Mis-estimation of coronary lesions and rectification by SYNTAX score feedback for coronary revascularization appropriateness

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Abstract

Background: Imprecise interpretation of coronary angiograms was reported and resulted in inappropriate revascularization. Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery (SYNTAX) score is a comprehensive system to evaluate the complexity of the overall lesions. We hypothesized that a real-time SYNTAX score feedback from image analysts may rectify the mis-estimation and improve revascularization appropriateness in patients with stable coronary artery disease (CAD).

Methods: In this single-center, historical control study, patients with stable CAD with coronary lesion stenosis ≥50% were consecutively recruited. During the control period, SYNTAX scores were calculated by treating cardiologists. During the intervention period, SYNTAX scores were calculated by image analysts immediately after coronary angiography and were provided to cardiologists in real-time to aid decision-making. The primary outcome was revascularization deemed inappropriate by Chinese appropriate use criteria for coronary revascularization.

Results: A total of 3245 patients were enrolled and assigned to the control group (08/2016–03/2017, $n = 1525$) or the intervention group (03/2017–09/2017, $n = 1720$). For SYNTAX score tertiles, 17.9% patients were overestimated and 4.3% were underestimated by cardiologists in the control group. After adjustment, inappropriate revascularization significantly decreased in the intervention group compared with the control group (adjusted odds ratio [OR]: 0.83; 95% confidence interval [CI]: 0.73–0.95; $P = 0.007$). Both inappropriate percutaneous coronary intervention (adjusted OR: 0.82; 95% CI: 0.74–0.92; $P < 0.001$) and percutaneous coronary intervention utilization (adjusted OR: 0.88; 95% CI: 0.79–0.98; $P = 0.016$) decreased significantly in the intervention group. There was no significant difference in 1-year adverse cardiac events between the control group and the intervention group.

Conclusions: Real-time SYNTAX score feedback significantly reduced inappropriate coronary revascularization in stable patients with CAD.

Clinical trial registration: Nos. NCT03068858 and NCT02880605; https://www.clinicaltrials.gov.

Keywords: Real-time SYNTAX score; Coronary revascularization; Appropriate use criteria; Quality improvement

Introduction

The revascularization strategy is determined by evaluating the complexity of the overall lesions in coronary angiography. However, many studies demonstrated that the mis-estimation may occur in visual assessment of coronary angiography, which may result in inappropriate revascularization.[1,2] For example, Leape *et al*[3] found that imprecise reading of angiogram led to an overestimation of appropriate use of coronary artery bypass graft (CABG) by 17% and of percutaneous trans-luminal coronary angioplasty by 10%.

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Although quantitative coronary angiography was developed for this issue, this technique can only assess stenosis and lesion length.[4] Methods to resolve the mis-estimation of overall lesion severity for improving procedural appropriateness were warranted.

Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery (SYNTAX) score is a tool to comprehensively evaluate the overall severity of coronary lesions based on visual interpretation of angiogram in patients with at least one ≥50% coronary stenosis.[5] Similarly, prior studies have noted considerable discrepancy in SYNTAX score calculation between angiographic core laboratories and cardiologists as well as inter- and intra-observer variability among cardiologists.[6-10] Such disagreement has been shown to affect therapeutic decisions.[11]

Thus, we hypothesized that a real-time SYNTAX score feedback by trained image analysts could be a method to rectify the mis-estimation of overall lesions severity. And this study was aimed to investigate whether the real-time SYNTAX score feedback reduced inappropriate coronary revascularization in patients with stable coronary artery disease (CAD). We also assessed whether the score feedback was associated with clinical outcomes.

Methods

Ethical approval

Our study protocol was approved by the Institutional Review Board of the National Center for Cardiovascular Diseases (Beijing, China, Certification No. 2016-778). All eligible patients provided informed consent for this study before undergoing coronary angiography.

Study design

This study was designed as a single-center, historical control study and was registered at ClinicalTrials.gov (NCT03068858). Study recruitment occurred concurrently with an angiographic registry (NCT02880605).

Participants

Twelve cardiologists, each with more than 100 percutaneous coronary interventions (PCIs) per year, participated in this study. Patients with stable CAD according to the National Cardiovascular Data Registry CathPCI criteria (stable angina, no or silent myocardial ischemia) and at least one coronary lesion stenosis ≥50% according to elective coronary angiography were eligible for study inclusion. Exclusion criteria included prior coronary artery bypass graft (CABG), staged PCI, and revascularization with no corresponding indication in the Chinese Appropriate Use Criteria for coronary revascularization (AUC) [Supplementary Material 1.1, http://links.lww.com/CM9/A225].

Study groups and intervention

After providing informed consent, patients undergoing elective coronary angiography by the participating cardiologists were consecutively enrolled in an angiography registry (NCT02880605) for data collection, which included baseline questionnaires and medical record abstraction. Eligible patients were subsequently enrolled in this study of SYNTAX score feedback. From August 2016 to March 2017 (the control period), patients who met study eligibility criteria were assigned to the control group. Twelve participating cardiologists assessed the SYNTAX score for these patients by visual estimation immediately after their coronary angiographies. When deciding upon the therapeutic strategy, the participating cardiologists maintained routine decision-making patterns based on their own subjective assessment [Supplementary Figure 1, http://links.lww.com/CM9/A225.

From March 2017 to September 2017 (the intervention period), patients were consecutively enrolled in the intervention group. During this period, participating cardiologists waited for the SYNTAX score calculation from the image analysts after coronary angiography. The scores were independently calculated online by the image analysts in the Imaging Core Lab. These image analysts conducted routine calibration assessments to verify the accuracy of their calculation [Supplementary Material 1.2, http://links.lww.com/CM9/A225]. The scores were provided to the participating cardiologists as a reference for decision-making [Supplementary Figure 1, http://links.lww.com/CM9/A225]. All participating cardiologists maintained autonomy in the decision-making process.

