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Comparing the use of coronary revascularization in France and the United States: Divergent trends

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ABSTRACT

Background: Coronary revascularization is a key treatment for coronary artery disease (CAD). Over the past 15 years, several randomized trials have shown that it failed to improve life expectancy in most patients with stable CAD.
Aim: To compare trends in the use of coronary revascularization from 2012 to 2018 in France and the United States (US).
Methods: Administrative databases were used in both countries to identify patients ≥ 35 years of age, hospitalized for CAD or congestive heart failure (CHF) undergoing coronary artery bypass graft (CABG) or percutaneous coronary intervention (PCI), as identified from the International Classification of Diseases coding system. Independent correlates of the use of coronary revascularization were also investigated.
Results: In France, from 2012 to 2018, coronary revascularization increased by 13.3% among patients aged 35–64 years and by 24.6% among those aged ≥ 65 years. In contrast, in the US, it decreased by 16.3% and 19.6%, respectively. These trends were mainly related to the use of PCI: +15.8% and +28.8% in France versus–17.6% and–20.4% in the US. These divergent trends could not be explained solely by changes in the number of hospitalizations for CAD/CHF. In both countries and for both periods, use of revascularization was independently related to age, number of medical diagnoses, sex and income.
Conclusion: Divergent trends in the use of coronary revascularization were observed in France and the US that could not be explained by trends in the number of CAD/CHF hospitalizations, nor by differences in the correlates of its use.

1. Introduction

In France and the United States (US), mortality rates of patients with coronary artery disease (CAD) and myocardial infarction have been moderately declining for the past decade, but it continues to be a leading cause of death in both countries [1–5]. Although the use of medical management has increased for patients with recognized heart disease, revascularization procedures – percutaneous coronary intervention (PCI) and coronary artery bypass graft (CABG) – remain primary tools for improving quality of life [6–9]. Importantly, key trials of myocardial revascularization in stable patients – the results of which have

Abbreviations: ACA, Affordable Care Act; AHRQ, Agency for Healthcare Research and Quality; CABG, coronary artery bypass graft; CAD, coronary artery disease; CHF, congestive heart failure; HCUP, Healthcare Cost and Utilization Project; ICD-9-CM, International Classification of Diseases, ninth revision, Clinical Modification; ICD-10-CM, International Classification of Diseases, tenth revision, Clinical Modification; ICD-9-PCS, International Classification of Diseases, ninth revision, Procedure Coding System; ICD-10-PCS, International Classification of Diseases, tenth revision, Procedure Coding System; NIS, National Inpatient Sample; PCI, percutaneous coronary intervention; PMSI, Programme de Médicalisation des Systèmes d'Information; US, United States.

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been known since the late 2000s – show no improvements in life expectancy or the risk of acute myocardial infarction for most stable patients [10–12]. This should have resulted in a limitation of the use of revascularization procedures in both countries. Previous studies in the US have found large disparities in the use of coronary revascularization by race and ethnicity, socioeconomic status, sex and insurance status [13,14]. Whether similar disparities may be observed in France has not been extensively studied.

Previous research comparing the use of revascularization procedures in France and the US generated two notable findings. Despite the frequent assumption that patients in the US are more likely to receive surgical interventions than patients in France (or other health systems in Europe), patients with heart disease are actually more likely to receive revascularization in France than in the US [15]. This appears to be due, in part, to the fact that patients without health insurance, those covered by US public insurance, racial and ethnic minorities, and people living in lower income neighbourhoods are far less likely to undergo revascularization in the US, even after they have been hospitalized with heart disease, than privately insured, White patients living in wealthier neighbourhoods [16–20]. Secondly, sex differences have been observed in both countries, with women less likely than men to undergo revascularization [21].

