ABSTRACT

Background: Although appropriate noninvasive cardiac tests (NICTs) after an acute coronary syndrome (ACS) provide useful prognostic information, inappropriate use leads to inefficient expenditure of existing healthcare resources. By using the Alberta Contemporary Acute Coronary Syndrome Patient Invasive Treatment Strategies (COAPT) Registry, we evaluated the use and costs of NICTs among patients discharged within 1 year after ACS.

Methods: All patients discharged from the hospital with a primary diagnosis of ACS in Alberta between 2004/2005 and 2015/2016 were included. Frequency of NICTs (stress tests [± imaging] and nonstress imaging tests) was determined from linked provincial databases. Costs were obtained from the Alberta Health Care Insurance Plan Medical Procedure List.

Results: Of 55,516 patients with ACS, 30,760 had at least 1 NICT (55.4%), with 13,505 (24.3%) having >1 NICT performed within 1 year. Temporal trends of NICT increased over time (stress tests: P trend < 0.001; nonstress imaging tests: P trend < 0.001). NICT most often involved exercise electrocardiogram (ECGE) and stress echocardiography (ECNE) performed within 1 year of the index event; however, inappropriate use could lead to inefficient use of limited healthcare resources. In addition, different testing modalities offer varying strengths and weaknesses, which can often lead to multiple tests ordered without added value. Existing guidelines in ACS do provide guidance when NICT is indicated,3-6 however, guideline recommendations may not have lasting effects in clinical practice. This may be due, in part, to the limited evidence supporting these recommendations after an ACS. Furthermore, inappropriate NICT may be influenced by a multitude of factors, including the lack of knowledge of previously completed investigations, patient requests for NICT to establish comfort with their current health status, and the perceived incentives of fee-for-service clinical billings.

As such, it has become important to assess use and costs of these tests in contemporary clinical practice. Using the Alberta Contemporary Acute Coronary Syndrome Patient Invasive Treatment Strategies (COAPT) Registry, we evaluated use and costs of diagnostic cardiac tests among patients discharged within 1 year after ACS.

Original Article

Utilization and Costs of Noninvasive Cardiac Tests After Acute Coronary Syndromes: Insights From the Alberta COAPT Study

Kevin R. Bainey, MD, MSc,a,b Daniel Durham, BSc,a,b Yinggan Zheng, MA, Med,b Cynthia M. Westerhout, PhD, b Padma Kaul, PhD,a,b and Robert C. Welsh, MDa,b

a Division of Cardiology, Mazankowski Alberta Heart Institute, University of Alberta, Edmonton, Alberta, Canada
b The Canadian VIGOUR Centre, University of Alberta, Edmonton, Alberta, Canada

Despite improvements in early invasive management coupled with contemporary pharmacotherapy, acute coronary syndrome (ACS) studies still report recurrent event rates of approximately 10% within 1 year of the index event.1,2 Appropriate noninvasive cardiac tests (NICTs) may provide useful prognostic information and risk stratification to reduce recurrent events; however, inappropriate use could lead to inefficient use of limited healthcare resources. In addition, different testing modalities offer varying strengths and weaknesses, which can often lead to multiple tests ordered without added value. Existing guidelines in ACS do provide guidance when NICT is indicated;3-6 however, guideline recommendations may not have lasting effects in clinical practice. This may be due, in part, to the limited evidence supporting these recommendations after an ACS. Furthermore, inappropriate NICT may be influenced by a multitude of factors, including the lack of knowledge of previously completed investigations, patient requests for NICT to establish comfort with their current health status, and the perceived incentives of fee-for-service clinical billings.

As such, it has become important to assess use and costs of these tests in contemporary clinical practice. Using the Alberta Contemporary Acute Coronary Syndrome Patient Invasive Treatment Strategies (COAPT) Registry, we evaluated use and costs of diagnostic cardiac tests among patients discharged within 1 year after ACS.
commonly occurred within the first 4 months after hospital discharge (stress tests at 2 months; nonstress imaging tests at 3-4 months). In 2015/2016, the total estimated costs of NICT were $1.35M, a 22.4% increase from 2004/2005 (1.10M) (P < 0.001), whereas a decrease in incidence of ACS over the same time period was noted (P = 0.008).

