age and experienced a slight decrease in the younger population strata (Figure 3). Absolute number of procedures and according to type of coronary syndrome is shown in supplementary 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 Supplementary Figure 4).

We detected a significant growth of PCI in centers without CABG: 1998-2002 (17.4%) 2013-2017 (41.1%) (p_{LT} <0.001). The proportion of patients who had three or more coronary arteries revascularized 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 PCI patients (p_{LT}<0.001). The number of outpatient percutaneous procedures was small but increased in the las two periods (see table 1). The proportion of patients with previous revascularization 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 revascularized 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 Supplementary 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 Supplementary 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%; -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%;27.6%) (Figure 4A).

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 revascularization (COPD, age, previous infarction, heart failure, etc.…). The effect of some variables changed depending on the type of revascularization such as the hospital volume of procedures and period of study. PCI mortality in centers without CABG was lower than in centers with CABG on site (OR 0.86,95%CI 0.8; 0.92, $p<0.001$) (more information can be found in Supplementary material)

Information regarding the estimation of RAMR is shown in Supplementary tables 4 and 5. A decrease in RAMR was detected in both CABG and PCI patients. 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 center

The number of centers with CABG and PCI on site grew from 37 (1998-2002) to 48 (2013-2017)(p_{LT}<0.001)(Supplementary Material : Table 6 and Figure 6). The number of centers with PCI but without CABG on site increased from 25 (1998) to 96 (2017). We observed a higher median volume of PCI per center from 136 to 232(p_{LT}<0.001) and a decrease in CABG from 137 to 74 CABG(p_{LT}<0.001) between 1998 and 2017. (Supplementary material). The 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 revascularizations in patients without ST elevation myocardial infarction increased to 776/million inhabitants (See Figure 2). However, these rates are very low as compared to other countries. For example, in the United States, the number of CABG per million inhabitants in 2007-2008 was 1,081/year, while that of PCI was 3,667/year(18). In Germany, in 2013, the proportion of revascularizations 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 our country, 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 revascularization.

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 32272 in 2017). During such a long period of time, the indications for CABG and PCI have varied, mainly in patients with stable 1 or 2-vessel coronary artery disease, with percutaneous revascularization 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 optimization 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 2015 "*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 stabilization 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 revascularizations 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 our country may be due to several factors such as difficulties in accessing one of the therapies, poor adherence to therapeutic recommendations, underindication of revascularization, 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 revascularization (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 both PCI and CABG patients: 14% raise in the prevalence of diabetes, 6-fold 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 aging 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 revascularization, 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, revascularizations with drug eluting stents grew as bare metal stents less became less frequently used.

The increase in the proportion of patients requiring a new revascularization increased throughout the study (see Table 1 and Supplementary material). This increase was more notable in PCI and, above all, at the expense of a previous percutaneous revascularization. This finding is consistent with the sustained increase in revascularizations over time, the lower need for re-intervention after CABG, and the preference for percutaneous approaches in the global series (1,2,6,8, 19, 20) (Table 1 and Supplementary 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 4- fold 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 centers that perform PCI without CABG (see Supplementary Table 6). Between 2013 and 2017, 41.1% of the patients treated with PCI were revascularized in a center without coronary surgery. In addition, there has been a very significant reduction in the median number of CABG procedures per center between the first and last period of the study (130.5 Vs 75.5, p_{LT} <0.001). This volume of interventions per center is different from that reported by Goicolea et al. (15) who detected a mean number of CABG procedures of 95/year between 2013 and 2015. Goicolea et al. misclassified procedures such as combined surgery of the aorta, pericardium, ventricular remodeling or cardiac arrhythmias as isolated coronary surgery interventions, which can explain the differences. In any case, the volume of CABG or PCI per center 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 Revascularization Guidelines recommend a minimum of 200 isolated CABG interventions to maintain viable coronary surgery programs(1).

There is an important relationship between the volume of CABG per center and in-hospital mortality, such that as the volume of the centers increases, mortality decreases. On the contrary, mortality after PCI increases as the volume of interventions increases (Table 2 and Supplementary Material). The latter can be explained by the fact that patients referred to centers with greater activity may have anatomical characteristics or comorbidities that confer a greater risk, and which have not been adequately contemplated in this study (i.e.: left man disease, severely calcified coronary arteries, poor left ventricular function…).

Conclusions

From 1998 to 2017 there has been a significant increase in the volume of revascularizations 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 revascularized patients. Finally, in Spain, there is not an adequate balance between the volume of revascularizations and the number of hospitals, with centers with a low number of CABG procedures and a great proportion of hospitals with PCI programs but without CABG onsite.

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 de study period. Surgical turndowns are known to have higher risk despite risk adjustment, but they could not be identified in this dataset. 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.

Footnotes:

Author Contributions: MCA, DHV, HCG, LCMC, JLM, contributed to developing the design of the study. MCA and LCMC requested the information from the Spanish Department of Health. MCA, MP, JAM, CV, IP and GCC contributed to interpreting the data. MCA, JCC, DHV performed the statistical analysis. AF and LCMC contributed to the critical review of the paper. MCA is the guarantor of this work and assumes full responsibility for the conduct of the study

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Data availability statement: Extra data can be accessed via the Dryad data repository at http://datadryad.org/ with the doi:10.5061/dryad.gqnk98smk

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º	CABG					PCI					TOTAL		
	1998-2002	2003-2007	2008-2012	2013-2017	$p_{(TL)}$	1998-2002	2003-2007	2008-2012	2013-2017	$p_{(TL)}$	CABG	PCI	p
n(%)[a]	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*			
≤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[b]	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[b]	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[b]	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[b]	**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[b]	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[b]	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[b]	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[b]	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)	
Revascularization 3+ vessels	11326 (41.7)	9206(37.5)	7947(36.8)	7357(36)	<0.001	-	-	11312(7)	11792(7.2)	<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)	
DES							34873(28.5)	89198(54.8)	115643(70.2)	<0.001		239714/449843(53.3)	
IVUS							1037(0.9)	6104(3.8)	4517(2.7)	<0.001		11658/449843 (2.6)	
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- Interm	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
Interm- 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

Table 1. Baseline and procedural characteristics of PCI (percutaneous coronary intervention) or CABG (Coronary artery bypass grafting). Data is expressed with n(%) or mean SD. $p_{(TL)}$ contrast test for linear trend. *No contrast for linear trend. a. Number of CABG or PCI divided by the volume of revascularizations. b. according to Charlson´s index definition(16,17). MI: Myocardial infarction. CHF: Congestive heart failure. PVD: peripheral vascular disease. CKD: Chronic kidney disease. CVD: Cerebrovascular disease. COPD Chronic obstructive pulmonary disease. BMS: bare metal stent, DES: drug eluting stent ITA: internal thoracic artery.

