Post-Print of an Evaluation Study on the Efficacy and Safety of the "Crowbar Effect" Technique for Facilitating Balloon Crossing of High-Resistance Coronary Artery Chronic Total Occlusion Lesions

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Abstract

Background: One reason for failure of percutaneous coronary intervention (PCI) to recanalize coronary chronic total occlusion (CTO) is that the balloon cannot cross the CTO lesion. Objective: To evaluate the efficacy and safety of the "Crowbar Effect" technique in facilitating balloon crossing through high-resistance coronary CTO lesions, and to provide a new alternative technique for CTO recanalization and improve the success rate of CTO recanalization. Methods: A total of 648 patients with coronary CTO lesions treated with antegrade technique at Beijing Anzhen Hospital, Capital Medical University and Affiliated Hospital of Beihua University from January 2010 to January 2019 were selected. Among them, 84 cases (12.96%) were high-resistance CTO lesions where the guidewire successfully crossed the lesion but the balloon could not cross. The "Crowbar Effect" technique was applied to these cases to facilitate small balloon crossing through the CTO lesion to complete PCI. PCI success rate and major adverse cardiac events (MACE) were observed. Results: The J-score of the 84 CTO lesions was (1.63$±$0.90) points. After the first guidewire successfully crossed the CTO lesion, the success rate of small balloon crossing through the CTO lesion was 91.67% (77/84) with the use of the "Crowbar Effect" technique. There were still 7 cases (8.33%) of failure, including 2 cases due to 360-degree severe calcified lesions and 5 cases due to coronary perforation. No perioperative cardiac death or non-fatal myocardial infarction occurred in the 84 patients. Conclusion: The "Crowbar Effect" technique is an effective and safe technique that enables small balloons to cross balloon-uncrossable CTO lesions. Application of this simple technique for CTO recanalization has high success rate and clinical value.

Full Text

Evaluation of the Efficacy and Safety of "Crowbar Effect" Technique to Facilitate Balloon Crossing Resistant Chronic Total Occlusion Lesions

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Abstract

Background: The inability of a balloon to cross coronary chronic total occlusion (CTO) lesions represents one of the primary causes of percutaneous coronary intervention (PCI) failure in CTO revascularization. **Objective:** To evaluate the efficacy and safety of the "Crowbar Effect" technique for facilitating balloon crossing of resistant CTO lesions, thereby providing an alternative novel approach to improve CTO recanalization success rates. **Methods:** We enrolled 648 patients with coronary artery CTO lesions treated via antegrade approach at Beijing Anzhen Hospital, Capital Medical University and the Affiliated Hospital of Beihua University between January 2010 and January 2019. Among these, 84 cases (12.96%) involved resistant CTO lesions where the guidewire successfully crossed but the balloon could not. The "Crowbar Effect" technique was applied to facilitate small balloon crossing of CTO lesions to complete PCI. PCI success rates and major adverse cardiac events (MACE) were observed. **Results:** The mean J-score for the 84 CTO lesions was (1.63$±$0.90). After successful crossing of the first guidewire through CTO lesions, the success rate of small balloon crossing was 91.67% (77/84) due to the "Crowbar Effect" technique. Seven cases (8.33%) remained unsuccessful, including 2 cases due to 360-degree severe calcification and 5 cases due to coronary artery perforation. No perioperative cardiac death or non-fatal myocardial infarction occurred among the 84 patients. **Conclusion:** The "Crowbar Effect" technique is an effective and safe method for facilitating small balloon crossing of balloon-uncrossable CTO lesions. This simple technique demonstrates high success rates and clinical value for CTO recanalization.

Keywords: Coronary occlusion; Chronic total occlusion; Crowbar Effect; Percutaneous coronary intervention

1. Methods

1.1 Patient Selection We selected 648 patients with coronary CTO lesions treated using antegrade techniques at Beijing Anzhen Hospital, Capital Medical University and the Affiliated Hospital of Beihua University between January 2010 and January 2019. Among these, 84 cases (12.96%) involved resistant CTO lesions where the guidewire successfully crossed but the balloon could not, despite optimal guide catheter support. These patients underwent the "Crowbar Effect" technique to facilitate small balloon passage through CTO lesions and complete PCI. All diagnoses conformed to the diagnostic criteria in the AHA/ACC and ESC guidelines for non-ST-elevation acute coronary syndromes [13,14]. Angina symptoms met Canadian Cardiovascular Society classification grades 2-4 [15]. All patients had a clear history of exertional angina for more than 3 months or documented prior myocardial infarction (OMI).

1.2 Definitions of CTO and Balloon-Uncrossable CTO Lesions Coronary angiography (CAG) showing RCA, LAD, or LCX with TIMI grade 0 or 1 and occlusion duration exceeding 3 months defined CTO. CTO duration estimation: For patients with documented myocardial infarction (MI) without prior PCI, the CTO history was estimated from the MI onset date; for those without clear MI history, estimation was based on angina symptom onset and severity timing. Balloon-uncrossable CTO lesions were defined as lesions where the guidewire successfully crossed the CTO, but a small balloon (diameter 1.0-1.5 mm) could not enter the CTO segment despite optimal guide catheter support [12].

