Increasing rates of angioplasty versus bypass surgery in Canada, 1994-2005

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Background Percutaneous coronary intervention (PCI) is increasingly being offered to patients with coronary artery disease. The purpose of this study was to determine the impact of this change in coronary revascularization strategy on PCI and coronary artery bypass grafting (CABG) utilization across Canada.

Methods All cases of PCI and isolated CABG between years 1994 and 2005 were identified through the Canadian Institute for Health Information. Age- and sex-standardized rates of PCI and CABG per 100,000 population as well as PCI-to-CABG ratios were calculated by year and province and across age, sex, income, diabetes, and recent acute coronary syndrome subgroups. In addition, risk-adjusted rates of in-hospital mortality after PCI and CABG were reported by year.

Results Between 1994 and 2005, PCI rates increased from 85.6/100,000 to 186.7/100,000 ($P < .001$), whereas CABG rates remained stable (75.6/100,000-70.8/100,000; $P = .43$), resulting in an increase in PCI-to-CABG ratio (1.13-2.64; $P < .001$). Significant increases in PCI-to-CABG ratios were seen across all provinces (except Newfoundland and Alberta), as well as across all age, sex, income, diabetes, and recent acute coronary syndrome categories. Decline in risk-adjusted in-hospital mortality was seen after both CABG (3.9%-2.2%; $P < .001$) and PCI (1.6%-1.3%; $P < .001$) but appeared larger after CABG.

Conclusions Since 1994, rates of PCI have increased significantly as compared to CABG. During the same period, greater declines in risk-adjusted rates of in-hospital mortality were seen among CABG versus PCI patients. Further study is needed to determine the appropriateness of PCI and CABG rates in terms of clinical outcomes and resource utilization. (Am Heart J 2010;160:958-65.)

Since its introduction in 1977, the practice of percutaneous coronary intervention (PCI) has changed considerably. Despite its established efficacy in the treatment of patients with acute coronary syndrome (ACS),[1,2] recent registry data from the United States demonstrated that most PCI procedures were performed electively in patients with stable coronary artery disease.[3] Furthermore, where PCI was traditionally offered only to patients with discrete coronary lesions and single-vessel coronary artery disease, significant advancements in catheter-based technology, radiographic imaging, and stent composition and deployment have allowed for the use of PCI in patients with diffuse lesions, multivessel disease, and left main disease.[4-7]

Numerous studies from the United States, Europe, and Asia have demonstrated a dramatic rise in rates of PCI relative to coronary artery bypass grafting (CABG),[6,8-19] with some pointing to a stabilization or even decline in rates of CABG in recent years.[6,8-12] Similar trends were seen across Canada between 1997 and 2001.[20,21] Since that time, however, the practices of both PCI and CABG have changed in Canada, with increased adoption of drug-eluting stents[22] and heightened utilization of multiple arterial grafting[23] and off-pump surgical techniques,[24] respectively. Little is known regarding the effect of these changes on previously observed trends in coronary revascularization. The objective of this study was to provide a current examination of PCI and CABG rates across Canada.

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Methods

Data sources

All cases of PCI and CABG between fiscal years 1994 and 2005 were identified through the Canadian Institute of Health Information, a government-run, administrative data-collecting agency that compiles records of acute care hospital admissions and same-day procedures in all Canadian provinces and territories. This allowed for the capture of all PCI and CABG procedures performed either during an admission to hospital or as a same-day procedure. Fiscal years will be referred to herein by the calendar year in which the relevant fiscal year started.

Baseline characteristics

Baseline data regarding age, sex, and each of the comorbidities listed in the Charlson comobidity index[25,26] were collected for all patients using information available from the index hospitalization. Rates of recent admission to hospital for an ACS (*International Classification of Diseases, Ninth Revision* [*ICD-9*] codes 410, 411, and 413 and *ICD-10* codes I20, I21, I22, I23.82, and I24) in the 6 months before the procedure were determined as well. To identify recent admission for ACS, a valid health card number that enabled linkage with prior hospitalization records was required. Valid health card numbers were available in all except the following provincial jurisdictions and fiscal years: Nova Scotia, 1994; Manitoba, 2001 to 2003; Saskatchewan 1994 to 1997; and Quebec, 2005. Finally, data regarding socioeconomic status were collected for all patients. A 5-category definition of income adequacy as developed by Statistics Canada[27] based on the Canadian 2001 census data was used to provide an aggregate measure of individual income status and to assign each patient an appropriate income quintile.