The literature comparing the use of revascularization in France and the US, however, is out of date. Since the last comparison was published, the role of medical management in the prevention and treatment of heart disease has increased, particularly regarding lipid-lowering treatment use, as has the use of lifestyle interventions (diet and exercise, smoking cessation). Whether the use of revascularization among patients with heart disease in France and the US has changed with the more widespread use of preventive measures therefore remains unknown. Even after the adoption of Medicare Part D in 2003 and the Patient Protection and Affordable Care Act (ACA) of 2010, French patients enjoy greater access to drugs than Medicare beneficiaries in the US [22]. As patients in France have better access to drugs, one might hypothesize a greater decline in the use of revascularization procedures in France than in the US. On the other hand, there is evidence that the French healthcare system has promoted – through financial incentives for the institutions – a greater use of several healthcare interventions (both non-surgical [23] and revascularization procedures [24]) during the past decade. This trend may have led to an increased use of revascularization.

The purpose of the present analysis was to compare trends from 2012 to 2018 in age-adjusted hospitalization rates for CAD or congestive heart failure (CHF), and the rates of coronary revascularization (CABG and/or PCI) in France and the US. In addition, potential changes in independent correlates of the use of myocardial revascularization from 2012 to 2018 were analysed from the French and US data.

2. Methods

2.1. Data sources

In order to identify hospitalizations of patients aged ≥ 35 years with diagnoses of CAD and/or CHF and coronary revascularizations in France and the US, we relied on hospital administrative data from both countries. In France, data are from the French Hospital Discharge Database (Programme de Médicalisation des Systèmes d'Information [PMSI]), which centralizes hospital discharge data by diagnosis, procedure, age and residence of patients. The PMSI includes data from all hospitals (public and private). This database contains approximately 30 million hospital stays per year, representing around 15 million patients admitted in hospitals at least once a year. The use of this database for setting hospital budget targets may encourage high levels of data quality in terms of coherence, accuracy and exhaustiveness.

In the US, data are from the Agency for Healthcare Research and Quality (AHRQ)'s National Inpatient Sample (NIS) of the Healthcare Cost and Utilization Project (HCUP). The NIS includes data from more than 7 million hospital stays each year, drawn from all states participating in the HCUP, which covers more than 97% of the US population. The AHRQ has created weights that allow estimates for the entire US. Thus, once the NIS data are weighted, it estimates more than 35 million hospitalizations nationally per year and captures diagnoses, procedures, length of stay, status at discharge and demographic and health insurance information for every hospitalization. The NIS data are routinely used to provide estimates of hospitalizations and hospital procedures in the US [25,26]. To determine age-adjusted population rates, we relied on data from the 2012 and 2018 French and US censuses with weights derived from the 2010 US Census.

To identify the diagnoses of patients in the US for the year 2012, we used International Classification of Diseases, ninth revision, Clinical Modification (ICD-9-CM) codes. For the year 2018 in the US and both years in France, we used International Classification of Diseases, tenth revision, Clinical Modification (ICD-10-CM) codes. We focused on CAD and CHF to identify the appropriate patient pool for this study for two reasons. First, these were patients for whom coronary revascularization may be an appropriate procedure. Second, in a previous analysis of our data, either a diagnosis of CAD or a diagnosis of CHF as part of ischaemic heart disease captured more than 99% of the revascularization procedures.

Table 1
ICD codes for diagnoses and procedures.

ICD-9-CM diagnosis codes	ICD-10-CM diagnosis codes
CAD and/or CHF	
401, 402, 404, 410–414.9, 428, 429	I10, I11, I13, I20–I25, I46.2, I46.9, I51, I70,
ICD-9-CM procedure codes	ICD-10-PCS procedure codes
Coronary revascularization	
00.66, 36.03–36.19, 36.31, 36.39	0210x, 0211x, 0212x, 0213x, 0270x, 0271x, 0272x, 0273x, 02C0x, 02C1x, 02C2x, 02C3x, 02Q0x, 02Q1x, 02Q2x, 02Q3x

CAD: coronary artery disease; CHF: congestive heart failure; ICD: International Classification of Diseases; ICD-9-CM: International Classification of Diseases, 9th revision, Clinical Modification; ICD-10-CM: International Classification of Diseases, 10th revision, Clinical Modification; ICD-10-PCS: International Classification of Diseases, 10th revision, Procedure Coding System.

