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Research paper

Visualization of collateral channels with coronary computed tomography angiography for the retrograde approach in percutaneous coronary intervention for chronic total occlusion

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ABSTRACT

Background: There have been no reports about the diagnostic ability of coronary computed tomography angiography (CTA) in evaluating collateral channels used for retrograde chronic total occlusion (CTO) percutaneous coronary intervention (PCI).
Objective: We investigated the ability and diagnostic accuracy of coronary CTA compared with invasive coronary angiography to detect collaterals used in retrograde CTO PCI and to compared the success rates for wire crossing between collaterals that are detectable and not detectable in coronary CTA.
Methods: We retrospectively reviewed data from 43 patients (55 collaterals) who underwent coronary CTA and PCI for CTO with the retrograde approach. We compared the ability of coronary CTA to visualize collaterals to invasive coronary angiography and evaluated the rates of successful wire crossing between CTA-visible and invisible collaterals.
Results: The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of coronary CTA for detecting collaterals which were used for the retrograde approach was 100.0%, 50.0%, 65.9%, 100.0%, and 74.5%, respectively. Guidewire collateral crossing was more successful in CT-visible collaterals than those not detectable in CT (74.1% vs. 46.4%, $p = 0.034$). There were fewer collateral vessel injuries in CTA-visible collaterals (11.1% vs. 32.1%, $p = 0.041$).
Conclusion: Coronary CTA provides good visualization of collaterals used in retrograde CTO PCI. For retrograde guidewire crossing, a higher success rate with fewer complications was observed in CTA-visible collaterals than in those not detectable in coronary CTA.

1. Introduction

A recent report shows that approximately one-fifth of patients undergoing coronary angiography for suspected stable angina have a chronic total occlusion (CTO) of the coronary artery[1]. There is increasing interest in CTO percutaneous coronary intervention (PCI) and an improved success rate due to continuous technical advances[2–5]. In particular, the retrograde approach through collateral channels has improved the success rate of PCI for CTO[6–8]. Successful guidewire collateral crossing is the most important factor in retrograde CTO PCI, which, if accomplished, leads to procedural success in approximately 90% of cases[9]. Appropriate collateral channel selection is therefore crucial to achieve successful revascularization. The most widely used method to assess collateral channels is invasive coronary angiography[10,11], and the presence of visible and non-tortuous collateral channels is known to be a significant predictor of successful retrograde wire crossing[9].

Abbreviations: CTA, computed tomography angiography; CTO, chronic total occlusion; PCI, percutaneous coronary intervention; ECG, electrocardiogram; MACE, major adverse cardiac events; MI, myocardial infarction; TIMI, thrombolysis in myocardial infarction.

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Septal collaterals are most frequently used in the retrograde approach and are safer to use than epicardial collaterals[12]. Unsuccessful wire collateral crossing has been reported in 17.7–26.8% of patients who underwent retrograde CTO PCI, despite it being performed by experienced CTO operators[6,8,9,13]. Furthermore, some fatal complications related to collateral wire passage during the retrograde approach, including perforation and septum hematoma, have been reported even though the collaterals were carefully chosen based on invasive coronary angiography, in some cases complemented by or selective angiography via a microcatheter[14,15].

Coronary computed tomography angiography (CTA) is a noninvasive method to diagnose coronary artery disease[16–18]. Improvements in spatial resolution permit visualization of small vessels, such as coronary collaterals in patients with chronic total occlusions[19,20]. However, there have so far been no reports regarding the diagnostic accuracy of coronary CTA to identify and evaluate septal and epicardial collaterals used for retrograde CTO PCI.

The purpose of this retrospective study was to assess the ability of coronary CTA to identify collaterals used for retrograde CTO PCI in comparison to invasive coronary angiography to compare the success rates for wire crossing between CT-visible and invisible collaterals.

2. Material and methods

2.1. Study population

With approval from our hospital's institutional review board, we retrospectively reviewed data from a total of 134 patients who underwent PCI for CTO at a single center (Japan Community Health care Organization, Hokkaido Hospital, Sapporo, Japan) between June 2010 and March 2013. CTO was defined as a lesion showing thrombolysis in myocardial infarctions (TIMI) of grade 0 for more than 3 months. Occlusion duration was estimated based on a history of angina, previous myocardial infarction (MI) in the same territory, or proven by previous invasive coronary angiography or coronary CTA. The retrograde approach was attempted in 75 patients; of which 49 who underwent coronary CTA before PCI within 5 weeks were enrolled in our study.