	CABG		PCI		
Variable	OR CI 95%	p	Variable	OR CI 95%	p
Region of Spain	Not Shown	<0.001	Region of Spain	Not Shown	<0.001
Hospital Volume of CABG (as compared to Low Volume centres)			Hospital Volume of PCI (as compared to Low Volume centres)		
Low-Intermediate	0.86(0.77;0.95)	0.004	Low-Intermediate	1.4(1.18;1.68)	<0.001
Intermediate-High	0.81(0.73;0.9)	<0.001	Intermediate-High	2.05(1.67;2.36)	<0.001
High	0.77(0.68;0.86)	<0.001	High	2.05(1.73;2.42)	<0.001
COPD	1.35(1.2;1.53)	<0.001	COPD	1.25(1.15;1.35)	<0.001
Age (as compared to <60)			Age (as compared to <60)		
60-70	1.72(1.55;1.91)	<0.001	60-70	1.69(1.54;1.85)	<0.001
70-80	3.02(2.73;3.33)	<0.001	70-80	2.6(3.38;2.84)	<0.001
>80	5.07(4.38;5.88)	<0.001	>80	3.58(3.26;3.93)	<0.001
Female sex	1.14(1.06;1.23)	0.001	Female sex	1.09(1.03;1.15)	0.004
Previous MI	2.81(2.62;3.01)	<0.001	Previous MI	2.62(2.49;2.76)	<0.001
NSTE ACS as primary diagnosis	1.2(1.12;1.28)	<0.001			
CHF	3.21(2.96;3.49)	<.001	CHF	4.63(4.39;4.9)	<0.001
PVD	1.43(1.29;1.57)	<.001	PVD	1.24(1.15;1.34)	<0.001
CVD	1.72(1.52;1-94)	<.001	CVD	2.29(2.08;2.52)	<0.001
CKD	1.75(1.55;1.99)	<.001	CKD	1.56(1.45;1.67)	<0.001
On pump CABG	1.09(1.02;1.17)	0.017			
Bilateral ITA	0.8 (0.71; 0.89)	0.042			
Period of study (as compared to 1997-2002)			Period of study (as compared to 1997-2002)		
2003-2007	0.66(0.61;0.72)	<0.001	2003-2007	1.09(0.99;1.21)	0.09
2008-2012	0.41(0.38;0.46)	<0.001	2008-2012	1.18(1.06;1.31)	0.002
2013-2017	0.29(0.26;0.32)	<0.001	2013-2017	1.18(1.06;1.32)	0.002
			Hospital without CABG on site	0.86(0.8;0.92)	<.001
			Diabetes	1.58(1.45;1.67)	<.001
			BMS	0.86(0.79;0.94)	<0.001
			DES	0.41(0.38;0.45)	0.001

Table 2. Factors associated to in-hospital mortality. CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. COPD: chronic obstructive pulmonary disease. MI: myocardial infarction. NSTEACS: non-ST elevation acute coronary syndrome. PVD: peripheral vascular disease. CHF: congestive heart failure. CVD: cerebrovascular disease. CKD: chronic kidney disease. ITA: Internal thoracic artery. BMS: Bare meta stent. DES: Drug eluting stent.

Figure 1. Flow diagram. Selection of episodes.

Figure 2. Number of procedures per million inhabitants and year. A) Volume of procedures per year. Number of total revascularizations and CABG are shown. B) number of procedures by sex and million inhabitants. The number of procedures of each type is represented by sex and million inhabitants of each sex throughout the study period.

Figure 3. Number of procedures per million inhabitants and year in age ranges. A: PCI B: CABG

Figure 4. Non adjusted and adjusted in-hospital mortality. RAMR: Risk adjusted mortality rate.

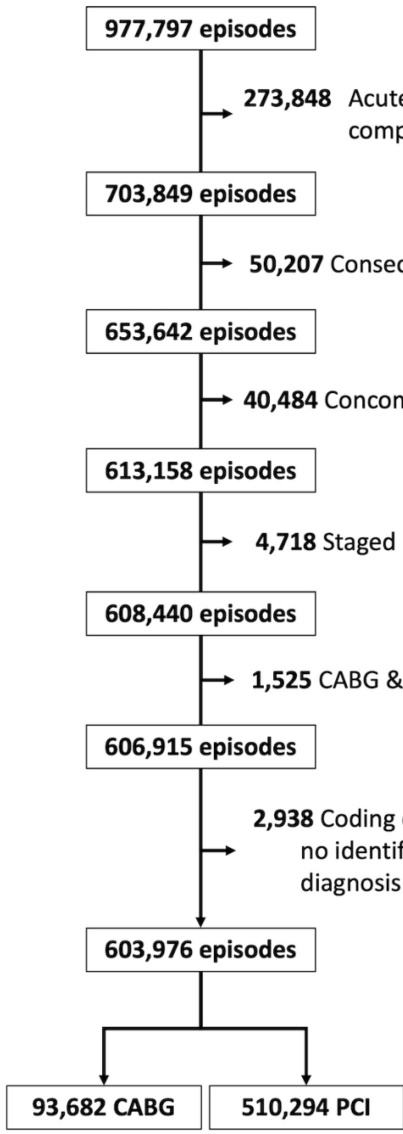

Figure 1. Flow diagram. Selection of episodes.