1.3 J-Score Assessment for CTO Lesions The J-score evaluated CTO lesion difficulty, comprising five components [16]: (1) blunt proximal cap (1 point); (2) tortuosity angle >45° (1 point); (3) occlusion length >20 mm (1 point); (4) lesion calcification (1 point); (5) prior failed PCI attempt (1 point). Scores of 0 indicated easy; 1, moderate; 2, difficult; and \$ \$3, very difficult. All selected cases in this study had J-scores \$ \$3.

1.4 Coronary Anatomical Segmentation Using the AHA/ACC coronary segmentation method [17], coronary arteries were divided into 15 segments: RCA as segments 1-4, left main (LM) as segment 5, LAD as segments 6-10, and LCX as segments 11-15.

1.5 Perioperative Medication and PCI Procedure All patients received routine oral loading doses of clopidogrel 600 mg and aspirin 300 mg within 24 hours pre-PCI. Post-PCI day 1, patients received clopidogrel 75 mg and aspirin 100 mg once daily. Successful cases continued this regimen. Heparin sodium 100 U/kg was administered intravenously during PCI, with additional 1,000 U hourly to maintain activated clotting time (ACT) at 350-500 seconds. Among the 84 patients, 78 (92.86%) underwent right radial or right brachial artery access. Standard PCI techniques were employed.

1.6 Guide Catheter Selection For LAD and LCX lesions, 6F XB, EBU, or BL guide catheters were selected. For RCA, 6F JR, BL, MAC, AL, or SAL catheters were routinely chosen. When guide catheter support was insufficient, deep intubation or Guidezilla extension catheters were used to enhance active support.

1.7 "Crowbar Effect" Technique Operative Points First, a soft PCI guidewire (e.g., Fielder XT or XTR, SION blue, Pilot50, Runthrough) was advanced through the lesion. If unsuccessful, a stiffer guidewire (e.g., Pilot150 or Pilot200, Gaia 2 or Gaia 3, Progress 80) was used. After confirming the guidewire traversed the distal true lumen, if balloon advancement failed, a second hydrophilic-coated, stiffer guidewire was advanced along the first guidewire's path to the distal segment. After withdrawing one guidewire, if a 1.5 mm$×15*mmsmallballoon*(*typicallythehighlydeliverableMaverickballoon*)*stillcouldnotenterthelesion*, *amedi*
stiffnessguidewirewasadvancedalongthefirstguidewiretothedistaltruelumen, *followedbyathirdstifferguid*
16*atm*), *advancing*1−2*mmwitheachinflationuntilcrossingthelesion*.*Thestifferguidewireswerethenwithdra*
mm) was used for lesion predilation and drug-eluting stent (DES) implantation. This high-pressure small balloon expansion drives the two additional guidewires to pry open dense, rigid lesion tissue from proximal to distal, creating a passable channel—the "Crowbar Effect" (Figure 1 [Figure 1: see original paper] and Figure 2 [Figure 2: see original paper]). If repeated attempts failed, the procedure was abandoned as PCI failure.

1.8 Definition of PCI Success PCI success required meeting all seven criteria: (1) antegrade guidewire crossing into distal true lumen; (2) PTCA balloon advancement into and through the CTO lesion; (3) successful PTCA with predilation; (4) successful DES implantation; (5) target lesion residual stenosis <10%; (6) TIMI 3 flow; (7) no PCI complications. Perioperative MACE included cardiac death, non-fatal MI, and coronary perforation requiring PCI termination.

1.9 Statistical Methods All data were analyzed using SPSS 17.0 software. Categorical data were expressed as percentages and compared using ^{2} tests. Continuous data were expressed as ($\bar{x}$±s) and compared using independent samples t-tests. P<0.05 indicated statistical significance.

2. Results

2.1 Baseline Patient Data The 84 patients included 56 males (66.67%) and 28 females (33.33%), aged 47-86 years (mean 64.3$±11.8*years*).*Tenpatients*(11.90±$26.49
months), with $ $6 months in 10 cases (11.90%) and >6 months in 74 cases (88.10%). Comorbidities included smoking (45 cases, 53.57%), hypertension (33 cases, 39.29%), hyperlipidemia (23 cases, 27.38%), diabetes (32 cases, 38.10%), stroke (11 cases, 13.10%), OMI (57 cases, 67.86%), stable angina (3 cases, 3.57%), unstable angina (60 cases, 71.43%), and NSTEMI (21 cases, 25.00%).

2.2 CAG Results Among the 84 balloon-uncrossable resistant CTO lesions, target vessel distribution was RCA in 43 cases (51.19%)—segment 1 in 14 (32.56%), segment 2 in 19 (44.19%), and segment 3 in 10 (23.26%); LAD in 19 cases (22.62%)—segment 6 in 7 (36.84%) and segment 7 in 12 (63.16%); LCX in 22 cases (26.19%)—segment 11 in 6 (27.27%), segment 12 in 4 (18.18%), and segment 13 in 12 (54.55%). All 84 lesions showed TIMI 0 flow. Collateral circulation from contralateral or ipsilateral vessels visualized the distal CTO segment in 72 cases (85.71%)—RCA in 37 (86.05%), LAD in 15 (78.95%), and LCX in 20 (90.91%).