Data collection

Patients' demographic, clinical, and procedural characteristics were collected via baseline questionnaires and medical record abstraction through the coronary angiography registry (NCT02880605). Seniority and annual procedural volume (January 2016 to December 2016) of participating cardiologists were collected as baseline information.

During the control period, we collected cardiologists' subjective assessments of the SYNTAX score during coronary angiography. After angiography, the scores were recalculated and recorded by the image analysts who were blinded to the patients' baseline characteristics. During the intervention period, SYNTAX scores were calculated and recorded by the image analysts during the intervention process.

Follow-up process

All participants in the present study were followed up by telephone or mail by the research staff using standard procedures and forms at 1 year. In the event that patients reported any adverse events after hospital discharge, their medical records were reviewed for further confirmation by independent clinicians.

Outcome measures

The primary outcome was inappropriate coronary revascularization (PCI or CABG) according to the Chinese AUC for coronary revascularization. The Chinese AUC followed the methodology and scenario design of the American AUC

(2012 version) with the addition of the "stress test was not done" scenarios.[12] Two investigators who did not participate in the procedures and data collection independently reviewed the clinical characteristics of each enrolled patient and classified each patient's treatment strategy as appropriate, inappropriate, or uncertain according to the Chinese AUC. Any disputes were settled via review by a third investigator, with decision by consensus.

Secondary outcome measures included the following: (1) inappropriate PCI, (2) inappropriate CABG, (3) PCI utilization, (4) CABG utilization, (5) medical therapy utilization, (6) major adverse cardiac events (MACE; ie, death from any cause, myocardial infarction, repeat revascularization) throughout the 12-month period after angiography. An independent clinical events committee (including cardiologists and cardiac surgeons) adjudicated all the clinical outcomes. Definitions of the clinical endpoints are provided in Supplementary Material 1.3, http://links.lww.com/CM9/A225.

Statistical analysis

Data are presented as mean ± standard deviation for continuous variables and as percentages for discrete variables. Baseline characteristics between the intervention and control groups were compared using Chi-squared or Fisher exact tests for categorical variables and *t* test for continuous variables.

Both hierarchical logistic regression model and logistic regression model were used to examine the association between SYNTAX score feedback and decision making with adjustment for demographic and AUC scenario variables, with a random effect for cardiologist annual caseload.

Multi-variable proportional hazards models were used to calculate hazard ratios and 95% confidence intervals (CIs) for relative risks in relation to the potential impact of confounding factors between SYNTAX score feedback and 1-year outcomes. All univariate variables in baseline with a $P < 0.1$ or clinical important variables were included in multivariate models.

All comparisons were two-sided, with statistical significance defined as *P* less than 0.05. Analyses were calculated using SPSS version 22.0 (IBM Corp, New York, NY, USA) and HLM version 7.0 (SSI Inc, Skokie, IL, USA). Additional information about the statistical analyses is provided in the Supplementary Material 1.4, http://links.lww.com/CM9/A225.

Results

Study participants

The study enrollment is presented in Figure 1. Finally, 1525 eligible patients were assigned to the control