Conclusions: Rates of NICT 1 year after ACS are high and increasing over time. Estimated costs of NICT appear to be escalating out of proportion to the ACS growth. Further investigation is warranted because it is speculative whether the increase in NICT and costs results in clinical benefit after ACS.

Methods

Study design and population

This was a retrospective, population-based cohort of all patients 18 years and older who were hospitalized and discharged alive with a primary diagnosis of ACS in Alberta, Canada, between April 1, 2004, and March 31, 2016. ACS hospitalizations were identified using the following International Classification of Diseases 10th Edition (ICD-10) codes: unstable angina: I20.0; non-STEMI: I21.4; and STEMI: I21.0, I21.1, I21.2 or I21.3. Concurrent ACS hospitalizations of the same patient occurring within 24 hours were considered as belonging to the same episode. The first ACS episode during the study period was considered as the index ACS episode (if multiple ACS episodes occurred per patient). We excluded individuals who died before discharge from the hospital and patients residing outside of Alberta. This study met the local requirements for ethics approval.

Data source and linkage

Data from the Alberta Ministry of Health used for this study, linked using a unique patient identifier, have been described. In brief, these include (1) the Discharge Abstract Database, which contains diagnostic and treatment information, length of stay, and discharge status for patients admitted to a hospital in Alberta; (2) the National Ambulatory Care Reporting System database, which includes information on emergency department or outpatient clinic visits and mode of arrival; and (3) the Alberta Health Care Insurance Registry, which tracks the vital status of all residents of Alberta. The Discharge Abstract Database and National Ambulatory Care Reporting System databases record up to 25 and 10 diagnosis fields, respectively, that are classified according to the ICD-10 codes. Because Alberta has a government-funded single-payer healthcare system with universal access, these datasets capture all patient interactions with the healthcare system.

Exposures and other covariates

NICTs were identified using the following ICD 9th Revision/ICD 10 code: exercise stress test (EST): 2HZ08EJ, 03.41A, 03.41B, 03.41C, pharmacologic stress test (PST): 2HZ08EK, 03.41D, 03.44A; echocardiography (ECHO): 3IP30, 3HZ30, X213, X215, X216, X217, X306, X307, 02.82A; cardiac myocardial perfusion imaging (MPI): 3IP70CC, 3IP70CE, 3IP70KG, 3IP70KGs, X170, X171; cardiac magnetic resonance imaging (MRI): 3IP40; and cardiac computed tomography (CT): 3IP20. Prices of cardiac tests were based on the Schedule of Medical Benefits in Alberta as of January 1, 2017.

Statistical analysis

Baseline patient characteristics were divided according to no tests, stress test (± imaging [ECHO, MPI, or MRI]) and nonstress imaging tests (ECHO, MPI, CT, or MRI without stress component), and presented as median and interquartile range or mean and standard deviation for continuous variables and number (percentage) for categorical variables. Differences among groups were tested using the Kruskal–Wallis test for continuous variables and chi-square test for categorical variables. Temporal trends over years were tested using the Cochran–Armitage test.

To examine factors associated with first NICT (stress test and nonstress imaging test as 1 group), a stepwise (P ≤ 0.20 as “in” criteria and P ≤ 0.05 as “out” criteria) multivariable logistic regression model was developed using available patient characteristics plus year of index ACS. Odds ratios with corresponding 95% confidence intervals and Wald statistic of the final model were reported.

The level of statistical significance was set at α < 0.05. Statistical analyses were performed using SAS version 9.4 (SAS Institute, Inc, Cary, NC).

Results

Of the 55,516 patients discharged alive from the hospital with ACS, 34.0% had unstable angina, 47.1% had NSTEMI, and 18.9% had STEMI. Of these, 30,760 patients had at least 1 NICT (55.4%), with 13,505 (24.3%) having > 1 NICT performed within 1 year. Of the stress tests [± imaging] performed, 3368 (6.1%) were pharmacologically induced. Of the nonstress imaging tests, 96.5% were ECHO, 7.5% were cardiac MPI, 5.1% were cardiac MRI, and 1.0% were cardiac CT.
ACS, acute coronary syndrome; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; IQR, interquartile range; MI, myocardial infarction; NICT, noninvasive cardiac test; NSTEMI, non–ST-elevation myocardial infarction; PCI, percutaneous coronary intervention; SD, standard deviation; STEMI, ST-elevation myocardial infarction.