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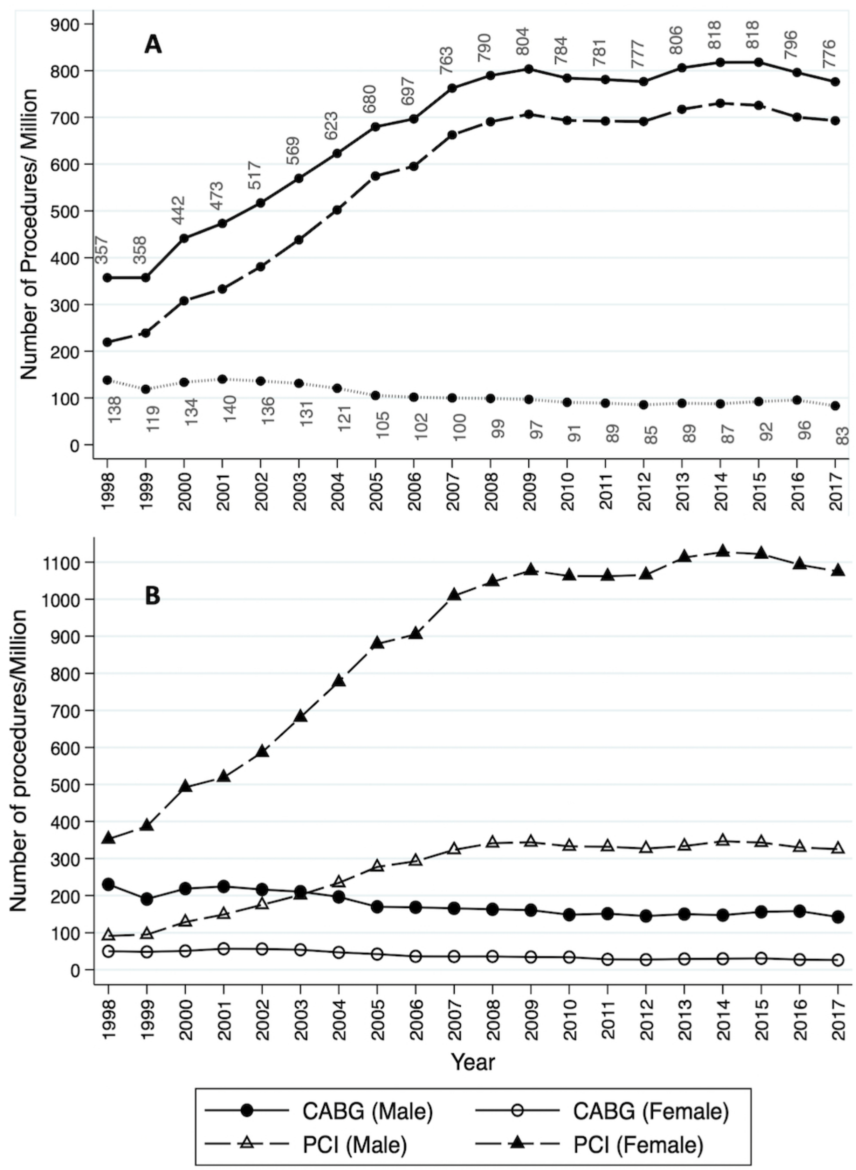

Figure 2. Number of procedures per million inhabitants and year. A) Volume of procedures per year. Number of total revascularizations and CABG are shown. B) number of procedures by sex and million inhabitants. The number of procedures of each type is represented by sex and million inhabitants of each sex throughout the study period.

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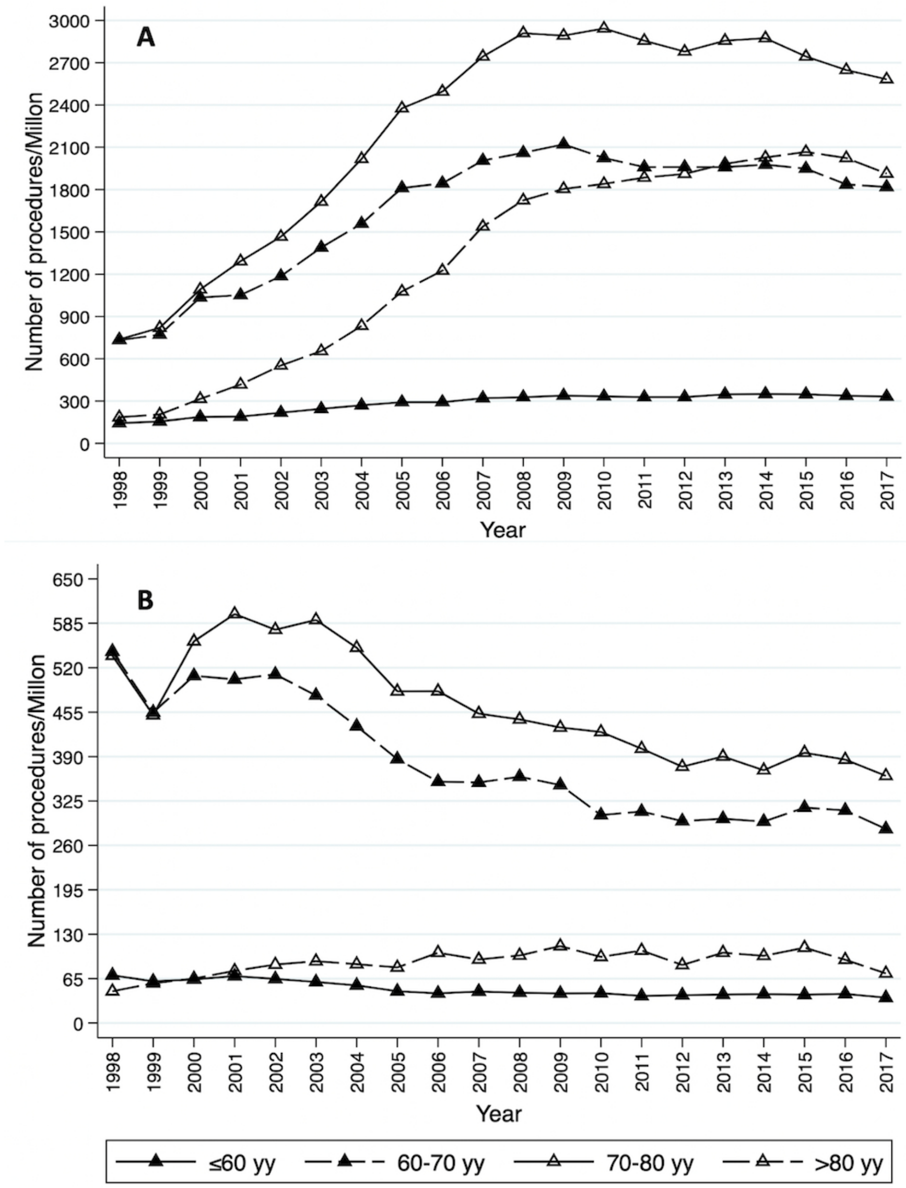