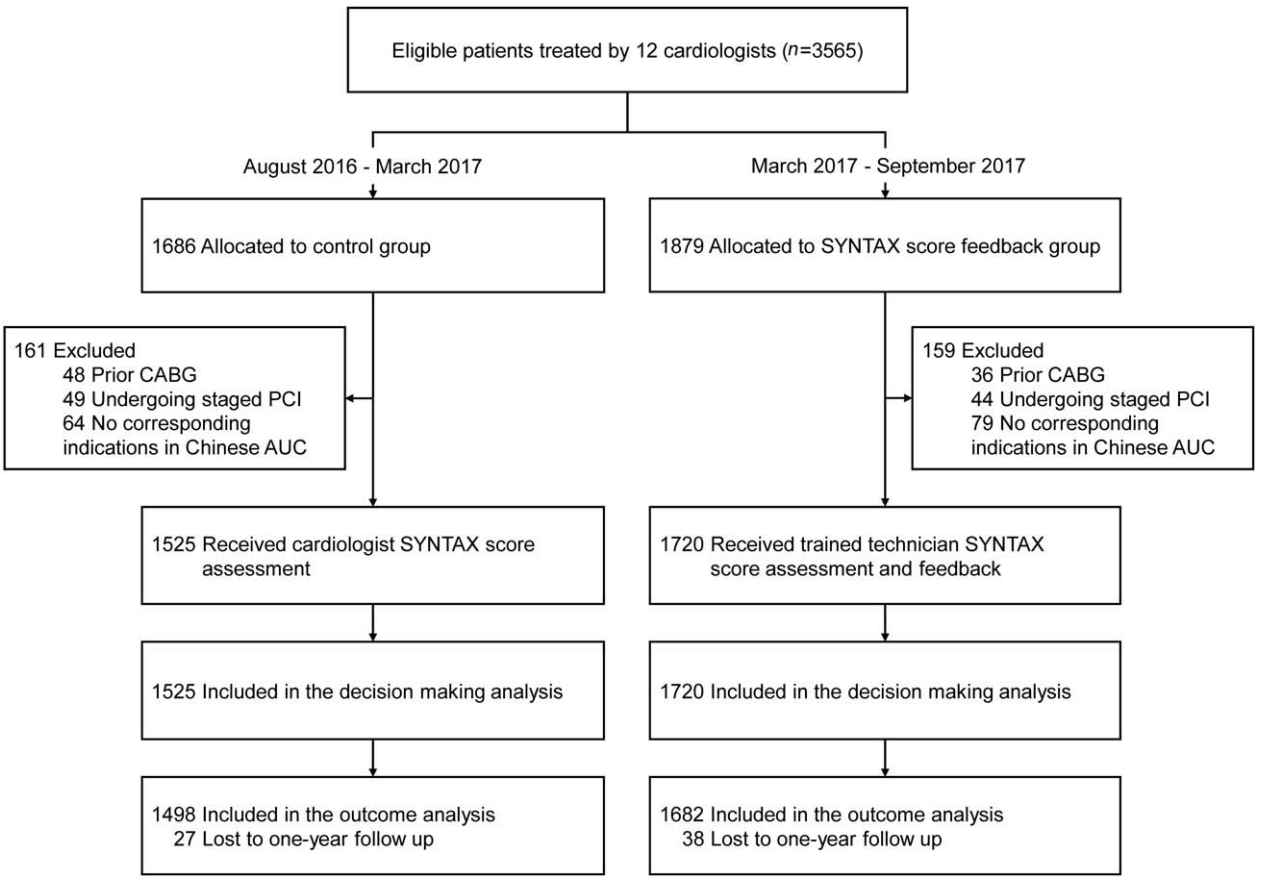

Figure 1: Study enrollment. AUC: Appropriate use criteria; CABG: Coronary artery bypass graft; PCI: Percutaneous coronary intervention; SYNTAX: Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery.

Table 1: Baseline characteristics of patients with stable coronary artery disease in control or intervention groups.

Characteristics	Control ($n = 1525$)	Intervention (SYNTAX score feedback) ($n = 1720$)	t/χ^2 values	P
Age (years)	59.9 ± 9.8	59.7 ± 9.7	−0.53*	0.60
Male	1183 (77.6)	1368 (79.5)	1.85†	0.17
Cardiac history				
Previous myocardial infarction	279 (18.3)	285 (16.6)	1.68†	0.20
Previous heart failure	31 (2.0)	43 (2.5)	0.79†	0.37
Previous PCI	465 (30.5)	496 (28.9)	1.06†	0.31
Cerebrovascular disease	199 (13.0)	201 (11.7)	1.39†	0.24
Peripheral vascular disease	100 (6.6)	91 (5.3)	2.34†	0.13
Cardiac risk factors and medical comorbidities				
Hypertension	937 (61.4)	1024 (59.5)	1.23†	0.27
Hyperlipidemia	1119 (73.4)	1097 (63.8)	34.39†	<0.001
Diabetes	474 (31.1)	511 (29.7)	0.72†	0.40
COPD	11 (0.7)	8 (0.5)	0.91†	0.34
Smoked during the last year	795 (52.1)	834 (48.5)	4.29†	0.04
CAD family history	5 (0.3)	10 (0.6)	1.13†	0.29
Severity of chest pain‡			42.54†	<0.01
Non-ischemic symptom	60 (3.9)	104 (6.0)		
No angina	680 (44.6)	645 (37.5)		
CCS class I	236 (15.5)	400 (23.3)		
CCS class II	448 (29.4)	466 (27.1)		
CCS class III	73 (4.8)	95 (5.5)		
CCS class IV	28 (1.8)	10 (0.6)		
Number of anti-anginal medications			80.08†	<0.01
0	324 (21.2)	551 (32.0)		
1	481 (31.5)	564 (32.8)		
2	508 (33.3)	485 (28.2)		
3	212 (13.9)	120 (7.0)		
Extent of coronary disease			2.71†	0.61
Mild disease (50–69%)	166 (10.9)	217 (12.6)		
1 vessel	567 (37.2)	624 (36.3)		
2 vessels	398 (26.1)	445 (25.9)		
3 vessels	263 (17.2)	298 (17.3)		
Left main stenosis	131 (8.6)	136 (7.9)		
SYNTAX score	12.3 ± 10.2	13.4 ± 10.6	2.90*	0.04
SYNTAX score tertiles			1.66†	0.49
Low risk (0–22)	1274 (83.5)	1414 (82.2)		
Intermediate risk (23–32)	169 (11.1)	198 (11.5)		
High risk (≥33)	82 (5.4)	108 (6.3)		
Stress test			10.08†	0.01
Positive	29 (1.9)	16 (0.9)		
Negative	27 (1.8)	16 (0.9)		
Not performed	1469 (96.3)	1688 (98.2)		
Left ventricular ejection			0.51†	0.92
≤35%	13 (0.9)	15 (0.9)		
36–50%	80 (5.2)	100 (5.8)		
>50%	1364 (89.4)	1528 (88.8)		
Not assessed	68 (4.5)	77 (4.5)		

Data are presented as n (%) or mean ± standard deviation. * t test statistical value. † χ^2 test statistical value. ‡ Severity of chest pain is defined as the symptom status prior current hospitalization according to the National Cardiovascular Data Registry CathPCI criteria. SYNTAX: Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery; PCI: Percutaneous coronary intervention; COPD: Chronic obstructive pulmonary disease; CAD: Coronary artery disease; CCS: Canadian Cardiovascular Society.

group and 1720 patients were assigned to the intervention group. Patients in the intervention group were more likely to smoke, have a high Canadian Cardiovascular Society class, and receive no or minimal anti-ischemic medical therapy, and were less likely to have hyperlipidemia [Table 1].