Procedure rates

To provide a comprehensive assessment of procedure utilization, all cases of PCI and isolated CABG performed between fiscal years 1994 and 2005 were identified using relevant Canadian Classification of Diagnostic, Therapeutic, and Surgical Procedures codes (PCI: 48.02, 48.03, 48.09; CABG: 48.11 to 48.19) and Canadian Classification of Health Interventions codes (PCI: 1IJ50, 1IJ57; CABG: 1IJ76). Cases performed in patients <20 and >105 years of age or in a hospital where <10 CABG and/or 10 PCI cases were performed per year were excluded. All remaining cases were considered for analysis. This included cases of first-time and repeat revascularization as well as cases performed in patients in whom multiple PCI and/or CABG procedures were performed during the study period. Cases were assigned to the patient's province of residence and not the province in which the procedure was actually performed.

Crude procedure rates were age and sex standardized using the age and sex distribution of the 1991 Canadian population and expressed as the number of cases per 100,000 persons. Standardized rates were reported by fiscal year and by province. To determine age- and sex-standardized PCI-to-CABG ratios, standardized PCI rates were divided by standardized CABG rates. In addition to reporting overall PCI-to-CABG ratios, PCI-to-CABG ratios stratified by age (20-49, 50-64, 65-74, ≥75 years), age-standardized PCI-to-CABG ratios stratified by sex (male vs female), and age- and sex-standardized PCI-to-CABG ratios stratified by income quintiles, diabetes status (yes vs no), and recent admission for ACS (yes vs no) were reported.

Mortality

To determine whether variations or trends in rates of PCI and CABG were associated with changes in outcomes after either procedure, risk-adjusted rates of in-hospital PCI and CABG mortality were calculated and reported by province and year. Risk-adjusted rates were derived using nonparsimonious multiple logistic regression models that adjusted for differences between patients in age, sex, and Charlson comorbidity index score. Given that most patients undergoing CABG or PCI had experienced an acute myocardial infarction either as part of the index admission or as part of prior admission, the role of "acute myocardial infarction" as a variable that would predict an adverse outcome in this population is significantly lessened. As such, the variable acute myocardial infarction was omitted when calculating the Charlson comorbidity index score. Comorbid disease burden was expressed as percentage of patients with Charlson comorbidity index score of 0, 1, or ≥2. Coding algorithms for defining comorbidities in *ICD-9* and *ICD-10* data as described by Quan et al[28] were used to ensure consistency in estimates of comorbidity prevalence across administrative datasets.

Statistical analysis

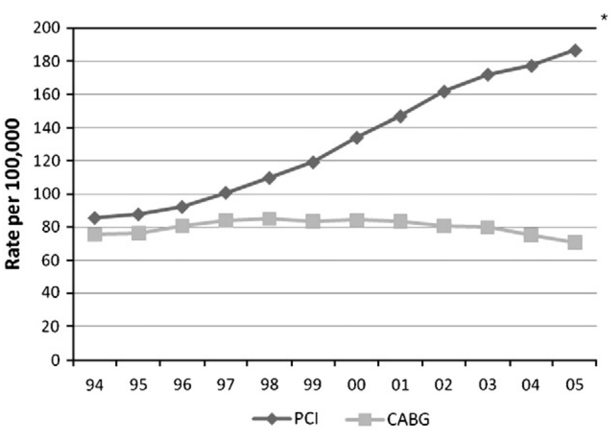
Procedure rates and ratios were compared across time using the analysis of variance statistical test. The F statistic from the regression analysis of variance table, which tests for a linear relationship with a nonzero slope, was used to derive the *p*-trend value. *P*-trend values <.05 were considered statistically significant. All statistical analyses were performed using SAS version 9.1.3 (Cary, NC).

