Late proximal coronary artery stenosis complicating percutaneous endovascular catheterisation procedures

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Abstract

Background Late-onset proximal coronary artery stenosis caused by preceding percutaneous catheterisation procedures remains under-surveyed.

Methods From 1993, all patients undergoing percutaneous coronary procedures and a second session within 3 years were included except those ever treated by coronary bypass surgery or chest radiotherapy during this 3-year period. Emergence of a new lesion or worsening of an initially insignificant lesion to >50% of diameter stenosis at the never-treated ostial/proximal coronary segment on the follow-up angiogram was defined as late coronary stenosis caused by the previous catheterisation procedure and was analysed.

Results From January 1993 to December 2005, 3240 patients who underwent 5025 procedures met the inclusion criteria. Of them, 23 patients experienced an event of late coronary artery stenosis (overall incidence 0.46%), and interventional procedures, specifically shaped catheters (Voda, XB, Amplatz Left) and atherosclerosis vulnerability correlated with risks of adverse events. Most of these events could be managed by contemporary medical, interventional, or surgical strategies,

yet hazards of mortality and long-term restenosis still existed from this catheter-induced complication.

Conclusions Percutaneous catheterisation procedures could be complicated by late proximal coronary artery stenosis. Thus, when conducting these procedures, operators should select and manipulate catheters with caution, especially in patients with susceptible clinical characteristics.

Keywords Coronary · Percutaneous · Catheterization · Complication · Stenosis

Introduction

Percutaneous coronary catheterisation procedures have been employed for decades as the standard diagnostic and therapeutic tools for management of coronary artery disease (CAD) [1]. However, as these endovascular procedures often require the catheters to abut on or even be seated in the coronary artery to achieve good quality angiograms or a steady platform for subsequent interventional processes, injury of the ostial/proximal coronary artery might consequently result, causing either acute intimal dissection [2–6] or delayed luminal stenosis [7–13]. The former complication almost invariably calls for immediate attention [2–6], whereas the latter usually remains occult initially, only to manifest at some later time [7–13]. Given the proximal location of the delayed coronary artery stenosis that may substantially impact the outcome of patients, knowledge of its presentation and manifestation represents a crucial yet inadequately learned lesson in performing catheterisation procedures. Therefore, this study was designed to explore the incidence, correlating variables, and clinical prognosis of late-onset catheter-induced proximal coronary artery injury in patients receiving percutaneous diagnostic and therapeutic coronary procedures.

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Patients and methods

Study population

From January 1993, all patients who underwent diagnostic and interventional coronary procedures in our tertiary referral centre for symptomatic coronary, myocardial, valvular, arrhythmic, and congenital diseases were screened. Those who had received another coronary catheterisation session at ≤ 3 years for suspected recurrence or aggravation of coronary artery disease were recruited. Patients were excluded from enrolment if they had ever undergone intention to treat the ostial/proximal portion of any of the three main coronary arteries, or if they underwent new coronary bypass surgery (which would cause atrophy of native coronary arteries) or chest radiation therapy (which might evoke coronary artery ostial stenosis) during the 3-year follow-up period [14–17]. Occurrence of catheter-induced late-onset proximal coronary artery stenosis was defined as emergence of a new stenotic lesion in the ostial (<5 mm from the aortic lumen) or proximal segment of any of the major coronary arteries shown on the follow-up angiogram, as described below.

Coronary arteriography and intervention

Most of the current diagnostic and interventional coronary procedures can be performed by experienced cardiologists in our institution using standard techniques in compliance with contemporary AHA/ACC guidelines [18]. Instruments utilised in these procedures included catheters of various shapes and gauges (4 to 8 Fr), steerable 0.014" guidewires of different shaft/tip/coating properties, angioplasty balloon catheters, balloon-expandable stents, rotablator burrs, cutting balloon catheters, thrombectomy devices, embolisation coils, intravascular ultrasound catheters, and Doppler/pressure wires. The only procedure that has never been performed in this institution is directional coronary atherectomy, owing to unavailability of suitable devices in this country.