Characteristics of the 12 participating cardiologists are presented in Supplementary Table 1, http://links.lww.com/CM9/A225. Among 1525 patients in the control group, we collected 1233 (80.9%) subjective SYNTAX score tertiles assessment from these cardiologists. Cardiologists' subjective SYNTAX score tertiles assessment were identical to

the calculations by the image analysts in 959 (77.8%) patients, underestimated in 53 (4.3%) patients, and overestimated in 221 (17.9%) patients [Figure 2].

Appropriateness and utilization of coronary revascularization

The rate of inappropriate coronary revascularization was lower in the intervention group than in the control group (12.6% *vs.* 15.7%; unadjusted odds ratio [OR]: 0.77, 95% CI: 0.64–0.94; $P = 0.011$) [Table 2]. This difference persisted after adjusting for patient and cardiologist characteristics, with the odds of inappropriate revascularization lower for the intervention group (adjusted OR: 0.83, 95% CI: 0.73–0.95; $P = 0.007$).

The intervention group also had reduced odds of inappropriate PCI compared with the control group (unadjusted OR: 0.76, 95% CI: 0.63–0.93; $P = 0.008$) [Table 2]. This difference remained significant after adjusting for patient and cardiologist characteristics (adjusted OR: 0.82, 95% CI: 0.74–0.92; $P < 0.001$). In addition, the odds of PCI utilization were lower in the intervention group (adjusted OR: 0.88, 95% CI: 0.79–0.98; $P = 0.016$). There were no differences in inappropriate CABG or CABG utilization. The odds of medical therapy significantly increased in the intervention group (adjusted OR: 1.18, 95% CI: 1.03–1.36; $P = 0.017$).

Subgroup analyses

The effect of SYNTAX score feedback on the primary outcome of inappropriate revascularization varied by the SYNTAX score tertiles and patient symptomatic status [Figure 3]. The score feedback significantly reduced the odds of inappropriate coronary revascularization in

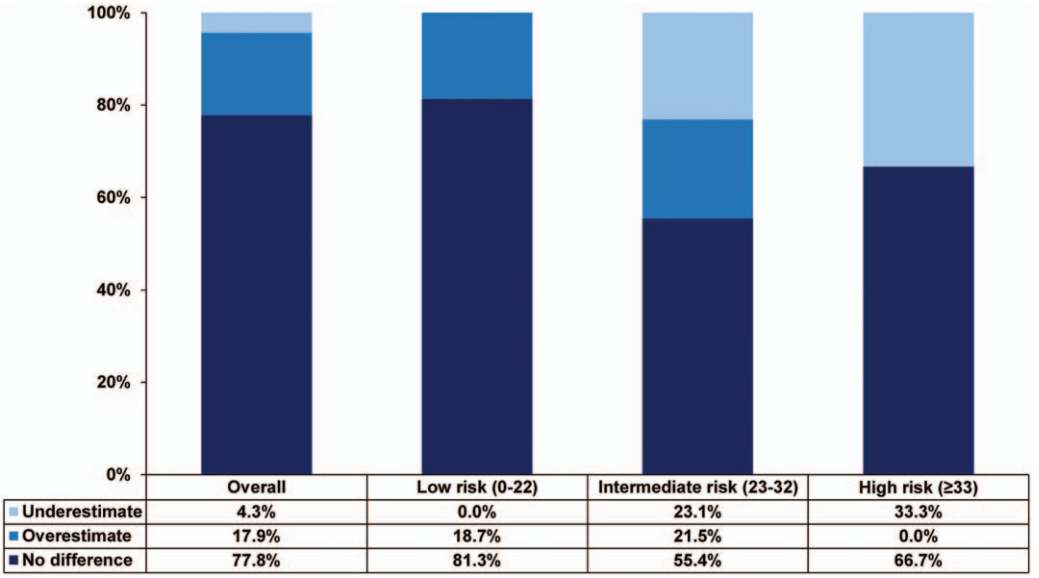

Figure 2: Agreement on SYNTAX score tertiles assessment between cardiologists and image analysts. Among 1525 patients in the control group, we recorded 1233 subjective SYNTAX score tertiles assessment by 12 enrolled cardiologists. SYNTAX: Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery.

Table 2: Appropriateness and utilization of coronary revascularization in the control and intervention groups.

Items	Control ($n = 1525$)	Intervention ($n = 1720$)	Unadjusted		Adjusted for patient characteristics		Adjusted for patient and cardiologist characteristics	
			OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Primary outcome								
Inappropriate revascularization	240 (15.7)	217 (12.6)	0.77 (0.63–0.94)	0.011	0.85 (0.74–0.97)	0.017	0.83 (0.73–0.95)	0.007
Secondary outcomes								
Inappropriate PCI	238 (15.6)	213 (12.4)	0.76 (0.63–0.93)	0.008	0.83 (0.75–0.93)	0.002	0.82 (0.74–0.92)	<0.001
Inappropriate CABG*	2 (0.1)	4 (0.2)	1.78 (0.33–9.71)	0.691	–	–	–	–
Utilization of PCI	894 (58.6)	976 (56.7)	0.93 (0.81–1.07)	0.280	0.88 (0.79–0.98)	0.017	0.88 (0.79–0.98)	0.016
Utilization of CABG	107 (7.0)	111 (6.5)	0.91 (0.69–1.20)	0.523	0.89 (0.72–1.11)	0.304	0.90 (0.72–1.12)	0.332
Utilization of medical therapy	533 (34.9)	644 (37.5)	1.11 (0.97–1.29)	0.141	1.18 (1.03–1.35)	0.017	1.18 (1.03–1.36)	0.017

Data are presented as *n* (%) or mean ± standard deviation. * Because of the small number of patients with this outcome ($n = 6$), models of inappropriate CABG were not adjusted for patient or cardiologist characteristics. OR: Odds ratio; CI: Confidence interval; PCI: Percutaneous coronary intervention; CABG: Coronary artery bypass graft; –: Not applicable.