2.2. Identification of CABG and PCI

To identify CABG and PCI use, we used the International Classification of Diseases, ninth revision, Procedure Coding System (ICD-9-PCS) for the year 2012 in the US and the International Classification of Diseases, 10th Revision, Procedure Coding System (ICD-10-PCS) for the year 2018 in the US. For France, we used the French Common Classification of Medical Procedures (Classification Commune des Actes Médicaux) and for both years. The specific diagnoses and procedure codes used are listed in Table 1 .

2.3. Statistical analyses

For both years, and in both countries, we conducted multiple logistic regression analysis to assess factors associated with coronary revascularization for hospitalized patients admitted with CAD and/or CHF. Models estimated the probability that patients aged ≥ 35 years with these discharge diagnoses received a revascularization procedure (PCI or CABG). For both countries, we ran models in which the independent variables were age category (35–64 and ≥ 65 years), sex, number of diagnoses on the record and median household income quartile of the patient (based

on postal codes). As a sensitivity test, we also ran versions of the models that included age as a continuous variable along with the variable 'age squared', to take account of a possible inverted U shape, in addition to the continuous age variable, because the probability of revascularization increases between the ages of 35 and 75 years and decreases thereafter due to increasing frailty. Analyses were performed using IBM SPSS 29.1 software. P values < 0.05 were considered statistically significant.

2.4. Regulatory aspects

The analysis presented in this paper relies on hospital administrative data from France and the US. The hospital administrative datasets include de-identified data from individual patients. The datasets do not include the names of patients and the only geographic identifier included in the dataset is postal code of residence. It is not possible to use these secondary data to re-identify or re-contact any person represented in the dataset. For the US, the HCUP dataset from the AHRQ on which we relied is exempt from Institutional Review Board review. For France, this study was approved by the National Committee for data protection: declaration of conformity to the methodology of reference 05 obtained on 7 August 2018 under the number 2204633 v0.

3. Results

3.1. Hospital admissions for CAD and/or CHF

Between the years 2012 and 2018, the age-adjusted rates of hospitalizations with CAD and/or CHF among US patients aged 35–64 years decreased by 6.5% (Table 2). Among French patients of the same age, the age-adjusted rate of hospitalization with CAD and/or CHF increased by 4.5%. Among US patients aged ≥ 65 years, this rate decreased by 15.8%, while it increased by 9.4% among French patients.

3.2. Trends in the use of coronary revascularization

In the US, the use of coronary revascularization decreased by 17.9% overall from 2012 to 2018 among patients aged ≥ 35 years, with larger reductions among those aged ≥ 65 vs 35–64 years and for PCI vs CABG (Table 2). However, in France, the use of coronary revascularization increased by 19.1% overall, with a large increase in the use of PCI and a reduction in the use of CABG.

Although the use of PCI increased among patients treated in public and private hospitals, the increase was particularly noticeable for patients treated in public hospitals in France and could not be explained by the lesser increase in hospitalizations for CAD/CHF compared with private institutions (Table 3).

3.3. Independent correlates of the use of coronary revascularization

In 2012 and 2018, age, sex, number of diagnoses and income quartile (based on postal code of residence) were all statistically significantly associated with coronary revascularization in France and the US (Table 4). In the US, women were 45% and 46% less likely to undergo coronary revascularization than men in 2012 and 2018, respectively. The odds of undergoing coronary revascularization were 17% lower among people living in the lowest versus highest income quartile postal codes in both years. In France, women were 45% less likely to undergo coronary revascularization than men in both years. The odds of undergoing coronary revascularization were 13% and 11% lower among people living in the lowest versus highest income quartile postal codes in 2012 and 2018, respectively.

In both countries, the odds of undergoing coronary revascularization were considerably lower for patients aged ≥ 65 vs 35–64 years (Table 4). This reflects the fact that the use of revascularization decreases after the age of 75 years in both countries. With the alternative model that included age as a continuous variable and the variable 'age squared' (Table A.1), the odds of revascularization increased by 11–20% for each additional year of age. These findings reflect the fact that the odds of revascularization continue to increase until the age of 75 years in both countries, and then decline.