Figure 3. Number of procedures per million inhabitants and year in age ranges. A: PCI B: CABG

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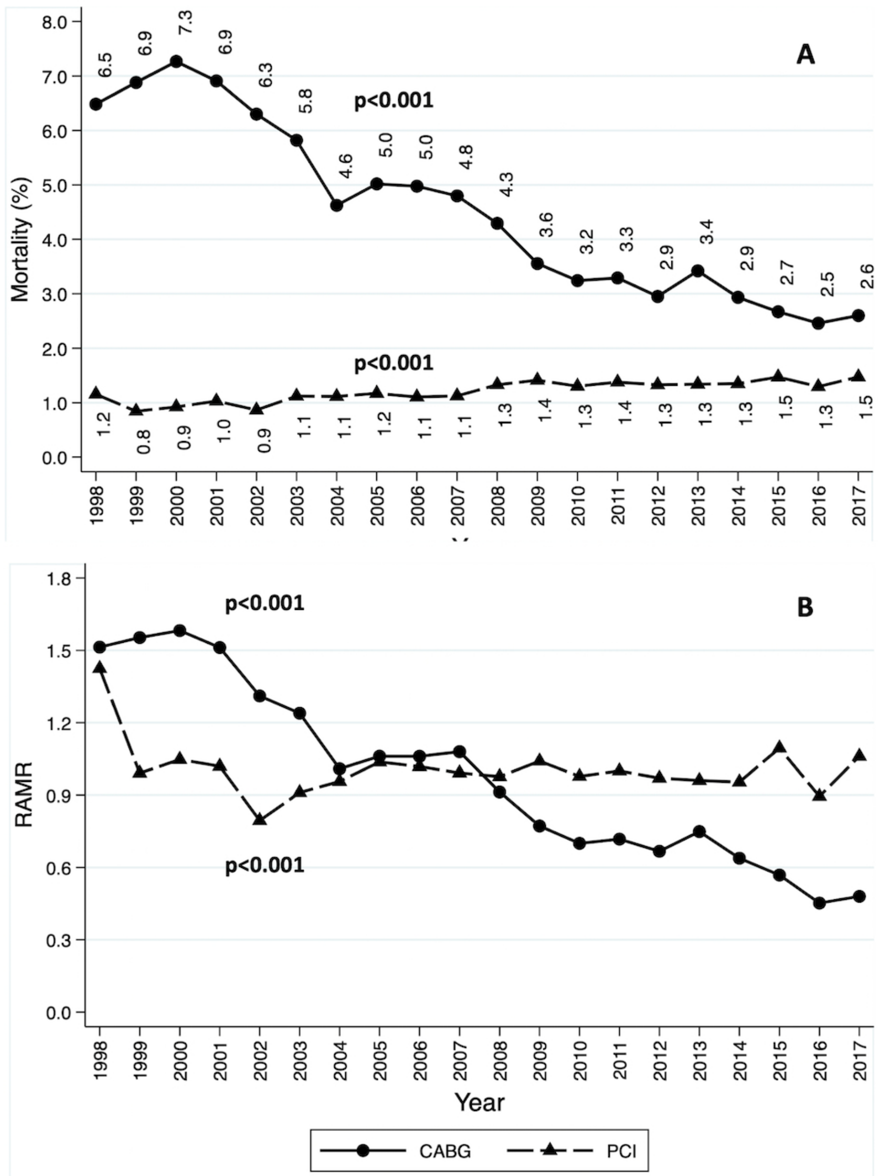


Figure 4. Non adjusted and adjusted in-hospital mortality. RAMR: Risk adjusted mortality rate.

83x111mm (300 x 300 DPI)

Supplementary Material

Table 1. ICD9 and ICD10 codes

	ICD9	ICD10
CABG	36.1x	0210xxx,0211xxx,0212xxx,0213xxx
PCI	00.66, 36.03, 36.06, 36.07, 36.09	0270xxx, 0271xxx,0272xxx,0273xxx, 02C0xxx, 02C1xxx, 02C2xxx, 02C3xxx, 02C4xxx
Excluded Concomitant procedures	35.xx, 37.3x, 37.51, 38.44, 38.45, 39.1x, 39.2x, 39.3x & 37.90	027Fxxx, 027Gxxx, 02NFxxx, 02NGxxx, 02Vxxxx, 027Jxxx, 02NJxxx, 02Nxxxx, 02Rxxxx, 02Qxxxx, 028xxxx, 02Bxxxx, 02Cxxxx (different from 02C0xxx, 02C1xxx, 02C3xxx and 02C4xxx), 02Fxxxx, 02Hxxxx, 02Jxxxx, 02Kxxxx, 02Nxxxx, 02Pxxxx, 02Uxxxx, 02Wxxxx, 02Yxxxx, 025xxxx
STEMI	410.x1	I21.x9, I21.x1, I21.x, I21.4, I21.3, I21.9

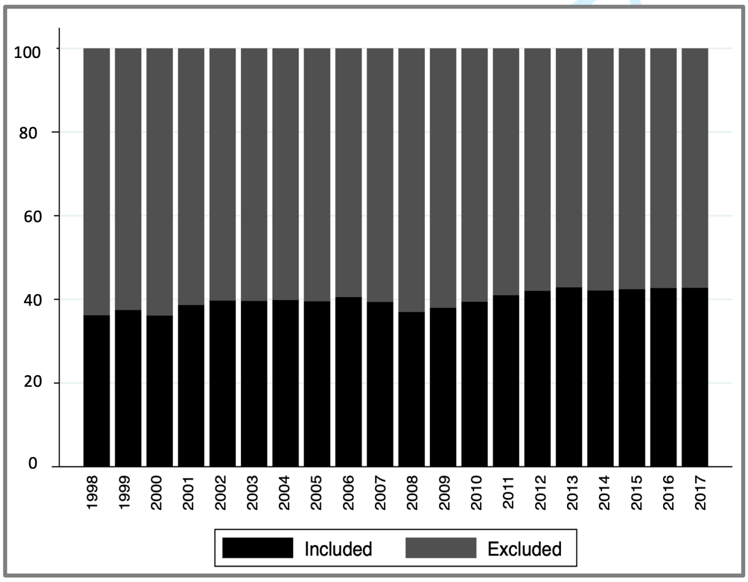
CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. AMI: acute myocardial infarction STEMI: ST elevation myocardial infarction

Table 2. Excluded volume and main reasons for exclusion throughout the study period.