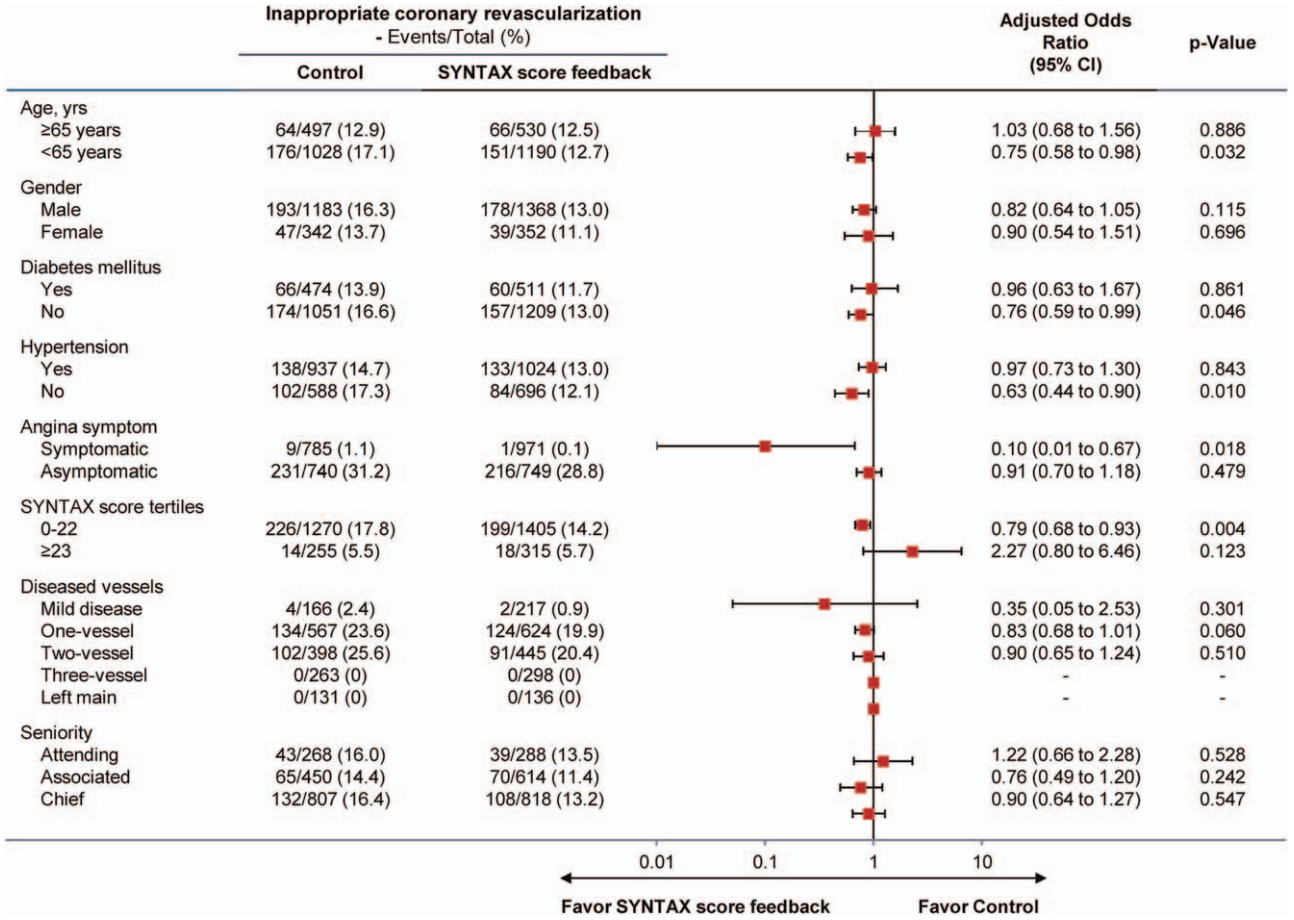

Figure 3: Subgroup analyses of inappropriate coronary revascularization. *No outcome events occurred in the subgroup of triple vessel and left main disease because revascularization procedures in the present study were all deemed appropriate according to Chinese appropriate use criteria. CI: Confidence interval; SYNTAX: Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery.

patients with low-risk SYNTAX score (adjusted OR: 0.79, 95% CI: 0.68–0.93; $P = 0.004$) and those with angina symptom (adjusted OR: 0.10, 95% CI: 0.01–0.67; $P = 0.018$). In addition, the score feedback reduced inappropriate PCI in patients with one-vessel disease (adjusted OR: 0.83, 95% CI: 0.68–0.99, $P = 0.049$) and angina symptom (adjusted OR: 0.09, 95% CI: 0.01–0.67; $P = 0.018$) [Supplementary Figure 2, http://links.lww.com/CM9/A225]. The score feedback was associated with decreased odds of PCI utilization in patients with low-risk lesions (SYNTAX score 0–22; adjusted OR: 0.83, 95% CI: 0.72–0.95; $P = 0.008$) [Supplementary Figure 2, http://links.lww.com/CM9/A225] and increased odds of PCI utilization in patients with triple-vessel disease (adjusted OR: 1.32, 95% CI: 1.12–1.54; $P < 0.001$).

One-year clinical outcomes

The 1-year follow-up rate was 98.0% in the overall patients. At 1 year, there was no significant difference in MACE, death, myocardial infarction and repeat revascularization between intervention and control groups after adjusting for patient characteristics [Figure 4, Supplementary Tables 2 and 3, http://links.lww.com/CM9/A225].