4. Discussion

In France, there were modest increases in hospitalizations for CAD and CHF among patients in both the 35–64 and ≥ 65 years cohorts. During the same time period, there were larger increases in the use of revascularization among patients in both age cohorts, particularly among the population aged ≥ 65 years. This increase was solely due to an increase in the rate of PCIs (+15.8% in younger patients and +28.8% in older patients), whereas the rate of CABG procedures decreased slightly. In contrast, hospital admissions for CAD and/or CHF in the US decreased, and there was an even greater decrease in coronary revascularization (−16.3% in younger patients and −19.6% in older patients).

The increase in hospitalizations for CAD among older patients and the large increase in the use of PCI in France are consistent with a study that examined trends in CABG and PCI from 2017 to 2022 in France [27]. However, these results stand out, not only in contrast to the US, but to other European nations. In the European Union, over the period from 2015 to 2020, the majority of member states with available data recorded a decrease in the use of PCI [28]. Significantly, the steep increase in the use of PCI for older French patients (+28.8%) is disproportionate with the increase in the prevalence of hospitalization for CAD/CHF (+9.4%).

Among hypotheses that might explain the increase in the French rate of PCIs among the older population is the fact that this procedure is characterized by greater uncertainty as to its effectiveness, which is why it is characterized by greater geographic variations in practice [29], reflecting discretion among cardiologists and their interventional colleagues who perform these procedures. Probably more importantly, the reimbursement incentives affecting hospitals and interventional cardiologists make it possible that over the 2012–2018 period, hospitals and interventional cardiologists grew more proficient in exploiting France's activity-based (T2A) system of financing acute hospital services. A previous analysis found that the T2A system, which has been in place since 2004, has been associated with an increase in hospital activity, particularly 'technical' activity [30]. In particular, the implementation of the T2A system is associated with a large increase in surgical stays. The same study found that the T2A was associated with a 'significant increase in the rate of 30-day readmissions among patients receiving the main types of cardiovascular and cancer treatments' and concluded that these changes were likely the result of supplier-induced demand.

Although this system was first adopted in 2004, it may have had a lagged effect on changes in the use of revascularization, particularly the use of PCI. Over the past 20 years, cardiologists in private hospitals have faced attractive financial incentives to increase procedures such as PCIs. Likewise, in public hospitals, because of the implementation of T2A, cardiologists have faced the same incentives and physicians have faced pressure by hospital managers to increase productivity as a way of maintaining their service unit's infrastructure and even improving it. The fact that the increase in PCI was larger among patients in public hospitals (Table 3) is consistent with the idea that the implementation of the T2A has contributed to the increase in the use of these procedures because this policy most likely resulted in a greater change in the incentives faced by public hospitals. PCIs remain an important source of revenue generation for hospitals. One difference between France and the US is that French cardiologists enjoy greater clinical autonomy than their US counterparts in being held to follow clinical guidelines by healthcare insurers and professional societies, particularly with respect to procedures characterized by greater discretion in standards of appropriate use.

Table 2
Age-adjusted[a] rates (per 100,000) of coronary revascularizations and hospitalizations with CAD and/or CHF in France and the US in 2012 and 2018.