*P* values are for comparison among no test, stress test, and nonstress imaging test groups.

In follow-up, 10.4% of patients died after the index ACS event at 1 year (death from index hospital discharge to 1 year). Of patients who survived their ACS and were discharged from the hospital, those with no subsequent NICT had the highest mortality (20.5%) but were noted to have the greatest baseline risk. Lower rates of 1-year mortality were observed in those with at least 1 NICT (2.3%).

**Patient characteristics**

Patient characteristics and treatment received during the index ACS hospitalization according to NICTs received are depicted in Table 1. Patients who did not receive any NICTs within 1 year of ACS were older, more commonly female, and more likely to have comorbidities. More commonly, these patients were treated conservatively without revascularization. The patients who received a stress test were younger and less likely to be female, and had a lower comorbid burden. These patients were more likely to have a percutaneous coronary intervention (PCI) as their treatment during the index ACS episode. Patients receiving a nonstress cardiac imaging test were older and had a higher likelihood of comorbidities. More commonly, these patients were treated with coronary artery bypass grafting for their index event.

**Temporal trends**

As depicted in Figure 1A, NICTs were commonly used in acute coronary syndrome (ACS) events. Figure 1B depicts the temporal trends of use of individual NICTs received within 1 year of ACS. Patients who did not receive any NICTs are shown in Table 1. Patients who received a nonstress imaging test had the greatest baseline risk. Lower rates of 1-year mortality were observed in those with at least 1 NICT (2.3%).

**Time to first NICT**

The first NICT was most often performed within 4 months of discharge from index ACS (Fig. 2). Stress tests were more common and peaked at 2 months, whereas nonstress imaging tests (lower proportion) were mostly performed between 2 and 4 months after discharge.

**Estimated costs**

From 2004/2005 to 2015/2016, the total estimated costs of NICTs have increased 22%, with estimated costs exceeding $20,516 in 2004/2005 to $47,946 in 2015/2016, *P* trend < 0.001) and nonstress imaging test (8.5% in 2004/2005 to 14.6% in 2015/2016, *P* trend < 0.001) use appears to be increasing over time in the follow-up of patients with ACS within 1 year (Fig. 1A).

With regard to the frequency of specific NICT (Fig. 1B), ESTs have steadily increased from 38.9% in 2004/2005 to 46.3% in 2015/2016 (*P* trend < 0.001), whereas PSTs have decreased over time from a peak of 9.7% in 2007/2008 to 5.3% in 2015/2016 (*P* trend < 0.001). As for nonstress imaging tests, ECHO rates have increased substantially from 8.5% in 2004/2005 to 14.1% in 2015/2016 (*P* trend < 0.001) 1 year after discharge for ACS and currently occupy the majority of nonstress imaging tests. Conversely, MPI (nonstress) declined from 18.4% in 2004/2005 to 11.6% in 2015/2016. As shown in Figure 1C, approximately one-half of patients with ACS who receive a NICT will undergo additional tests, a pattern that appears consistent over time.

### Table 1. Baseline patient characteristics and treatment during index ACS hospitalization according to NICT received within 1 year