Late-onset catheter-induced coronary artery stenosis

The standardised procedures for coronary arteriography in our institution require that all segments of the coronary tree be clearly demonstrated from multi-directional projections on biplane fluoroscopy, and each ostial/proximal coronary lesion be ascertained by intra-coronary nitrate administration to exclude the possibility of transient vasospasm. Severity of coronary artery stenosis was routinely examined using the on-site quantitative coronary analysis (QCA) system. Late catheter-induced coronary artery stenosis was defined as emergence of a *de novo* lesion $>50\%$ of luminal

diameter or progression of a pre-existing sub-critical lesion to $>50\%$ of luminal diameter at ostial/proximal segments in left main coronary (LMCA) or right coronary artery (RCA) on the follow-up angiogram. Cases of late coronary stenosis were explored from the report database of the catheterisation laboratory containing the operation notes of all coronary procedures, and all cases thus identified were confirmed by two experienced interventional cardiologists who reviewed the cineangiograms thoroughly.

Outcome

Immediate and long-term (up to 3 years) outcomes of patients with late-onset coronary artery stenosis were assessed based on chart review and, if patients were lost to follow-up, telephone interviews with a standardised questionnaire to trace major adverse cardiovascular events, including non-fatal myocardial infarction, target-vessel revascularisation, cerebral stroke, and death.

Statistics

Continuous variables were expressed as mean $\pm$ standard deviation (SD). Normally distributed continuous data were compared by unpaired student's *T*-test, while non-parametric continuous data were compared by Mann–Whitney *U* test. Categorical variables were compared by χ^2 analysis with Yate's correction. Statistical significance was defined as $p < 0.05$. All analyses were performed using SPSS software version 10.1.

Results

Patient and procedure characteristics

From January 1993 to December 2005, of the 21,862 percutaneous coronary procedures carried out on 16,184 patients with the intention of diagnosis or intervention in various types of symptomatic heart diseases, a total of 5025 procedures were performed on 3240 patients who met with the inclusion criteria and thus constituted the study population. The characteristics of these patients and the corresponding coronary procedures are detailed in Fig. 1a.

Incidence and correlating factors of catheter-induced late coronary stenosis

Among the 5025 procedures performed, 23 sessions were complicated with late coronary artery stenosis (12 in LMCA and 11 in RCA) within a period of 3 years (Fig. 2). The overall incidence was therefore 0.46%, and interven-

Fig. 1 a Schematic presentation of the operative characteristics of the procedures that were scrutinised for evaluation of late-onset catheter-induced coronary artery stenosis. CBA, cutting balloon angioplasty, POBA, plain-old balloon angioplasty; PTCRA, percutaneous transluminal coronary rotational ablation PTSMA, percutaneous transluminal septal myocardial ablation. **b** Schematic presentation of the vulnerability of individual coronary arteries to late-onset catheter-induced coronary artery stenosis caused by percutaneous procedures for either diagnostic or therapeutic purposes

tional procedures carried a higher risk (15 in 2848 sessions, or 0.53%) than diagnostic ones (8 in 2177 sessions, or 0.37%) (Fig. 1b). Nineteen of the 23 patients with late coronary artery stenosis (83%) were male, and the involved vessel size was 3.4 ± 0.2 mm in diameter (mean 3.8 ± 0.2 mm, range 3.0–4.5 mm for LMCA; mean 3.0 ± 0.2 mm, range 2.5–4.5 mm for RCA). Nine of the 23 procedures (39%) were performed through radial access and the other 14 (61%) from a femoral approach. Three (13%) procedures were carried out as an emergency, while 20 (87%) were done in elective situations. Compared with the other 3217 patients free of this complication, those confronted with late coronary stenosis were older (71 ± 10 vs. 65 ± 10 years, $p=0.008$), hypertensive (57% vs. 29%, $p=0.027$), diabetic (67% vs. 29%, $p=0.022$), and current smokers (48% vs. 14%, $p<0.001$). In diagnostic procedures, RCA was more vulnerable (6 in 2177 sessions, or 0.28%) to late

catheter-induced stenosis than LMCA (2 in 2177 sessions, or 0.09%). In interventional procedures, both RCA (5 in 939 sessions, or 0.53%) and LMCA (10 in 1894 sessions, or 0.53%) carried comparable risks of late stenosis. Only one of these patients received special technique (rotablation atherectomy) for diffusely calcified stenotic lesions at left anterior descending artery, whereas the other 14 underwent classical interventional procedures employing plain-old balloon angioplasty or merely stenting.