Discussion

In this single-center, historical control study, we found that SYNTAX score tertiles were overestimated in 17.9% patients and underestimated in 4.3% patients. The SYNTAX score feedback by image analysts significantly reduced the risk of inappropriate coronary revascularization in patients with stable CAD, especially for patients with low-risk lesions (SYNTAX score <23). In addition, the score feedback significantly reduced the rates of inappropriate PCI and PCI utilization, especially for inappropriate PCI in one-vessel lesion and PCI utilization in low-risk lesions (SYNTAX score <23). There was no significant difference in 1-year MACE between control and intervention groups.

Previous studies have noted the underestimation of SYNTAX scores by cardiologists using randomly selected patients with three-vessel or left main diseases.[6-10] For example, Généreux *et al*[6] reported that 63.3% of patients were considered low risk by cardiologists *vs*. 46.7% by the angiographic core laboratory among 50 multi-vessel disease cases randomly selected from the Cardiovascular Foundation database. However, no study was conducted

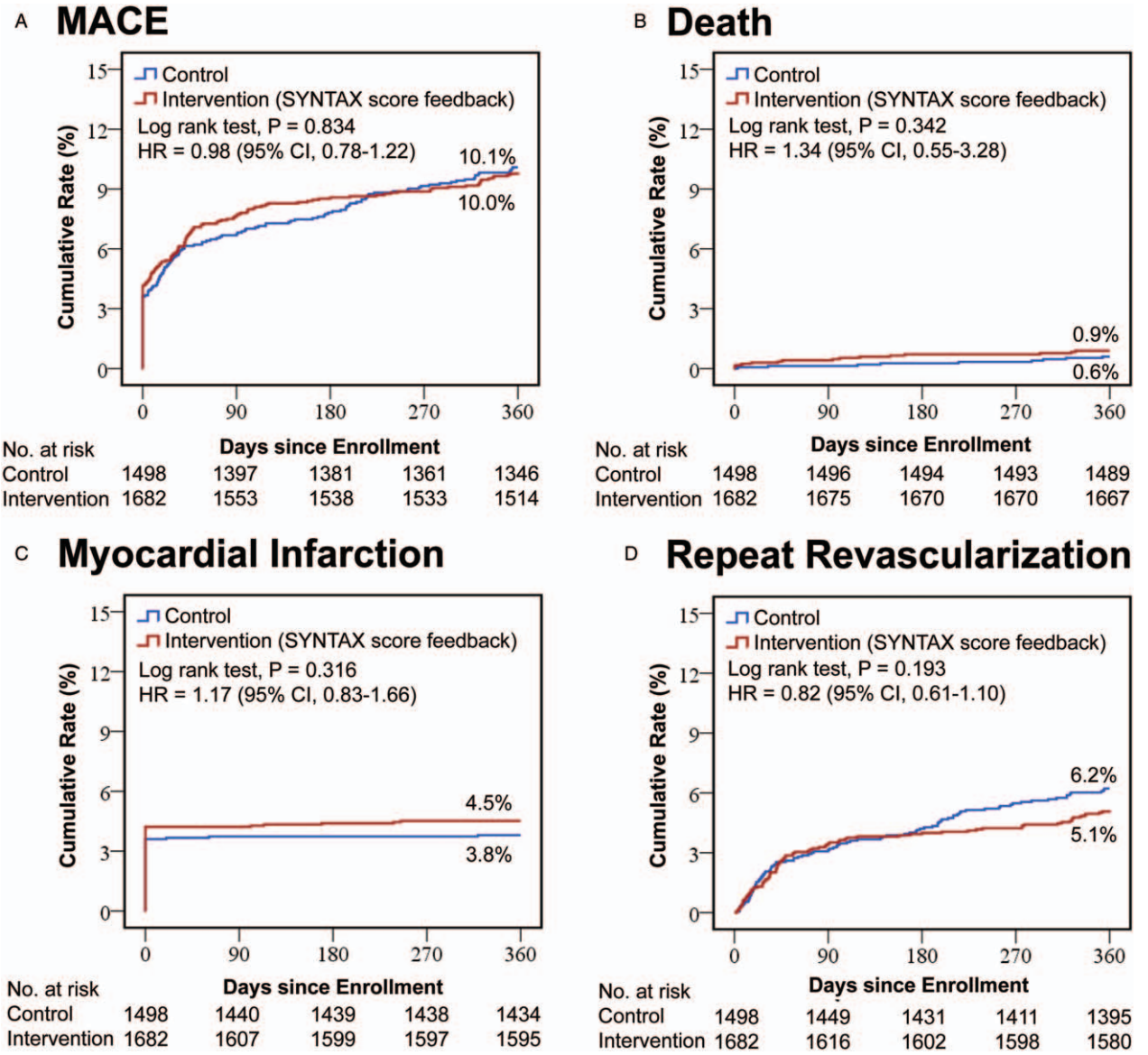

Figure 4: Kaplan-Meier cumulative event curves for 1-year clinical outcomes. Kaplan-Meier curves are shown for 1-year MACE (A), death (B), myocardial infarction (C), repeat revascularization (D) between control and intervention groups. MACE: Major adverse cardiac events; SYNTAX: Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery; HR: Hazard ratio; CI: Confidence interval.

to assess the score mis-estimation in all-comer, real-world practice. In this all-comer study, we found more score overestimation (17.9%) than underestimation (4.3%), indicating that the overestimation of low-risk or simple lesions should also be noted in clinical practice.