| Comorbidity                        | All patients | No test      | Stress test  | Nonstress imaging test | P value* |
|------------------------------------|--------------|--------------|--------------|-------------------------|----------|
| **Age, y (mean, SD)**              | 66.3 (13.9)  | 71.1 (14.3)  | 61.0 (11.5)  | 67.2 (13.3)             | < 0.001  |
| **Unstable angina**                | 18,876 (34.0)| 6637 (26.8)  | 9693 (40.5)  | 2546 (37.4)             | < 0.001  |
| **NSTEMI**                         | 26,145 (47.1)| 12,920 (52.2)| 10,149 (42.4)| 3076 (45.1)             | < 0.001  |
| **STEMI**                          | 10,495 (18.9)| 5199 (21.0)  | 4104 (17.1)  | 1192 (17.5)             | < 0.001  |
| **Female gender, n (%)**           | 20.1%        | 21.7%        | 17.8%        | 22.2%                   |          |
| **Prior MI**                       | 6281 (11.3)  | 3497 (14.1)  | 1910 (8.0)   | 874 (12.8)              | < 0.001  |
| **Heart failure**                  | 7374 (13.3)  | 4425 (17.9)  | 1494 (6.2)   | 1455 (21.4)             | < 0.001  |
| **Peripheral vascular disease**    | 2168 (3.9)   | 1280 (5.2)   | 552 (2.3)    | 336 (4.9)               | < 0.001  |
| **Cerebrovascular disease**        | 1496 (2.7)   | 911 (3.7)    | 356 (1.5)    | 229 (3.4)               | < 0.001  |
| **Dementia**                       | 1479 (2.7)   | 1339 (5.4)   | 50 (0.2)     | 90 (1.3)                | < 0.001  |
| **COPD**                           | 5871 (10.6)  | 3343 (13.5)  | 1657 (6.9)   | 871 (12.8)              | < 0.001  |
| **Rheumatic disease**              | 638 (1.1)    | 321 (1.3)    | 206 (0.9)    | 111 (1.6)               | < 0.001  |
| **Pepic ulcer disease**            | 463 (0.8)    | 242 (1.0)    | 134 (0.6)    | 87 (1.3)                | < 0.001  |
| **Liver disease**                  | 345 (0.6)    | 198 (0.8)    | 91 (0.4)     | 56 (0.8)                | < 0.001  |
| **Diabetes**                       | 14,373 (25.9)| 7149 (28.9)  | 5184 (21.6)  | 2040 (29.9)             | < 0.001  |
| **Paralysis**                      | 270 (0.5)    | 188 (0.8)    | 37 (0.2)     | 45 (0.7)                | < 0.001  |
| **Renal disease**                  | 3552 (6.0)   | 2238 (9.0)   | 628 (2.6)    | 486 (7.1)               | < 0.001  |
| **Cancer**                         | 1402 (2.5)   | 930 (3.8)    | 293 (1.2)    | 179 (2.6)               | < 0.001  |
| **Charlson score (median, SD)**    | 1.6 (1.3)    | 1.5 (1.3)    | 0.8 (1.2)    | 1.4 (1.6)               | < 0.001  |
| **Charlson score (median, IQR)**   | 0 (0, 2)     | 0 (0, 2)     | 0 (0, 1)     | 1 (0, 2)                | < 0.001  |
| **Rural residence, n (%)**         | 11,149 (20.1)| 5563 (21.7)  | 4271 (17.8)  | 1515 (22.2)             | < 0.001  |
$1.35 million (CAD) yearly in 2015/2016 ($P < 0.001$) (Fig. 3A, purple), which have increased to a larger degree than the occurrence of incident ACS events (overall decrease in incidence of ACS, $P = 0.008$). The cost trends for both stress tests and nonstress imaging tests appear to increase over time (Fig. 3A), with the majority of these costs attributed to EST and ECHO (Fig. 3B).
Factors associated with the use of NICT

As shown in Table 2, male gender and urban residence were significantly associated with a higher likelihood of receiving a NICT. In contrast, older patients with comorbidities such as diabetes, prior MI, peripheral vascular disease, chronic obstructive pulmonary disease, liver disease, paralysis, renal disease, and cancer were less likely to receive a NICT. Of note, patients with an index invasive procedure (vs a conservative approach) more commonly received a follow-up NICT. Finally, the year of the index ACS event (latter year) (2004/2005-2015/2016) was associated with a higher likelihood of receiving a NICT within the year after discharge.

Discussion

In a large comprehensive provincial registry with a single-payer, government-funded healthcare system, approximately one-half of patients with ACS receive at least 1 NICT within the first year of their index event. Moreover, one-quarter underwent multiple NICTs within the first year. Over time, a greater number of NICTs are being performed for patients with ACS after discharge, with the majority of these performed within the first 4 months. Finally, over time, estimated costs of NICTs appear to be escalating out of proportion to the ACS patient population. As such, further investigation is warranted to address the optimal use of limited healthcare financial resources, specifically related to NICT use in patients with ACS.

It is interesting to note that older patients and those with comorbidities were less likely to receive NICT. Although for many patients this may be considered justified, there may be a cohort of patients who would be at higher risk for recurrent events and may benefit from further testing after an ACS. As such, there may be a risk-treatment paradox in patients with ACS, an observation that has been demonstrated previously. Conversely, we found lower-risk patients were more likely to receive NICTs, of which the utility may be of limited benefit.