	2012		2018		Change in age-adjusted rates (%)
	n	Age-adjusted rates (per 100,000)	*n*	Age-adjusted rates (per 100,000)	
US					
CAD and/or CHF					
≥ 35 years	5,609,070	3194.4	5,492,275	2783.3	–12.8
35–64 years	1,712,020	1334.7	1,666,635	1248.1	–6.5
≥ 65 years	3,897,050	8936.0	3,825,640	7518.6	–15.8
Coronary revascularization					
≥ 35 years	705,155	410.0	652,570	336.5	–17.9
35–64 years	336,890	263.0	292,765	220.2	–16.3
≥ 65 years	368,265	858.1	359,805	690.2	–19.6
CABG					
≥ 35 years	198,595	115.1	199,510	100.2	–12.9
35–64 years	84,915	65.7	80,310	59.1	–10.0
≥ 65 years	113,680	266.1	119,200	225.7	–15.2
PCI					
≥ 35 years	530,440	308.7	480,975	250.2	–18.9
35–64 years	260,375	203.8	221,730	167.9	–17.6
≥ 65 years	270,065	628.3	259,245	500.3	–20.4
France					
CAD and/or CHF					
≥ 35 years	398,545	943.9	469,444	1011.4	+7.2
35–64 years	154,513	570.4	163,307	595.9	+4.5
≥ 65 years	244,032	2085.8	306,137	2282.4	+9.4
Coronary revascularization					
≥ 35 years	139,467	339.0	183,255	403.6	+19.1
35–64 years	59,999	221.6	68,946	251.2	+13.3
≥ 65 years	79,468	696.3	114,309	867.6	+24.6
CABG					
≥ 35 years	15,068	36.6	15,293	33.7	–7.9
35–64 years	6052	21.9	5625	20.1	–8.2
≥ 65 years	9016	81.4	9668	75.2	–7.6
PCI					
≥ 35 years	124,670	303.0	168,318	370.6	+22.3
35–64 years	54,052	200.0	63,464	231.6	+15.8
≥ 65 years	70,618	616.4	104,854	794.1	+28.8

CABG: coronary artery bypass graft; CAD: coronary artery disease; CHF: congestive heart failure; PCI: percutaneous coronary intervention; US: United States.
[a] Age adjustment was based on the 2010 US Census population.

In the US, concerns about healthcare spending and variations in the practice of medicine have led health insurers to put pressure on providers to reduce hospitalizations and the use of high-cost procedures. Over the past two decades, the French health system provided hospitals with a financial incentive to increase service volume and has not engaged in the US 'crusade' to reduce volume [31]. In contrast to France, between 2012 and 2018, US hospitalizations for CAD, CHF and revascularization fell at a higher rate than the reduction in heart disease deaths. These findings are consistent with the clinical literature on the growth of medical management of heart disease [32].

Our analysis, based on administrative data that do not include clinical information, cannot account for individual patient characteristics that may influence the decision to proceed with hospital admission or with a PCI, unlike the study in France based on the ENCOCHE Registry, which included patients with coronary chronic total occlusions [33]. Differences in individual characteristics among the US and French patients, however, seem an unlikely explanation for the differences in PCI trends. Differences in patients' values and preferences in France and the US seem equally implausible.

Independent correlates of revascularization were common to France and the US and were similar for both time periods. In the US and in France, and in both time periods, women were less likely than men to undergo revascularization. Despite efforts to promote awareness of heart disease among women, the sex differences in the two countries are nearly identical and did not change over the study period. The lack of clinical data and the limited number of variables used in the analysis, however, render any extrapolation from these results hazardous. As we limited the logistic regressions to patients aged ≥ 35 years who were hospitalized with CAD and/or CHF, the differences cannot easily be explained by the well-known differences in heart disease by sex [34]. Part of the difference in the use of revascularization according to sex, however, may rely in the different nature of CAD in women and men, with higher rates of non-obstructive CAD in women.

Age as a continuous variable was associated with an increased risk of revascularization. However, analysis by age group showed a 'protective' effect for the highest age group (≥ 65 years) compared to the reference group (35–64 years). This difference can be explained by a non-linear relationship between age and risk, as well as by the choice of reference category and the loss of information resulting from age categorization. The introduction of a quadratic term for age made it possible to account for the non-linearity of the association between age and risk. The age-squared term was significant, indicating that the effect of age varied according to age level, which explains the differences observed between age modelled continuously and in classes. We think that this econometric approach may also be useful because it anticipates the curve of the relationship between age and revascularization in both countries.

Table 3
Changes from 2012 to 2018 in age-adjusted rates (per 100,000) of hospitalizations with CAD and/or CHF, and coronary revascularization in France according to the status (public versus private) of the hospital.