Results

Overall rates of PCI increased from 85.6 per 100,000 in 1994 to 186.7 per 100,000 in 2005 (*p*-trend < .001), whereas rates of CABG appeared to remain stable (1994: 75.6 per 100,000; 2005: 70.8 per 100,000; *p*-trend = .43) (Figure 1). The rise in PCI rates was reflected in an increase in overall PCI-to-CABG ratios from 1.13 to 2.64 (*p*-trend < .001). Upon closer examination of CABG utilization during this time, CABG rates peaked between 1997 (84.2 per 100 000) and 2001 (83.5 per 100 000) before steadily declining until 2005.

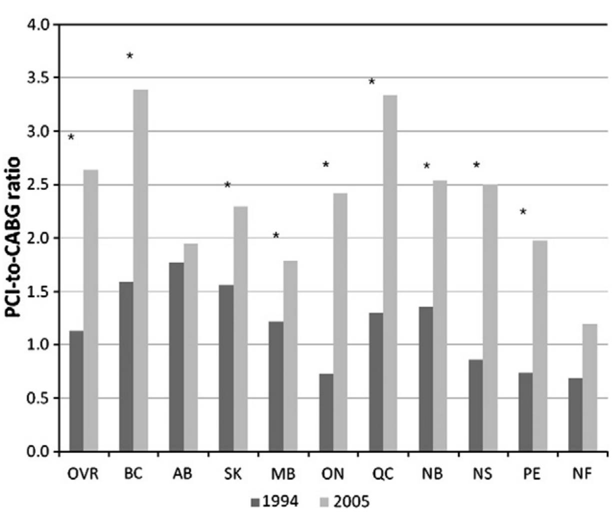
When analyzed by province, significant increases in PCI-to-CABG ratios were seen for all provinces with the exception of Alberta and Newfoundland, where increases in PCI-to-CABG ratios failed to reach statistical significance (Figure 2). Despite near-uniform increases in PCI rates relative to CABG rates, procedure utilization rates as well as PCI-to-CABG ratios differed by province (Table I). Furthermore, the magnitude of increase in PCI-to-CABG ratios differed across provinces such that the order of provinces from lowest PCI-to-CABG ratio to highest changed between 1994 and 2005. For example, Alberta, which possessed the highest PCI-to-CABG ratio in 1994,

Figure 1



Age- and sex-standardized rates of PCI and CABG per 100,000 persons by year, Canada, 1994-2005. *Statistically significant trend at *P* < .05.

Figure 2



Comparing age- and sex-standardized PCI-to-CABG ratios between 1994 and 2005 by province. *OVR*, Overall; *BC*, British Columbia; *AB*, Alberta; *SK*, Saskatchewan; *MB*, Manitoba; *ON*, Ontario; *QC*, Quebec; *NB*, New Brunswick; *NS*, Nova Scotia; *PE*, Prince Edward Island; *NF*, Newfoundland. *Statistically significant trend at *P* < .05.

had the second lowest ratio in 2005, whereas Ontario went from having the second lowest ratio in 1994 to having the fifth highest ratio in 2005.

The PCI-to-CABG ratios were also found to increase across all age, sex, income, diabetes, and recent ACS admission categories (*p*-trend < .001) (Figure 3). These increases were most pronounced in patients between the ages of 20 and 49, males, nondiabetics, and patients with a recent admission for ACS. No difference in the magnitude of PCI-to-CABG ratio increases across income quintiles was appreciated.

Table I. Comparing age- and sex-standardized PCI and CABG rates (per 100 000) and PCI-to-CABG ratios between 1994 and 2005 by province

	PCI		**CABG**		**PCI-to-CABG ratio**	
Province	**1994**	**2005**	**1994**	**2005**	**1994**	**2005**
British Columbia	96.0	183.3	60.4	54.1	1.59	3.39
Alberta	119.0	114.4	67.4	58.7	1.77	1.95
Saskatchewan	100.4	208.8	64.6	90.6	1.56	2.30
Manitoba	75.9	137.3	62.4	76.6	1.22	1.79
Ontario	53.3	179.8	72.6	74.2	0.73	2.42
Quebec	118.1	229.1	90.6	68.5	1.30	3.34
New Brunswick	95.5	172.0	70.1	67.8	1.36	2.54
Nova Scotia	81.3	177.9	94.8	71.1	0.86	2.50
Prince Edward Island	72.2	132.7	98.0	66.9	0.74	1.98
Newfoundland	55.5	136.3	80.3	113.6	0.69	1.20
Total	85.6	186.7	75.6	70.8	1.13	2.64