Our finding of 55.4% of patients with ACS receiving at least 1 NICT (the majority being stress tests) within 1 year after ACS deserves attention. Although stress tests have potential attributes, the clinical benefit still remains largely unknown. This is particularly relevant in an era of rapid reperfusion for STEMI and an early invasive approach in non—ST-elevation ACS coinciding with advancements in evidence-based pharmacotherapy. In a large registry of U.S. patients receiving PCI (National Cardiovascular Data Registry CathPCI Registry, 2005-2007), in which 62% of enrolled patients presented with an ACS, diagnostic testing was common after revascularization but was not associated with a lower risk of death or MI. Among the 10,293 Veterans Affair patients with PCI (more than one-half had ACS), 21.8% had a stress test within 1 year (most being performed with PST [79.8%]), yet stress testing rates did not correlate with improved survival. In 112,691 patients with PCI (39.1% with MI) performed in Ontario, Canada, 59.8% had at least 1 stress test performed within 2 years; however, only 5.9% underwent subsequent coronary angiography and only 3.1% received repeat revascularization within 60 days of the stress test. Thus, these data suggest a low yield of routine stress testing to alter clinical practice or improve patient outcomes.

Similar arguments can be made for risk stratification of patients with ACS with nonstress imaging tests to assess left ventricular function. Largely based on historic studies, left ventricular systolic dysfunction was associated with increased mortality at 6 months and 1 year, but limited to the small number of patients with a left ventricular ejection fraction of $\leq 30\%$. In the current era, a minority of patients with ACS present with severe left ventricular dysfunction or
develop it during their index event, yet the majority of patients with ACS routinely receive outpatient nonstress imaging tests. These higher-risk patients arguably could be identified on the basis of clinical presentation and standard inpatient investigation (in-hospital left ventricular assessment) and selected for outpatient nonstress imaging tests, which would still align with current ACS guidelines and would preclude subsequent nonstress imaging tests for those with normal (or near normal) left ventricular function. This could support a cost-effective strategy of tailored use of clinically appropriate NICTs, while avoiding the broad application of these tests for all patients with ACS.

Particularly alarming are the increasing trends toward a greater number of NICTs being performed in patients with ACS. Of particular concern are the frequent and increasing use of ESTs (most common stress test) and increasing rates of ECHOs performed (the most common stress imaging test), which has nearly doubled over the study period. Although functional testing is used in cardiac rehabilitation assessment and for the development of exercise prescriptions (and not for functional ischemia in many cases), in our opinion these should not be used as a diagnostic EST for defining myocardial ischemia and should not be clinically billed. Moreover, if an EST is performed in cardiac rehabilitation, it should be made widely available for clinicians to review in the outpatient setting, which currently is a challenge in Alberta. However, more than one-half of patients with ACS do not participate in cardiac rehabilitation. Data from the Edmonton zone found only 43% of European Canadians with coronary disease attended cardiac rehabilitation (despite efforts); thus, a considerable number of these tests are performed in clinical follow-up, which needs to be curtailed. With the emergence of more sophisticated forms of NICTs (ie, positron emission tomography, cardiac MRI, stress ECHO), it has become more attractive to routinely risk stratify patients noninvasively with the aim of reducing subsequent cardiac events. However, these advancements in cardiac testing may not be justified given the equivocal benefits of NICTs 1 year after ACS. As such, further efforts are required to promote appropriate NICTs, while curtailing inappropriate investigations in

![Figure 3. Cost of NICTs over years (A). Cost of NICTs over years according to type of test (B).](image-url)
clinical practice given the lack of sustainability of increasing healthcare expenditure, particularly in a government-funded single payer health system.

The development of guidelines for appropriateness of NICTs after an ACS is of paramount importance because they do not currently exist. However, the American College of Cardiology Foundation Appropriateness Use Criteria for cardiac tests in stable ischemic heart disease have been developed and report testing in asymptomatic patients to be rarely appropriate.16 Of note, a recent Canadian study of > 3 million MPIs from 2000 to 2015 found a significant decline in MPI rates associated with the publication of the 2009 Appropriate Use Criteria statement in stable ischemic heart disease. This translated to a cost savings of CAD$72 million for the province of Ontario.17 Although limited to a single imaging modality, this study emphasizes the economic impact that lies in development of Appropriate Use Criteria guidelines. In our study, the escalating costs of NICTs appears out of proportion to the growth in the ACS patient population, and ascertainment of these findings should prompt funding authorities to reexamine quality metrics in a cost-efficient manner after ACS.