	1997-2002	2003-2007	2008-2012	2013-2017	Total	p_{LT}
N	123593	229843	304095	320266	977797	
Acute STEMI	24316 (19.7)	60527 (26.3)	89136 (29.3)	99969 (31.2)	273948 (28)	<0.001
Coding *	7048 (5.7)	16264 (7.1)	28490 (9.4)	36700 (11.5)	88502 (9.1)	<0.001
Concomitant procedures	6319 (5.1)	11559 (5)	12603 (4.1)	15173 (4.7)	45654 (4.7)	<0.001
PCI & CABG in the same episode	447 (0.4)	580 (0.3)	777 (0.3)	781 (0.2)	2585 (0.3)	<0.001
Age <18 or >100	179 (0.1)	193 (0.1)	236 (0.1)	175 (0.1)	783 (0.1)	<0.001
Exclusion	36012 (29.1)	83012 (36.1)	119665 (39.4)	135132 (42.2)	373821 (38.2)	<0.001

PCI: Percutaneous coronary intervention. CABG: Coronary artery bypass grafting. LT: Linear trend. * Including coding errors, consolidated episodes, staged procedures..

Figure 1. Changes in the volume of excluded episodes.



Proportion (%) of excluded episodes per year

Figure 2. Absolute number of procedures per year.

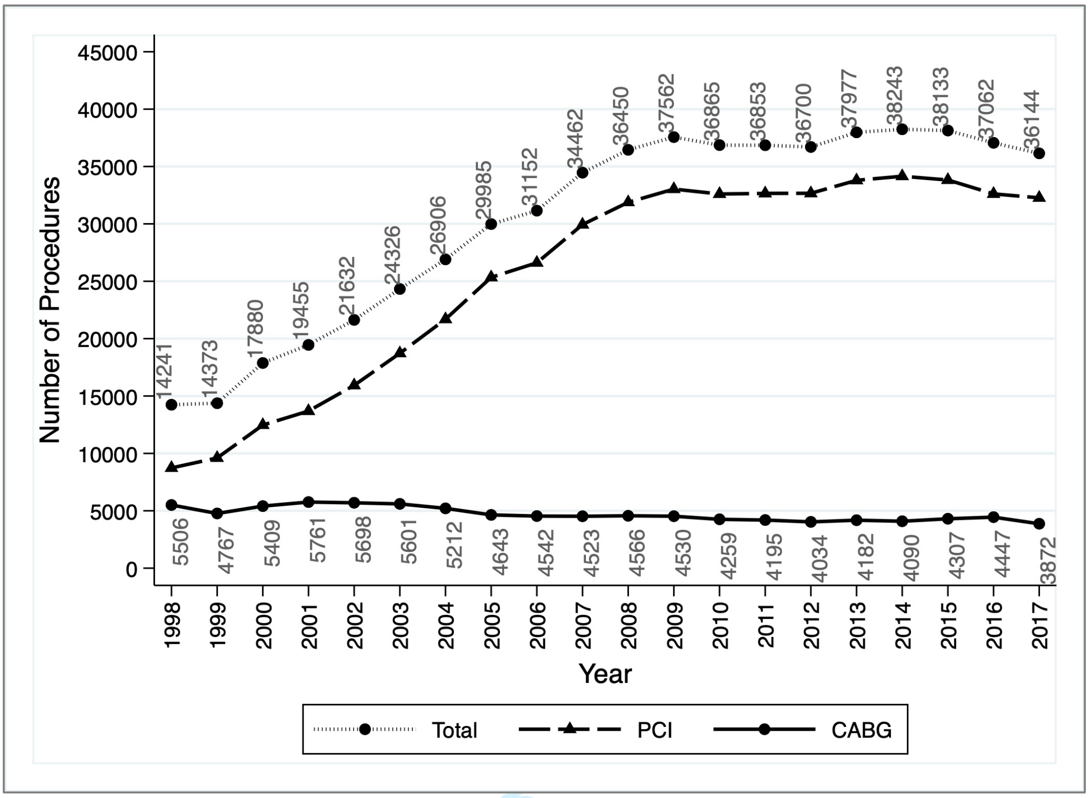
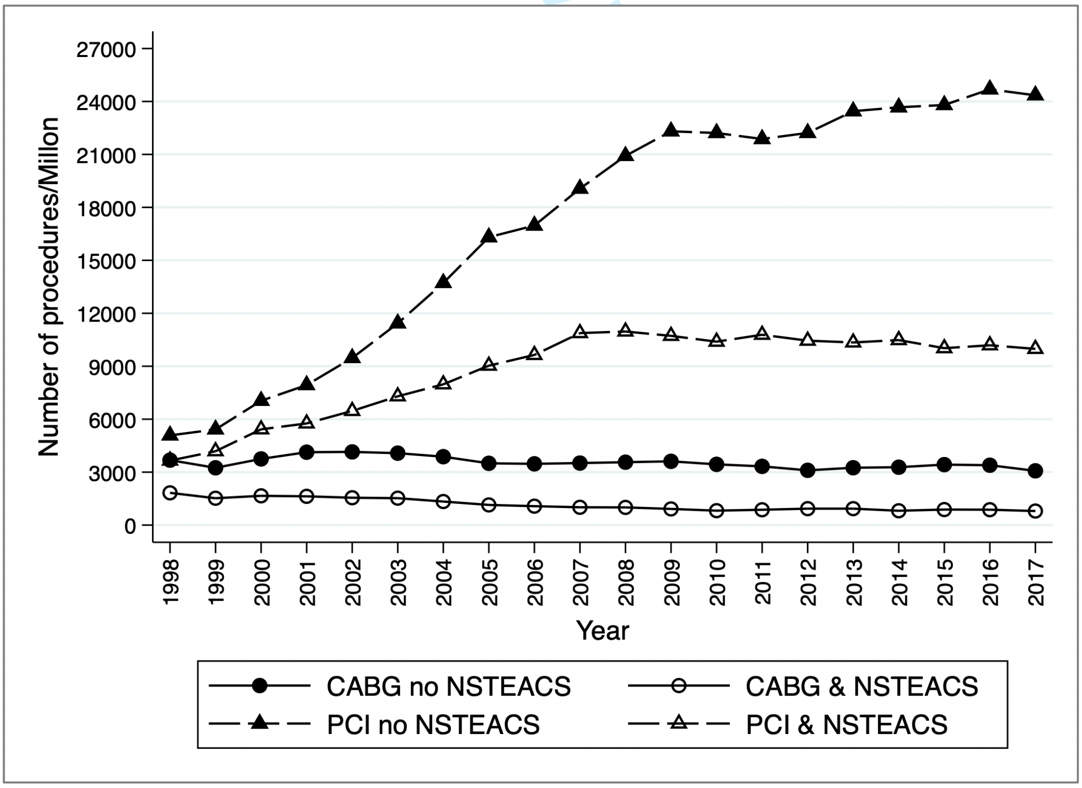