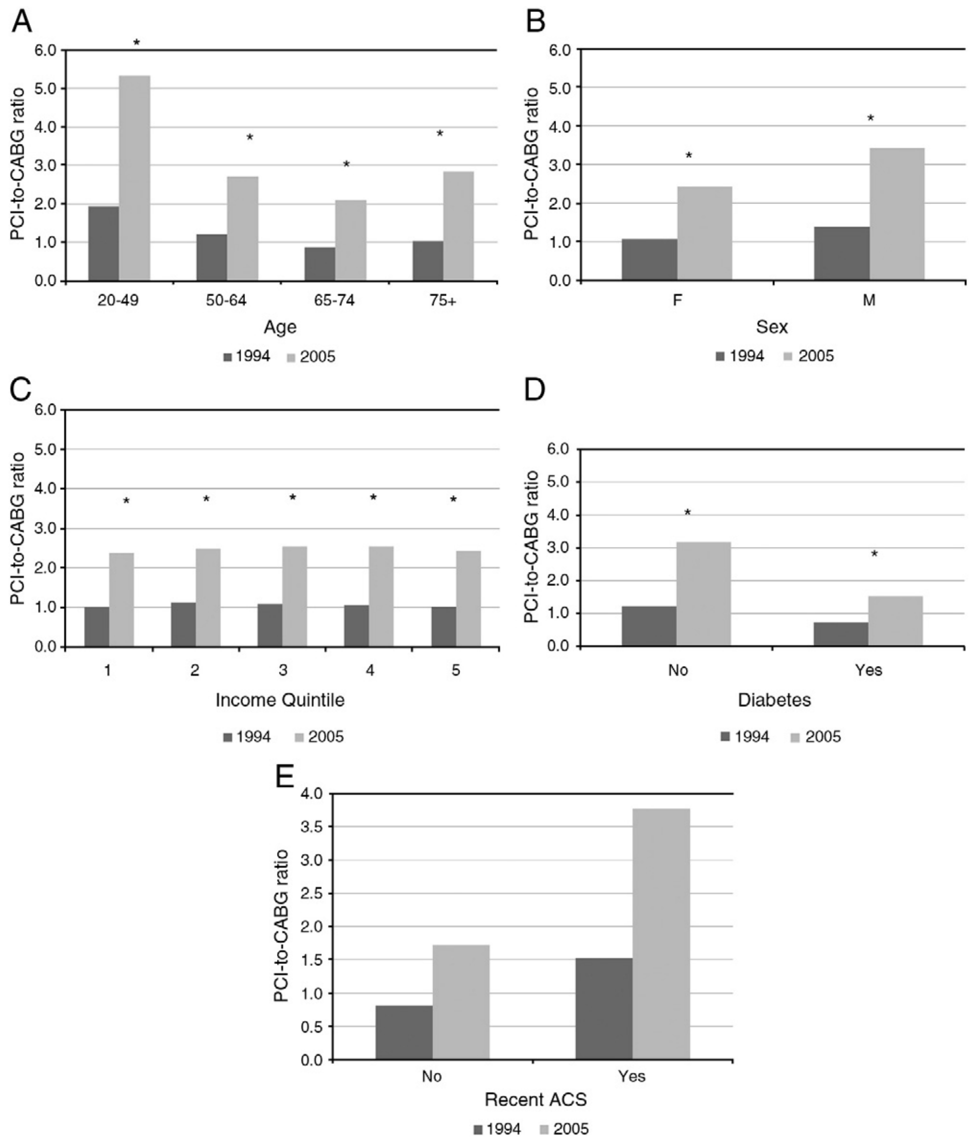
The percentage of patients undergoing either PCI or CABG with age >75 and with ≥2 Charlson comorbidity index score increased over time (Table II). Despite this increase in comorbid disease burden among both PCI and CABG patients, risk-adjusted in-hospital mortality rates after both PCI and CABG declined (*p*-trend < .001) (Figure 4). However, a greater drop in risk-adjusted mortality was noted in outcomes after CABG (1994: 3.9%; 2005: 2.2%) when compared to outcomes after PCI (1994: 1.6%; 2005: 1.3%).