Although the SYNTAX score was only recommended to guide decision making in patients with complex CAD, we still hypothesized that the score feedback may influence the decision making in all-comer CAD patients including one or two-vessel diseases. This is because SYNTAX score is a comprehensive system to evaluate the overall complexity of lesions. Thus, we hypothesized that the score feedback may improve decision making by correcting the mis-estimation of overall lesions severity. And finally, we found that the score feedback significantly reduced the risk of inappropriate coronary revascularization in patients with stable CAD, especially for low-risk lesions (SYNTAX score <23) which were more frequently mis-estimated. In addition, we also found the score feedback reduced inappropriate PCIs and PCI volume, especially for one-vessel or low-risk (SYNTAX score <23) lesions. These results may be because the score feedback rectified cardiologist overestimation of the complexity of the overall lesions. Findings from our study may provide evidence supporting the broader use of SYNTAX score in clinical practice. Moreover, in our experience, image analysts were able to calculate and feedback SYNTAX scores in a few minutes after adequate training [Supplementary Material 1.2, http://links.lww.com/CM9/A225]. We believed that SYNTAX score feedback may be a viable approach for improving procedural appropriateness and could be attempted in different centers.

It should be emphasized that the score feedback was aimed at improving cardiologist decision-making rather than

limiting PCI utilization. We observed significant reduction in both inappropriate PCI and PCI volume in the intervention group. These findings may indicate that cardiologists were better able to recognize the patients who were most likely to benefit from revascularization. Thus, SYNTAX score feedback may represent a valuable strategy to reduce the overutilization of PCI and increase guideline adherence.

Despite more patients were treated with medical therapy rather than PCIs in the intervention group, there was still no difference in 1-year outcomes between control and intervention groups [Figure 4, Supplementary Tables 2 and 3, http://links.lww.com/CM9/A225]. This result was consistent with COURAGE trial and ORBITA trial showing no benefit in overall clinical outcomes between patients with stable CAD who underwent PCI and optimal medical therapy.[13,14] Our results showed that SYNTAX score feedback reduced invasive PCI procedures and saved medical resources without increasing adverse clinical events. And these results further supported SYNTAX score feedback for optimal decision making in patients with stable CAD.

A heart team approach was emphasized by latest guideline for optimal decision making in complex coronary disease.[15] In the SYNTAX II trial, heart team-based PCIs have been found to be associated with improved clinical results compared to patients in original SYNTAX trial.[16] However, in real-world practice, multi-disciplinary decision making was rarely used despite heart team was highly recommended.[17] In the present study, we found that SYNTAX score feedback promoted multi-disciplinary decision making in patients with complex lesions. In subgroup analysis, we found that the rate of surgical consultation increased in patients with three-vessel or left main coronary disease [Supplementary Figure 3, http://links.lww.com/CM9/A225], and the rate of *ad hoc* PCI decreased in patients with left main disease [Supplementary Figure 4, http://links.lww.com/CM9/A225]. SYNTAX score feedback may rectify cardiologist's underestimation of lesions' complexity and made them give up *ad hoc* PCI for optimal decision with interdisciplinary discussion. Thus, SYNTAX score feedback may be a possible, non-administrative way to promote multi-disciplinary decision making, and further study is needed to confirm this result.

It is noteworthy that the SYNTAX score feedback is most appropriate for *ad hoc* PCI. *Ad hoc* PCI was commonplace in clinical practice but controversial in guideline.[15] In New York state, more than 80% of PCIs were reported to be *ad hoc*.[18] *Ad hoc* PCIs were convenient, associated with fewer access site complications, and often cost-effective and safe.[18] However, a prior study found that nearly 30% of patients undergoing *ad hoc* PCI were potential candidates for CABG, which called for methods to improve the appropriateness of *ad hoc* PCI.[18] As a real-time intervention during coronary angiography, SYNTAX score feedback may be an approach to improve the appropriateness of *ad hoc* PCI. Moreover, in subgroup analysis, we found that SYNTAX score feedback significantly decreased inappropriate PCIs especially in patients with one-vessel disease. As previous study reported nearly 60% of *ad hoc* PCIs were performed for one vessel disease, SYNTAX score feedback may be more valuable for these patients.[18]

This study has several limitations that should be noted. First, this is a single-center, historical control study and not a multi-center, randomized controlled trial. Although there is possible confounding from both the patients and cardiologists, we found that the effect of the intervention remained significant after adjustment for a number of factors. Second, cardiologist selection bias may influence the outcomes. Cardiologists who participated in the study were all experienced operators (>100 PCIs per year), potentially limiting the generalizability of the results to other cardiologists at different centers. Third, the primary outcome was not evaluated by widely known American AUC in 2017. This is because few patients may get recommendations by American AUC considering the low rate of stress tests used in Chinese population (2.7% in our study). Despite these limitations, our study has shown that SYNTAX score feedback may significantly reduce unnecessary coronary revascularization in daily clinical practice.

Conclusions

Real-time SYNTAX score feedback by image analysts reduced the proportion of inappropriate coronary revascularization in patients with stable CAD. Both inappropriate PCI and overall PCI utilization also decreased. The score feedback was not associated with 1-year clinical outcomes. SYNTAX score feedback may be a practical approach to improve decision-making regarding coronary revascularization. Further study of a more diverse pool of cardiologists and centers is warranted.

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Conflicts of interest

None.

References

1. Zhang H, Mu L, Hu S, Nallamothu BK, Lansky AJ, Xu B, *et al*. Comparison of physician visual assessment with quantitative coronary angiography in assessment of stenosis severity in China. JAMA Inter Med 2018;178:239–247. doi: 10.1001/jamainternmed.2017.7821.
2. Nallamothu BK, Spertus JA, Lansky AJ, Cohen DJ, Jones PG, Kureshi F, *et al*. Comparison of clinical interpretation with visual assessment and quantitative coronary angiography in patients undergoing percutaneous coronary intervention in contemporary practice: the Assessing Angiography (A2) project. Circulation 2013;127:1793–1800. doi: 10.1161/circulationaha.113.001952.
3. Leape LL, Park RE, Bashore TM, Harrison JK, Davidson CJ, Brook RH, *et al*. Effect of variability in the interpretation of coronary angiograms on the appropriateness of use of coronary revascularization procedures. Am Heart J 2000;139:106–113. doi: 10.1016/s0002-8703(00)90316-8.