It is of interest to note the 10% mortality in our population-based observational cohort of patients with ACS at 1 year. Although ACS mortality has declined over time,18 long-term mortality remains a concern. In the Worchester Heart Attack Study of patients with acute MI between 1997 and 2005, the 1-year postdischarge mortality did decrease over time; however, in 2005 the case fatality rate was still 8.4% for STEMI and 18.7% for NSTEMI.19 Thus, further efforts are required to improve survival in these patients; however, the role of NICT in mitigating these outcomes is still unclear.

### Study strengths and limitations

Our study has some strengths and limitations. We acknowledge this is mainly a descriptive analysis of NICTs in Alberta. Still, the trends of increasing use after ACS and the estimated costs (using Alberta Health Care Insurance Plan Medical Procedure List data) are unique and provide useful data for governmental bodies faced with higher costs of provincial healthcare budgets. In our opinion, our data support further investigation into the use of NICTs to identify those patients who would truly benefit. Moreover, further exploratory analyses are required to determine whether the increased trend of NICTs is justified but speculative. This is an observational analysis using administrative datasets, which may be susceptible to residual unmeasured confounders (ie, comorbidities precluding NICTs). There may have been some NICTs performed outside of the province and would not have been captured. The detailed clinical interpretations of NICTs were not available, making it difficult to assess the patients who may derive benefit. Conversely, it is difficult to comment on the use of these tests for identifying patients who are low risk. Thus, the absence of interpretive results makes it difficult in determining the diagnostic yield of these tests after ACS. However, our intent for the current analysis was to provide a descriptive analysis on the use, trends, and costs of NICTs, which we believe provides support for further exploratory analyses. Last, patient outcomes were not explored in depth because this was beyond the scope of the current study.

### Conclusion

In patients who are discharged from the hospital with an ACS, rates and costs of NICTs within the year are high and appear to be increasing at a pace much faster than Alberta's ACS growth. Given the financial costs and burden on provincial health budgets, further investigation is warranted because it is speculative whether the increase in cardiac tests and costs results in clinical benefit after ACS.

### Disclosures

The authors have no relevant conflicts of interest to disclose.

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**Table 2. Factors significantly associated with use of NICT (includes stress test and nonstress imaging test)**

| Risk Factor                          | Wald chi-square | Odds ratio (95% CI) | P value |
|--------------------------------------|-----------------|---------------------|---------|
| Age, per 10-y increase               | 2437.58         | 0.69 (0.69-0.70)    | < 0.001 |
| Male                                 | 117.57          | 1.25 (1.20-1.30)    | < 0.001 |
| Diabetes                             | 71.89           | 0.84 (0.80-0.87)    | < 0.001 |
| Prior MI                             | 40.22           | 0.83 (0.78-0.88)    | < 0.001 |
| Peripheral vascular disease          | 22.18           | 0.80 (0.73-0.88)    | < 0.001 |
| COPD                                 | 31.80           | 0.84 (0.79-0.90)    | < 0.001 |
| Liver disease                        | 16.83           | 0.62 (0.49-0.78)    | < 0.001 |
| Paralysis                            | 20.12           | 0.53 (0.40-0.70)    | < 0.001 |
| Renal disease                        | 75.08           | 0.70 (0.65-0.76)    | < 0.001 |
| Cancer                               | 58.46           | 0.63 (0.56-0.71)    | < 0.001 |
| Urban vs rural                       | 71.93           | 1.21 (1.16-1.27)    | < 0.001 |
| Index invasive (PCI/CABG) vs medical management | 1885.20 | 2.33 (2.24-2.42)    | < 0.001 |
| Year of index ACS from 2004 to 2015, per year | 53.92 | 1.02 (1.01-1.03)    | < 0.001 |

ACS, acute coronary syndrome; CABG, coronary artery bypass grafting; CI, confidence interval; COPD, chronic obstructive pulmonary disease; MI, myocardial infarction; NICT, noninvasive cardiac test; PCI, percutaneous coronary intervention.
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