2.2. Angiographic assessment of collaterals

Diagnostic coronary angiography was performed using an INNOVA 2000 (GE Healthcare, Milwaukee, Wisconsin) or Aulla XPER FD-10 (Philips Medical Systems, Best, the Netherlands) in all patients before CTO PCI. Collaterals by coronary angiography were categorized into two groups, as modified from previous reports[10]: invisible collateral with coronary angiography, no continuous connection between donor and recipient vessel; or visible collateral with coronary angiography, continuous thread-like or small branch-like connections were visualized. Two experienced observers blinded to clinical history evaluated collaterals by coronary angiography independently. In cases of disagreement, consensus readings were performed.

2.3. CTA acquisition and data analysis

Coronary CTA was performed using a 64-slice computed tomography (CT) scanner (Light Speed VCT, GE Healthcare, Milwaukee, Wisconsin). Patients with irregular heart rates or heart rates >60 beats/min received 2–20 mg of propranolol hydrochloride intravenously. For heart rates <60 beats/min despite injection of propranolol hydrochloride, the step and shoot technique (Snapshot Pulse, GE Healthcare, Milwaukee, Wisconsin) was applied. If the heart rate remained irregular or >60 beats/min, the helical technique with low helical pitch (cardiac helical) was used. Coronary images were acquired with the following parameters: slice collimation, 64 × 0.625 mm; gantry rotation time, 0.35 ms; table feed, 7.2–8.2 mm/rotation; tube energy, 120 kV; and tube current, 600–800 mA. For the screening of coronary artery disease, 280 mgI/kg of nonionic contrast material (350 mgI/mL of iohexol, Omnipaque-350, Daiichi-Sankyo, Tokyo, Japan) was injected at a fixed duration of 12 s in 21 patients. When the existence of CTO was known before coronary CTA, 320–350 mgI/kg of nonionic contrast material was injected at a fixed duration of 12 s in 28 patients. Mean contrast volume was 61.4 ± 9.9 ml. Contrast administration was followed by 0.9% saline solution at a fixed duration of 7 s at the same flow rate as the contrast material (test-bolus tracking method)[21]. Raw CT data were reconstructed using algorithms optimized for retrospective electrocardiogram (ECG)-gated segment reconstruction. CT image data were transferred to a computer workstation for post-processing (Ziostation 2, Ziosoft Inc., Tokyo, Japan). Volume-rendered images, curved multiplanar reformations, maximum intensity projections, and cross-sectional images were reconstructed. Image quality of each coronary artery was visually assessed and divided into four groups: 3, all main coronary vessels could be clearly evaluated; 2, all main coronary vessels were acceptable for evaluation; 1, one main coronary vessel was difficult to evaluate due to motion artifact; or 0, more than two main vessels had motion artifact. The visibility grade of collaterals with CT was defined as that defined with invasive coronary angiography: invisible collateral with CT, no continuous connection between donor and recipient vessel (Fig. 1A); visible collateral with CT, collateral is seen as a tiny connection as a completely continuous, small branch-like connection (Fig. 1B). Two experienced observers independently evaluated image quality and collateral visibility. In cases of disagreement, consensus readings were performed.

2.4. Retrograde procedure

The retrograde approach was defined as introducing the guidewire from the donor vessel into collaterals, which might be connected to the distal end of the CTO. The choice of collaterals and guidewire was completely at the operator's discretion. First, a hydrophilic coated guidewire or a tapered polymer jacket guidewire was inserted into the target collateral with the aid of a microcatheter. After the successful crossing of the guidewire into the CTO's distal end, either retrograde wire crossing, the kissing wire technique, or the reverse controlled antegrade and retrograde subintimal tracking technique was attempted to cross the wire through the CTO.

2.5. Statistical analysis

Continuous data are presented as mean ± SD and their differences were compared using the Student *t*-test. Discrete variables are expressed as counts and percentages, with their differences assessed by Fischer exact tests and χ^2 tests. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of coronary CTA were computed for visualization of collaterals in comparison with invasive coronary angiography. All statistical tests were two-tailed and significance was set at $p < 0.05$. Analyses were performed using JMP Pro, version 11.0.0 (SAS Institute, Cary, NC).

3. Results

3.1. Patient and procedural characteristics

We excluded 6 patients with coronary CTA image quality scores