Figure 3. Absolute number of procedures depending on coronary syndrome.



It is observed that the proportion of CABG performed in patients with NSTEACS remained stable throughout the study period. However, there was a more marked increase in the number of PCI procedures in patients without NSTEACS. NSTEACS: non-ST elevation acute coronary syndrome.

Figure 4. Mean modified Charlson´s Index.

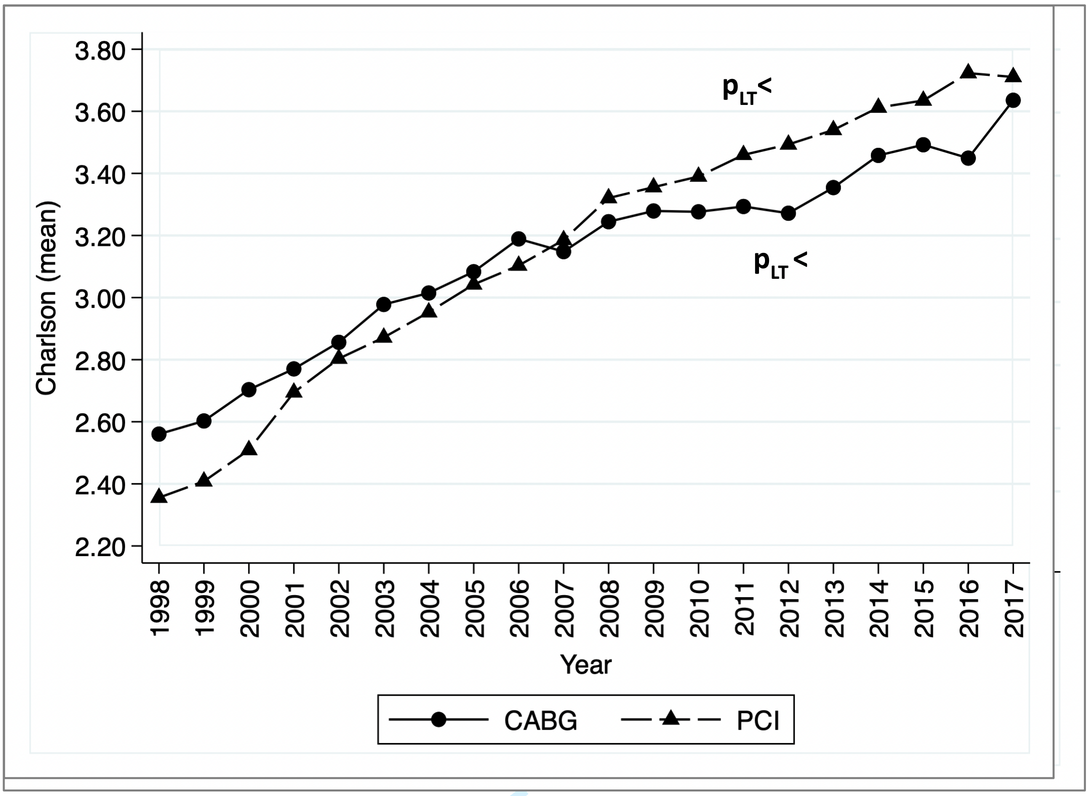
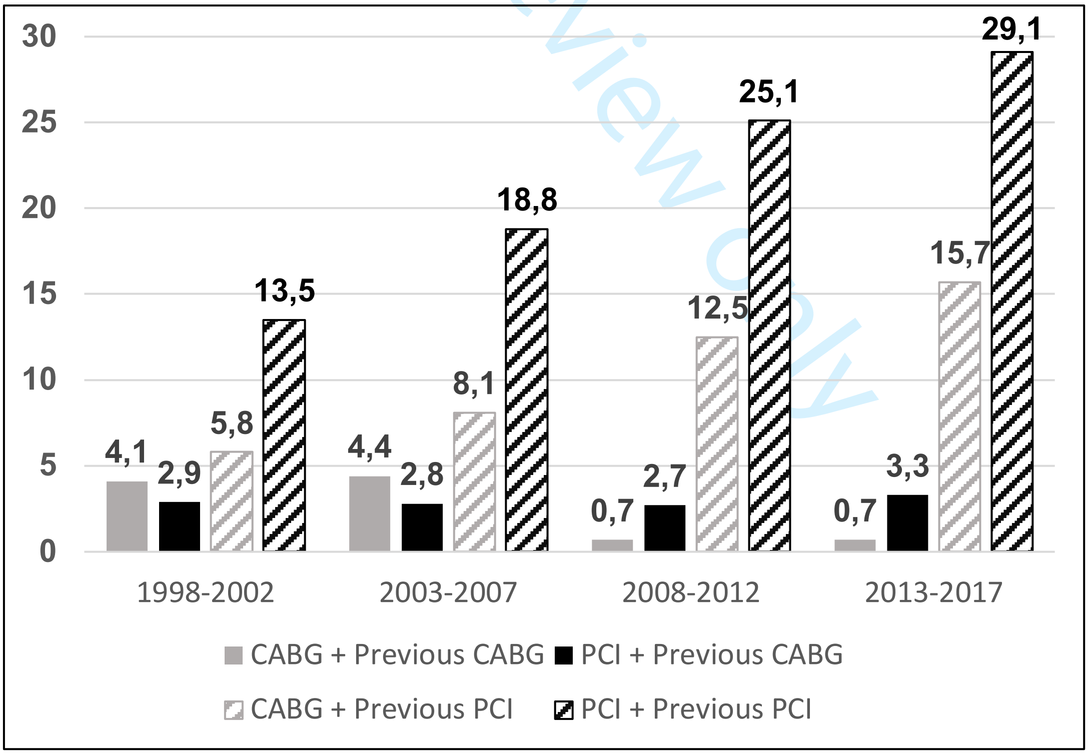