Discussion

During the study period, PCI rates increased significantly, whereas CABG rates appeared to decline. Significant increases in PCI-to-CABG ratios were seen across most provinces, as well as across all age, sex, income, diabetes, and recent ACS admission categories. Decline in risk-adjusted in-hospital mortality was greater after CABG when compared with PCI.

The trends in PCI and CABG utilization demonstrated in this study mirror those seen in other studies from around the world.[6,8-19] The global rise of PCI and fall of CABG have been driven by a number of clinical and nonclinical factors. First, trials such as FRISC-II[29,30] and TACTICS-TIMI-18[31] were among the earliest studies to suggest an aggressive approach in the management of ACS. Coupled with data to support the role of primary angioplasty,[32,33] and more recently rescue angioplasty,[34] early cardiac catheterization, and consequently early PCI, have become an established modalities in patients with symptomatic coronary artery disease. Secondly, the introduction of bare-metal stents and subsequently drug-

Figure 3



Comparing PCI-to-CABG ratios stratified by age **A**, sex **B**, income **C**, diabetes **D**, and recent ACS **E** subgroups between 1994 and 2005. *Statistically significant trend at $P < .05$.

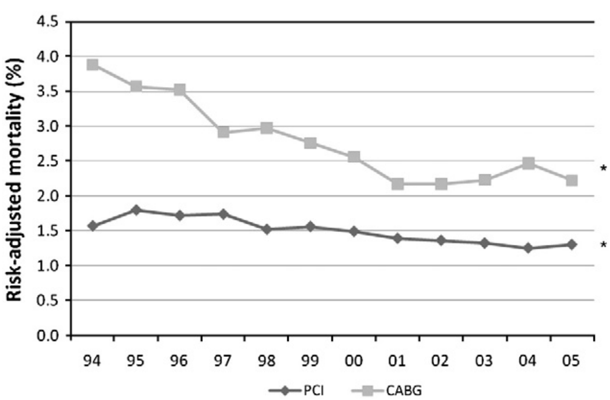
eluting stents has enabled the performance of increasingly complex PCI with reduced rates of short-term adverse events,[5,7,35] a fact reflected in the results of randomized controlled trials, large observational studies, and meta-analyses, which support the equivalence of PCI and CABG in the setting of multivessel disease.[36-41] Thirdly, patient preference for a procedure that is considered less invasive and more apt to incur less interruption of employment and daily activities is a significant driver for PCI over CABG. Finally, provider preference plays an important role in determining which patients are put forward for PCI versus CABG. In a pilot study examining the effect of specialty on panel judgments of the appropriateness of coronary revascularization, Bernstein et al[42] found that cardiologists' ratings were higher for PCI indications and lower for CABG indications than the corresponding ratings of surgeons. Similarly, Denvir et al,[43] in examining variations in decisions to revascularize patients, found surgeons more likely to choose CABG, whereas interventional cardiologists were more likely to choose PCI. Where patients with coronary artery disease are most likely to see a cardiologist before seeing a cardiac surgeon, the decision to proceed with PCI may be the

Table II. Prevalence (%) of clinical and demographic risk variables among patients undergoing PCI and CABG by year, in Canada, 1994-2005

	PCI			CABG		
Variables	**1994**	**2005**	***P***	**1994**	**2005**	***P***
Age, mean ± SD	60.2 ± 11.0	63.6 ± 11.8	<.001	62.8 ± 9.8	65.2 ± 9.9	<.001
Age >75, %	9.0	20.4	<.001	10.0	18.8	<.001
Female, %	28.2	27.8	<.001	22.9	21.0	<.001
Diabetes, %	11.2	16.7	<.001	17.4	29.4	<.001
Charlson Comorbidity Index						
0	77.5	71.3	<.001	63.8	52.8	<.001
1	16.6	18.9	<.001	24.3	27.0	<.001
≥2	5.9	9.8	<.001	11.9	20.2	<.001
Recent admission ACS (<6 m), %*	62.2	56.0	<.001	46.6	36.8	<.001

* Note that data for recent admission for ACS <6 months in 2005 does not include data from the province of Quebec.

Figure 4



Overall risk-adjusted in-hospital PCI and CABG mortality rates across Canada by year. *Statistically significant trend at $P < .05$.

result of provider preference, further leading to increased rates of PCI with a corresponding decline in CABG utilization.