Catheters responsible for late proximal coronary artery stenosis

In diagnostic procedures, Judkins Right catheters (6 Fr in 4 patients and 8 Fr in 2 patients) contributed to all 6 events of RCA stenosis, and Kimny-3.5 and Judkins Left catheters

Fig. 2 Example angiograms of catheter-induced late proximal coronary artery stenosis. **a** left panel, left coronary angiogram of a 79-year-old male undergoing diagnostic cardiac catheterisation showing a healthy left main coronary artery; right panel, follow-up left coronary angiogram 6 months later revealing a critical de novo lesion at the ostium of the left main coronary artery (*arrow*). **b** left panel, right coronary angiogram of a 69-year-old male just finishing angioplasty for downstream lesions demonstrating merely insignificant narrowing at the proximal portion of this vessel; right panel, follow-up right coronary angiogram 14 months later disclosing a significant new lesion at the ostium of this artery (*arrow*)

(both of 6 Fr) accounted for the 2 events in LMCA. In interventional procedures, Voda-3.5 (2 events in 11 utilisations, or 18.2%), XB-3.5 (1 in 75 utilisations, or 1.33%), Judkins Left (6 in 1289 utilisations, or 0.47%) and Kimny-3.5 (1 event in 719 utilisations, or 0.24%) catheters contributed to LMCA events, whereas Amplatz Left-1 (2 in 71 utilisations, or 2.82%), Kimny-3.5 (1 in 301 utilisations, or 0.33%) and Judkins Right (1 in 434 utilisations, or 0.23%) accounted for RCA events. All of these catheters were of medium gauges (6 and 7 Fr).

Immediate and long-term outcomes

The duration between the preceding culprit coronary procedures and emergence of late coronary stenosis was 16 ± 8 months (range, 1.3 to 34.3 months). At presentation, 22 of the 23 patients (95.7%) manifested as stable angina and were favourably managed with contemporary therapeutic strategies [percutaneous coronary intervention (PCI) for 14, coronary artery bypass surgery for 3, medical for 6], though 2 patients with LMCA stenosis suffered transient acute closure of the targeted left main coronary artery during PCI and developed non-fatal myocardial infarction. The remaining patient (4.3%), an 81-year-old male,

however, presented with acute ostial RCA occlusion and fatal inferior myocardial infarction 1 month after a diagnostic coronary procedure despite the attempt of an emergency coronary intervention. In the long term, of the 22 survivors followed up for 3 years, one patient (4.5%) with LMCA stenosis who declined bypass surgery died suddenly at 6 months. Three other subjects (13.6%) (1 with LMCA and 2 with RCA stenosis) treated with PCI needed target-lesion revascularisation, and one of them died of transitional cell carcinoma of the urinary bladder 30 months later. The remaining 18 patients (81.8%) were free of major adverse cardiac events at follow-up.

Discussion

Manipulation of catheters during endovascular coronary procedures could inadvertently irritate the ostial/proximal artery segments and create luminal stenosis at a later time [7–13]. The present study, which enrolled a large number of subjects to explore clinical features of this complication, depicts the incidence, correlating factors, and outcome of late catheter-induced proximal coronary artery stenosis in patients undergoing percutaneous diagnostic and interven-

tional coronary procedures. The results illustrate the clinical presentation of this complication, and may shed light on prevention and management of this rare yet serious adverse event in daily endovascular practice.

Manifestations of catheter-induced coronary artery stenosis

The development of catheter-induced late-onset coronary stenosis has been attributed to initial subtle catheter injury and subsequent reactive intimal proliferation [11, 19]. This pathogenesis is similar to that of restenosis post-balloon injury except that the lumen diameter of the proximal coronary artery is larger than downstream vessel segments and the subclinical intimal disruption evoked by catheters theoretically less violent than barotrauma caused by balloons. Accordingly, it could be deduced that the duration for emergence of catheter-induced proximal coronary artery stenosis would be longer than that for balloon-injury restenosis (usually 6 to 9 months). The present study therefore delineated 3 years as the duration limit for manifestation of catheter-induced late coronary artery stenosis based on the hypothesis that this time period would allow all catheter-induced late stenoses to develop at the proximal coronary artery, yet not long enough for any *de novo* atherosclerotic lesion to emerge (typically more than 10 years), or for a subcritical plaque to significantly worsen (usually no less than 5 years) [18]. However, with this criterion there might be a risk of recruiting patients with naturally evolving atherosclerotic rather than catheter-induced coronary stenosis and overestimating the incidence of this event. Its sensitivity and specificity therefore need further study.