Figure 5. Previous revascularization



Proportion of CABG or PCI patients with previous coronary surgery or percutaneous coronary intervention. The proportion of CABG with previous CABG significantly decreased (4.1% Vs 0.7%, $p_{LT}<0.001$). Proportion of PCI with previous CABG increased from 2.9% to 3.3% ($p_{LT}<0.001$). Proportion of CABG patients with previous PCI increased from 5.8% to 15.7% ($p_{LT}<0.001$). Proportion of PCI patients with previous PCI increased from 13.5% to 29.1% ($p_{LT}<0.001$).

	CABG					PCI					TOTAL		
	1998-2002	2003-2007	2008-2012	2013-2017	$p_{(TL)}$	1998-2002	2003-2007	2008-2012	2013-2017	$p_{(TL)}$	CABG	PCI	p
n(%)[a]	7494 (36.3)	8799 (18.9)	8509 (13.4)	8805 (13.3)	<0.001	13131 (63.7)	37878 (81.2)	55246 (86.7)	57518 (86.7)	<0.001	33607 (17)	163773 (83)	<0.001
Revascularization 3+ vessels	2118(32.7)	2182(28.4)	2043(27.4)	1835(22.9)	<0.001	-	-	4853 (8.9)	4876 (8.5)	<0.001	8178 (27.6)	9729/112764 (8.6)	<0.001
Number of stents													
<3								44791 (81.1)	51306 (91.2)	<0.001		96097/112764 (85.2)	<0.001
≥3								10455 (18.9)	6212 (10.8)	<0.001		16667/112764(14.8)	<0.001
BMS						60440 (99.5)	91514 (74.8)	67011 (41.2)	34085 (20.7)	<0.001		252715(20.7)	<0.001
DES							34868 (28.5)	89196 (54.8)	115652 (70.2)	<0.001		239716 (47)	<0.001
Bilateral ITA	519 (6.9)	1037 (11.8)	1175 (13.8)	1844 (20.9)	<0.001	-	-	-	-	-	4575 (13.6)	-	-
Off Pump CABG	8496(31.3)	8708(35.5)	7178(33.3)	6984(34.2)	<0.001	-	-	-	-	-	31365(33.5)	-	-

Table 3. Procedural characteristics of PCI (percutaneous coronary intervention) or CABG (Coronary artery bypass grafting) among patients with diabetes. Data is expressed with n(%). $p_{(TL)}$ contrast test for linear trend. *No contrast for linear trend. a. Number of CABG or PCI divided by the volume of revascularizations in diabetic patients. BMS: bare metal stent, DES: drug eluting stent ITA: internal thoracic artery.

Table 4. Variables included in the model to detect factor associated to in-hospital mortality after CABG and PCI.

	Model to detect factors associated for in hospital mortality after CABG	Model to detect factors associated for in hospital mortality after PCI
Variables	Spanish region, Groups of hospitals according to the volume of CABG/year-center, COPD, Age ranges, Sex, Previous MI, NSTEACS on admission, PVD, CVD, Diabetes, CKD, Previous CABG, Previous PCI, Off-Pump, CHF, bilateral ITA, Period of study	CABG on site, Spanish region, Groups of hospitals according to the volume of PCI/year-center, COPD, Age ranges, Sex, Previous MI, NSTEACS on admission, PVD, CVD, Diabetes, CKD, Previous CABG, Previous PCI, BMS, DES, CHF, Period of study
AUC	0.76 (95%CI 0.76;0.77)	0.81 (95%CI 0.81;0.82)

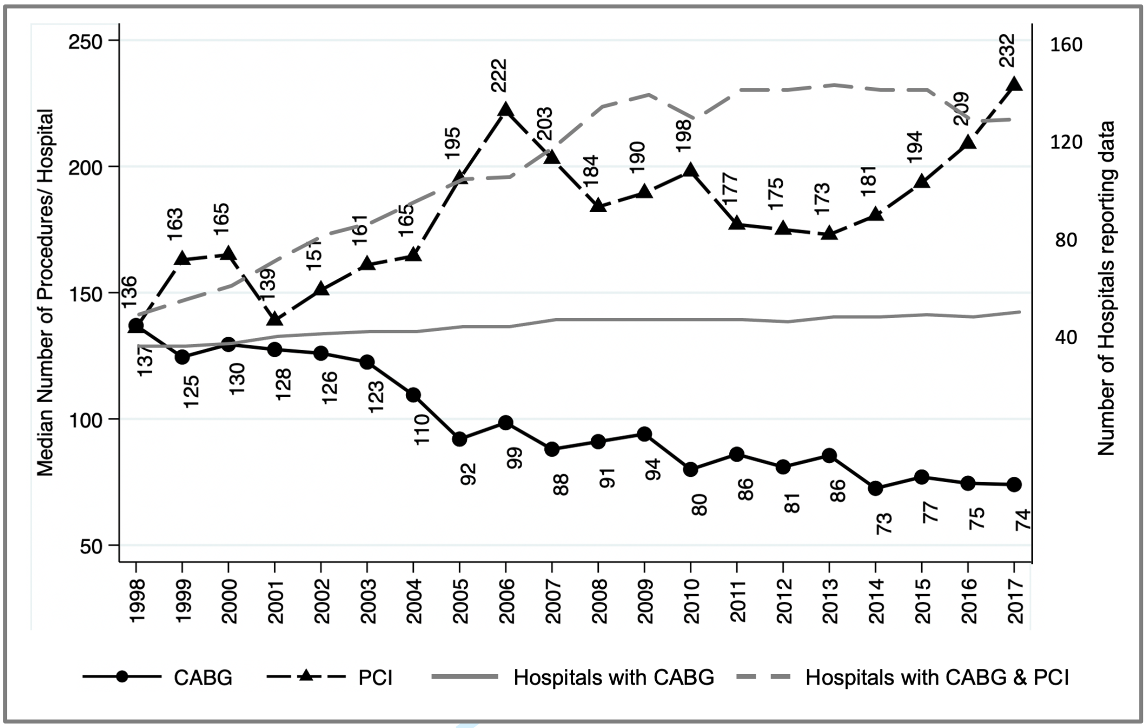
CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. COPD: chronic obstructive pulmonary disease. MI: myocardial infarction. NSTEACS: non-ST elevation acute coronary syndrome. PVD: peripheral vascular disease. CHF: congestive heart failure. CVD: cerebrovascular disease. CKD: chronic kidney disease. ITA: Internal thoracic artery. BMS: implantation of bare metal stent. DES: Implantation of drug eluting stent. AUC Area Under the Curve.