	Change in age-adjusted rates (%)		
	Overall	Public[a]	Private
CAD and/or CHF			
≥ 35 years	+7.2	+5.1	+10.9
35–64 years	+4.5	+3.5	+6.3
≥ 65 years	+9.4	+6.4	+14.5
Coronary revascularization			
≥ 35 years	+19.1	+21.9	+14.7
35–64 years	+13.3	+15.9	+9.3
≥ 65 years	+24.6	+28.5	+19.4
CABG			
≥ 35 years	–7.9	–4.6	–14.0
35–64 years	–8.2	–3.4	–17.6
≥ 65 years	–7.6	–5.7	–11.0
PCI			
≥ 35 years	+22.3	+25.4	+17.8
35–64 years	+15.8	+18.1	+11.9
≥ 65 years	+28.8	+33.6	+22.8

CABG: coronary artery bypass graft; CAD: coronary artery disease; CHF: congestive heart failure; PCI: percutaneous coronary intervention.

[a] Includes private non-profit hospitals that are part of the 'service public hospitalier'.

There is greater income inequality in the US and a higher proportion of lower income patients in the US. Even after the implementation of the ACA, patients in the US face greater barriers to healthcare services than patients in France. There are statistically significant differences by neighbourhood income in France as in the US. These differences are even larger in the US, but fell after the implementation of the ACA [35]. It is possible that this decline reflects a greater use of medical management and appropriate treatment of disease. It is not possible for us to evaluate this hypothesis with hospital administrative data alone. It is clear that inequities, by sex and place, remain high.

Our study has obvious limitations, as already mentioned, regarding the analysis of correlates of the use of coronary revascularization. Beyond the limitations associated with the use of an administrative database and the fact that clinical data were not available, important potential incentives for physicians performing revascularization procedures, such as the type of professional regime (100% salaried versus receiving personal fees for procedures) were also not available. Moreover, we do not have any variables in either country data set that would allow us to assess residual confounding. However, we were able to identify exhaustive and accurate variables available in both countries to see whether these factors, which could influence revascularization, emerged in the same way and changed over two different years. In addition, the main analysis, i.e. an epidemiologic description of temporal trends in the use of revascularization procedures in both countries, is indisputable.