Factors correlating with development of late coronary artery stenosis

A number of patient- and procedure-related factors may correlate with catheter-induced late coronary stenosis based on the results of the present study. The finding that both diagnostic and interventional coronary procedures could be complicated by late proximal coronary artery stenosis suggested that once the coronary artery is touched by catheters there would be potential hazard of intimal damage and ensuing luminal stenosis. The higher propensity for this complication to occur with interventional rather than diagnostic procedures implied that more complex manipulation of the catheter, as required in interventional procedures, may be responsible for increased incidence of late coronary artery stenosis. The finding that RCA is more liable to catheter injury than LMCA in diagnostic sessions

might be explained by the variation in take-off positions and angles of this vessel, which rendered coaxial engagement harder to accomplish and catheter manipulation more demanding [13]. The fact that catheters of particular shapes are prone to inducing late coronary injury (Amplatz Left for RCA and Voda/XB for LMCA) is consistent with previous reports indicating that specially shaped catheters tend to impose more traumatic force on the proximal coronary artery [19] with their longer tips, stress-exerting angles, and potential deep-seating properties. As these long-tipped, backup-provided catheters are often needed to overcome complexity of downstream target lesions during PCI, patients undergoing coronary procedures utilising any of these sorts of catheters may need close surveillance for possible occurrence of late proximal coronary artery stenosis. The reason smaller-size catheters (6–7 F) accounted for a higher incidence of late vessel injury in interventional procedures was not clear, but tendency of these catheters to pop and seat deeply into the proximal coronary artery segment might be a contributing factor. The findings that risk factors of atherosclerosis (ageing, hypertension, diabetes, cigarette smoking) are significantly more prevalent in subjects with late coronary stenosis suggested that patients carrying these factors are susceptible to catheter irritation due to underlying insufficiency of vascular/endothelial integrity [13, 20]. Overall, these results reflect two major determinative factors for the occurrence of late coronary stenosis, i.e. the degree of extrinsic disturbance evoked by the catheters on the proximal segment of the coronary arteries and the intrinsic vulnerability of atherogenesis of the patients undergoing the procedure.

Prognosis for late catheter-induced coronary artery stenosis

Although most of the events of late coronary artery stenosis could be managed by current medical, interventional or surgical strategies, the possibility of morbidity (non-fatal myocardial infarction in two subjects during treatment by PCI) and even mortality (ostial RCA occlusion and acute inferior wall myocardial infarction in 1 patient) still existed. Moreover, the long-term (3-year) outcome was also similar to that of typical ostial coronary lesions treated with medical [21], interventional [22, 23] or surgical [24] modalities and carried a substantial risk of major adverse cardiovascular events as reflected by sudden cardiac death of a patient with left main coronary stenosis treated medically and target-vessel revascularisation in 2 patients treated with PCI. These findings implicate the potentially dismal outcome of catheter-induced late coronary stenosis and thereby underline the importance of both prevention and aggressive management of this complication when it occurs.

Clinical implications

As late coronary artery stenosis represents a potentially fatal complication of endovascular catheterisation procedures, it is essential for all cardiologists to meticulously manipulate catheters liable to cause vessel injury, closely follow up the coronary condition especially for patients at higher risk of atherogenesis, and consider application of alternative non-invasive, non-coronary contacting tools (such as multi-slice CT or MRI) [25–27] instead of invasive coronary catheterisation whenever possible to avoid unnecessary coronary artery injury.

Study limitations

This study has three limitations. First, since no routine follow-up coronary arteriography was performed for patients who had received percutaneous coronary procedures, the incidence of late coronary stenosis might be underestimated owing to missing patients either with no symptoms or with debilitating or fatal events. On the other hand, though catheter-induced intimal injury is a reasonable cause of late coronary artery stenosis, natural progression of a subclinical atherosclerotic streak to an overt lesion during the study period cannot be totally excluded. This possibility could result in overestimation of the incidence of catheter-induced late coronary stenosis. Second, the severity of coronary artery stenosis was purely determined by QCA and was not verified by intravascular ultrasonography. Third, the patient data were collected in the chronological period from the no-stent to the bare-metal-stent eras. Clinical outcomes of this complication in the current drug-eluting-stent era could differ considerably from those in our study, so further investigation may be needed to clarify any discrepancy.

Conclusions

Catheter-based diagnostic and interventional coronary procedures carry the hazard of ostial/proximal artery injury that may manifest months to years later as significant luminal stenosis. Although current therapeutic strategies can, for the most part, effectively manage this complication, risks of immediate and long-term major adverse events do exist, thereby underscoring the need for prevention of this complication especially when manoeuvring specially styled catheters in susceptible patients, and awareness and aggressive treatment of this complication when it occurs.

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