4. Garrone P, Biondi-Zoccai G, Salvetti I, Sina N, Sheiban I, Stella PR, *et al*. Quantitative coronary angiography in the current era: principles and applications. J Interv Cardiol 2009;22:527–536. doi: 10.1111/j.1540-8183.2009.00491.x.
5. Sianos G, Morel MA, Kappetein AP, Morice MC, Colombo A, Dawkins K, *et al*. The SYNTAX score: an angiographic tool grading the complexity of coronary artery disease. EuroIntervention 2005;1:219–227.
6. Généreux P, Palmerini T, Caixeta A, Cristea E, Mehran R, Sanchez R, *et al*. SYNTAX score reproducibility and variability between interventional cardiologists, core laboratory technicians, and quantitative coronary measurements. Circ Cardiovasc Interv 2011;4:553–561. doi: 10.1161/circinterventions.111.961862.
7. Shiomi H, Tamura T, Niki S, Tada T, Tazaki J, Toma M, *et al*. Inter- and intra-observer variability for assessment of the synergy between percutaneous coronary intervention with TAXUS and cardiac surgery (SYNTAX) score and association of the SYNTAX score with clinical outcome in patients undergoing unprotected left main stenting in the real world. Circ J 2011;75:1130–1137. doi: 10.1253/circj.cj-10-1112.
8. Garot P, Tafflet M, Kumar S, Salvatella N, Darremont O, Jouven X, *et al*. Reproducibility and factors influencing the assessment of the SYNTAX score in the left main Xience study. Catheter Cardiovasc Interv 2012;80:231–237. doi: 10.1002/ccd.23443.
9. Garg S, Girasis C, Sarno G, Goedhart D, Morel MA, Garcia-Garcia HM, *et al*. The SYNTAX score revisited: a reassessment of the SYNTAX score reproducibility. Catheter Cardiovasc Interv 2010;75:946–952. doi: 10.1002/ccd.22372.
10. Tanboga IH, Ekinci M, Isik T, Kurt M, Kaya A, Sevimli S, *et al*. Reproducibility of syntax score: from core lab to real world. J Interv Cardiol 2011;24:302–306. doi: 10.1111/j.1540-8183.2011.00645.x.
11. Stéphane Z, Christophe G, Julien R, Tada T, Tazaki J, Toma M, *et al*. Can the SYNTAX score be used in clinical practice? Results of a inter- and intra-observer variability study. J Am Coll Cardiol 2010;55(Suppl 10):10. doi: 10.1111/j.1540-8183.2011.00645.x.
12. Patel MR, Dehmer GJ, Hirshfeld JW, Smith PK, Spertus JA, Masoudi FA, *et al*. ACCF/SCAI/STS/AATS/AHA/ASNC/HFSA/SCCT 2012 appropriate use criteria for coronary revascularization focused update: a report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, Society for Cardiovascular Angiography and Interventions, Society of Thoracic Surgeons, American Association for Thoracic Surgery, American Heart Association, American Society of Nuclear Cardiology, and the Society of Cardiovascular Computed Tomography. J Thorac Cardiovasc Surg 2012;143:780–803. doi: 10.1016/j.jtcvs.2012.01.061.
13. Al-Lamee R, Thompson D, Dehbi HM, Sen S, Tang K, Davies J, *et al*. Percutaneous coronary intervention in stable angina (ORBITA): a double-blind, randomised controlled trial. Lancet 2018;391:31–40. doi: 10.1016/S0140-6736(17)32714-9.
14. Boden WE, O'Rourke RA, Teo KK, Hartigan PM, Maron DJ, Kostuk WJ, *et al*. Optimal medical therapy with or without PCI for stable coronary disease. N Engl J Med 2007;356:1503–1516. doi: 10.1056/NEJMoa070829.
15. Neumann FJ, Sousa-Uva M, Ahlsson A, Alfonso F, Banning AP, Benedetto U, *et al*. 2018 ESC/EACTS guidelines on myocardial revascularization. Eur Heart J 2019;40:87–165. doi: 10.1093/eurheartj/ehy394.
16. Escaned J, Collet C, Ryan N, De Maria GL, Walsh S, Sabate M, *et al*. Clinical outcomes of state-of-the-art percutaneous coronary revascularization in patients with de novo three vessel disease: 1-year results of the SYNTAX II study. Eur Heart J 2017;38:3124–3134. doi: 10.1093/eurheartj/ehx512.
17. Yates MT, Soppa GK, Valencia O, Jones S, Firoozi S, Jahangiri M, *et al*. Impact of European Society of Cardiology and European Association for Cardiothoracic Surgery Guidelines on Myocardial Revascularization on the activity of percutaneous coronary intervention and coronary artery bypass graft surgery for stable coronary artery disease. J Thorac Cardiov Sur 2014;147:606–610. doi: 10.1016/j.jtcvs.2013.01.026.
18. Hannan EL, Samadashvili Z, Walford G, Holmes DR, Jacobs A, Sharma S, *et al*. Predictors and outcomes of ad hoc versus non-ad hoc percutaneous coronary interventions. JACC Cardiovasc Interv 2009;2:350–356. doi: 10.1016/j.jcin.2009.01.006.

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