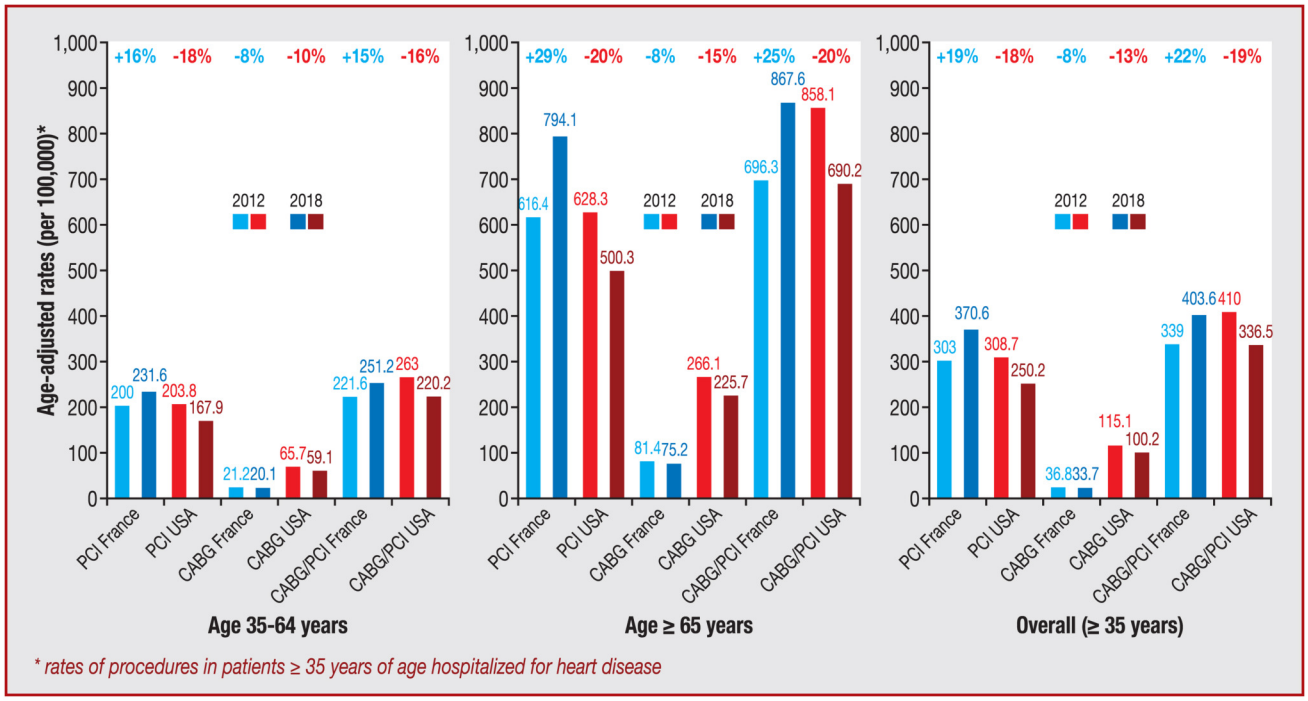
5. Conclusions

Divergent trends were observed over the 2012–2018 period between the US and France. In the US, hospital admissions for CAD and/or CHF decreased, and revascularization procedures decreased even more markedly. In France, hospital admissions increased and revascularization procedures increased more markedly. Our findings suggest the need for more research on the regulatory and financial differences in the two countries, which may explain these divergent trends (Central illustration).

Table 4
Independent correlates of coronary revascularization among patients hospitalized with CAD and/or CHF in France and the US, 2012 and 2018, with age as a binary variable.

Variable	US				France			
	2012		2018		2012		2018	
	P	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)
Age	< 0.001		< 0.001		< 0.001		< 0.001	
35–64 years		1		1		1		1
≥ 65 years		0.495 (0.492–0.498)		0.562 (0.559–0.562)		0.789 (0.778–0.800)		0.834 (0.823–0.845)
Number of diagnoses on the record	< 0.001	0.926 (0.926–0.927)	< 0.001	0.940 (0.939–0.940)	< 0.001	1.041 (1.041–1.043)	< 0.001	1.031 (1.030–1.032)
Sex	< 0.001		< 0.001		< 0.001		< 0.001	
Male		1		1		1		1
Female		0.550 (0.547–0.553)		0.541 (0.538–0.545)		0.546 (0.538–0.555)		0.555 (0.547–0.563)
Income (from postal code)	< 0.001		< 0.001		< 0.001		< 0.001	
4th quartile		1		1		1		1
3rd quartile		0.991 (0.983–0.998)		0.999 (0.999–1.007)		0.939 (0.921–0.958)		0.956 (0.940–0.973)
2nd quartile		0.968 (0.961–0.976)		0.951 (0.943–0.958)	0.917 (0.899–0.935)		0.944 (0.927–0.961)	
1st quartile		0.827 (0.821–0.833)		0.830 (0.824–0.836)	0.875 (0.858–0.892)		0.889 (0.874–0.905)	

CAD: coronary artery disease; CHF: congestive heart failure; CI: confidence interval; OR: odds ratio; US: United States.



Central illustration. Trends in the use of PCI, CABG and either procedure in France and the US from 2012 to 2018. CABG: coronary artery bypass graft; PCI: percutaneous coronary intervention; US: United States. *Rates of procedures in patients aged ≥ 35 years hospitalized for heart disease.

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Author contribution statement

Conceptualization: MKG, VGR, CQ. Methodology: MKG, VGR, JC, CQ. Statistical analysis: MKG, JC. Supervision: MKG, VGR, CQ. Writing – original draft: MKG, VGR. Writing – review and editing: DW, JC, ND, CQ.

Disclosure of interest

The authors declare that they have no competing interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.acvd.2026.02.002.

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