Significant increases in PCI-to-CABG ratios were seen across all provinces, with the exception of Newfoundland and Alberta. Furthermore, PCI-to-CABG ratios, while increasing, appeared to differ between provinces. Such interprovincial differences in procedure rates may be attributable in part to regional variation in cardiovascular risk factor and coronary disease burden.[44,45] However, Hannan et al[46] described significant differences in practice patterns in relation to choice of coronary revascularization across 11 states that were not entirely explained by variation in patient clinical characteristics alone, and Nallamothu et al[47] identified a significantly greater increase in rates of either PCI or CABG in hospital referral regions within the United States where a new cardiac hospital had been built as compared with hospital referral regions where new cardiac programs had been started at general hospitals or no new programs opened. Further study is needed to determine whether nonclinical factors, such as access to cardiac catheterization and primary PCI facilities and regional distribution of cardiac care specialists, are responsible for these Canadian interprovincial differences despite the presence of a universal access health coverage system.

The PCI-to-CABG ratios were found to significantly increase across all age, sex, income, diabetes, and recent ACS subgroups. However, the most pronounced increases were noted among patients between the ages of 20 and 49, males, nondiabetics, and patients with recent ACS. The dramatic increase among younger patients likely speaks to increasing rates of cardiac catheterization in this age group and the resulting discovery of less complex coronary obstructive disease, which would be more amenable to PCI. The gender discrepancy identified in this study further highlights the differential revascularization strategy afforded men and women with cardiovascular disease.[48,49] Women tend to have lower rates of revascularization after admission for ACS.[50] However, the lower rates of revascularization are likely a derivative of the lower rates of cardiac catheterization,[49] which may further serve to explain decreased likelihood that women are to undergo ad hoc or staged PCI procedures. The greater increase in PCI-to-CABG ratio among nondiabetics when compared to diabetics reflects in large part the long-standing effect of the results of the BARI trial[36] on coronary revascularization practice patterns, where inferior survival was noted among diabetics with multivessel disease undergoing PCI when compared to similar patients undergoing CABG. Finally, the finding of increasing PCI-to-CABG ratios among patients with a recent admission for ACS, especially when compared to PCI-to-CABG ratios among patients without a recent admission for ACS, likely reflects the increasing preponderance of literature supporting an early aggressive approach in the management of ACS.[29-33]

Although risk-adjusted in-hospital mortality rates after both PCI and CABG declined over the study period, the decline in risk-adjusted in-hospital mortality was more pronounced among CABG patients, a finding that is impressive given the greater increase in comorbid disease burden in this patient population as reflected by the percentage of patients with Charlson comorbidity index score of ≥2. The improved outcomes seen among both PCI and CABG patients may be attributable to earlier detection of disease using invasive and noninvasive testing, improved interventional and surgical techniques, and advancements in periprocedural pharmacotherapy. However, the greater improvement in CABG outcomes versus PCI outcomes likely speaks to advanced myocardial protection techniques, superior perioperative critical care, and improved patient selection and surgical timing.

The future of coronary revascularization in Canada remains uncertain. One would expect, based on the trends seen between 1994 and 2005, that rates of PCI would continue to rise, whereas rates of CABG would either stabilize or continue to decline. An aging population coupled with high prevalence of cardiovascular disease risk factors[45] would appear to support the increased prevalence of coronary artery disease over time and hence increased rates of either PCI or CABG. However, data from April 2006 to the present are unavailable to us, and these past years have seen the publication of the landmark COURAGE trial, which showed that initial management of patients with stable coronary artery disease with PCI did not reduce the risk of death, myocardial infarction, or other major cardiovascular events when added to optimal medical therapy.[51] These data are felt to be largely responsible for the perceived decline in cardiac catheterization volumes across Canada, which in turn are likely to affect PCI and CABG rates.

In conclusion, between 1994 and 2005, Canadian national PCI rates increased significantly, whereas national CABG rates remained stable. Most provincial jurisdictions exhibited a statistically significant increase in PCI-to-CABG ratios during this period. Further study is needed to identify factors underlying these revascularization trends and whether these factors differ from those found in health care jurisdictions, where universal health care coverage is not implemented. Finally, appropriateness of these trends in terms of long-term patient outcomes and overall cost-effectiveness must be investigated.

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