Table 5. Variables included in the model to estimate expected in-hospital mortality after CABG and PCI.

	Model to detect factors associated for in hospital mortality after CABG	Model to detect factors associated for in hospital mortality after PCI
Variables	Spanish region, Groups of hospitals according to the volume of CABG/year-center, COPD, Age ranges, Sex, Previous MI, NSTEACS on admission, PVD, CVD, Diabetes, CKD, Previous CABG, Previous PCI, Off-Pump, CHF, bilateral ITA, High blood pressure	CABG on site, Spanish region, Groups of hospitals according to the volume of PCI/year-center, COPD, Age ranges, Sex, Previous MI, NSTEACS on admission, PVD, CVD, Diabetes, CKD, Previous CABG, Previous PCI, BMS, DES, CHF, high blood pressure.
AUC	0.74 (95%CI 0.73;0.75)	0.81 (95%CI 0.81;0.82)

CABG: coronary artery bypass grafting. PCI: percutaneous coronary intervention. COPD: chronic obstructive pulmonary disease. MI: myocardial infarction. NSTEACS: non-ST elevation acute coronary syndrome. PVD: peripheral vascular disease. CHF: congestive heart failure. CVD: cerebrovascular disease. CKD: chronic kidney disease. ITA: Internal thoracic artery. BMS: implantation of bare metal stent. DES: Implantation of drug eluting stent. AUC Area Under the Curve.

Figure 6. Median Number of Procedures/Hospital- year and Number of Hospitals reporting data to MBDS.



Left axis: median procedures/hospital. Right axis: number of hospitals reporting data to MBDS

Table 6. Number of hospitals and volume of procedures/hospital in each study period

	1998-2002	2003-2007	2008-2012	2013-2017	p(LT)
Median number of hospitals/year					
(+)CABG(+)PCI	37(36;40)	44(42;44)	47(47;47)	48(45;50)	<0.001
(-)CABG(+)PCI	25(19;32)	61(54;62)	93(88;95)	96(77;99)	<0.001
Median number of procedures/center-year					
CABG	130.5(102;163)	103(73;145)	89(58;120)	75.5(50.5;114)	<0.001
PCI	148(58;249)	195(77;334)	186(71;340)	198(80.5;350.5)	<0.001
Mortality according to hospital volume of procedures					
Hospital Volume of CABG					
Low Volume	330/3866(8.5)	206/3053(6.8)	87/2406(3.6)	74/2079(3.6)	<0.001
Low-Intermediate	411/5511(7.5)	322/4671(6.9)	170/4272(4)	108/3901(2.8)	<0.001
Low-High	530/7149(7.4)	345/6984(4.9)	226/6446(3.5)	172/5694(3)	<0.001
High	469/9156(5.1)	352/9524(3.7)	265/8376(3.2)	222/8708(2.6)	<0.001
Hospital Volume of PCI					
Low Volume	18/3259(0.6)	31/6004(0.5)	45/7613(0.6)	65/8052(0.8)	0.04
Low-Intermediate	67/8160(0.8)	155/17226(0.9)	204/21446(1)	264/23081(1.1)	0.003
Low-High	172/15950(1.1)	426/33545(1.3)	682/45088(1.5)	758/47881(1.6)	<0.001
High	296/30869(1)	745/61896(1.2)	1225/84334(1.5)	1140/80415(1.4)	<0.001

Table 3. Data are shown as n(%) or median and IQR. CABG: "Coronary Artery Bypass Grafting". PCI: "Percutaneous Coronary Intervention. (+)CABG(+)PCI: Hospitals with CABG and PCI: (-)CABG(+)PCI. Hospitals without CABG but with PCI.

The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	Title	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	**Article Summary** Title **Article Summary** NA
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction		
Objectives	3	State specific objectives, including any prespecified hypotheses	Introduction		
Methods					
Study Design	4	Present key elements of study design early in the paper	**Article Summary**		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Materials and Methods		

Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case	Materials and Methods	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	Materials and Methods and Supplemental material NA NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	Materials and Methods and Supplemental Material	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Materials and Methods and supplemental material
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Materials and Methods and Supplemental Material		

Bias	9	Describe any efforts to address potential sources of bias	Materials and Methods (Statistical Analysis)		
Study size	10	Explain how the study size was arrived at	Materials and Methods & Figure 1		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	Materials and Methods		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses	Materials and Methods (Statistical Analysis)		
Data access and cleaning methods		..	Materials and Methods	RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	Materials and Methods and Introduction

				RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	Materials and Methods. Figure 1.
Linkage		..	NA	RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram	Results. Section: 2 *Study Population*". Figure 1.	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	Results. Section: 2 *Study Population*". Figure 1.
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)	Results. Section: "*Study Population"* Table 1. Supplemental material.		
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure	Results. Section "Mortality"		

		category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Results. Table 2. Section: "Mortality"		
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	NA		
Discussion					
Key results	18	Summarise key results with reference to study objectives	Discussion. Par 1.		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion. Par 1 "Limitations" section	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	Discussion. Par 1 "Limitations" section
Interpretation	20	Give a cautious overall interpretation of results considering objectives,	Discussion. Par 1 "Conclusion" section		

		limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA		
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Footnotes		
Accessibility of protocol, raw data, and programming code		..	Footnotes	RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	Footnotes

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.