2.3 J-Score Assessment of CTO Lesions The mean J-score for the 84 CTO lesions was (1.63$±$0.90): 0 points in 13 cases (15.48%), 1 point in 16 cases (19.05%), 2 points in 44 cases (52.38%), and 3 points in 11 cases (13.10%) (Table 1). No significant differences existed between RCA vs. LAD, LAD vs. LCX, or RCA vs. LCX (t=0.935, P=0.352; t=0.291, P=0.772; t=1.349, P=0.181).

2.4 PCI Success Rate and Coronary Perforation Rate PCI success was achieved in 77 cases (91.67%), with 7 failures (8.33%) (Table 2). No significant differences in success rates existed between RCA vs. LAD, LAD vs. LCX, or RCA vs. LCX (^{2}=0.212, P=0.645; ^{2}=0.155, P=0.694; ^{2}=0.022, P=0.881). Among failures, 2 cases were due to uncrossable severe 360° calcification and 5 due to coronary perforation.

2.5 MACE Incidence No perioperative cardiac death or non-fatal myocardial infarction occurred. Five patients (5.95%) experienced coronary perforation with visible contrast extravasation, which was managed by small balloon occlusion (10-20 minutes) and heparin reversal with protamine. Perforations were sealed, PCI was terminated, and no hemodynamic compromise or adverse consequences occurred.

3. Discussion

3.1 Significance and Success Rates of CTO Recanalization Contemporary research confirms that CTO recanalization improves blood supply to ischemic myocardium, promotes collateral circulation formation, relieves angina, and enhances left ventricular function and prognosis [18,19]. However, CTO lesions—characterized by atherosclerotic plaque, thrombosis, and fibrointimal proliferation—present significant challenges for PCI, with prolonged fluoroscopy time, lower success rates, and higher complications [20]. Over the past decade, advances in CTO devices and appropriate case selection have substantially improved success rates, now reported at 70-90% [21]. HAN et al. [22] reported a 90.8% success rate in 1,263 CTO patients, while MORINO et al. [23] reported 86.6% in a Japanese multicenter registry, and a Canadian multicenter study reported 70% [24]. Overall, CTO-PCI success correlates with lesion selection criteria and operator experience. Our study included cases with J-scores $ $3, with 86.91% (73/84) having J-scores $ $2, representing less difficult cases that contributed to the high antegrade success rate (98.92%). We recommend selecting CTO cases with favorable clinical features (typical angina) and angiographic characteristics (J-score) to maximize success rates and patient benefit.

3.2 Primary Causes of CTO-PCI Failure CTO-PCI failure stems from three main issues: (1) guidewire inability to reach the distal true lumen; (2) balloon inability to cross after guidewire success; and (3) balloon inability to dilate the lesion [25]. Balloon uncrossability results from: (1) long lesions (>20 mm) with fibrosis and calcification; (2) tortuous fibrocalcific lesions; and (3) angulated calcified lesions. Literature reports balloon uncrossability in 6-10% of CTO lesions [11], varying by case selection. In our 648 CTO cases, 84 (12.96%) were balloon-uncrossable, correlating with our inclusion of many low J-score ($ $2) cases (65.48%). The "Crowbar Effect" technique enabled balloon crossing in 91.67% of these cases, demonstrating its effectiveness and safety.

3.3 Strategies to Facilitate Balloon Crossing When small balloons fail to cross CTO lesions, several strategies exist: (1) switching to stronger-support guide catheters (EBU, Amplatz, XB, MAC), though this risks losing distal wire position; (2) using extension catheters (GuideLiner, TrapLiner, Guidezilla) [26]; (3) side-branch anchoring with small balloons (1.5-2.0 mm); (4) microcatheter passage (Tornus, Corsair, Finecross) [27]; (5) dual-wire techniques ("buddy wire," "wire cutting," "see-saw wire-cutting") [28-30]; and (6) excimer laser or rotational atherectomy [31,32]. However, when microcatheters fail, switching to rotational atherectomy wires is difficult and risks losing true lumen position. The "Crowbar Effect" technique overcomes these limitations for resistant CTO lesions, improving PCI success [33].

The key operative principle involves advancing a third guidewire along the path of existing wires after single or dual wire success. A small balloon (commonly 1.5 mm$\times$15 mm Maverick) is then advanced with sustained pushing force and repeatedly inflated at high pressure (12-16 atm, 5 seconds each), advancing 1-2 mm per inflation until crossing. This method is simple, safe, and effective, as demonstrated by our results.

In summary, the "Crowbar Effect" technique is an effective and safe method for facilitating small balloon crossing of balloon-uncrossable CTO lesions, offering high success rates and clinical value. However, our study only demonstrated its efficacy and safety without comparative analysis, thus proving it as a viable option rather than a superior method for treating resistant CTO lesions.

Author Contributions

LIU Ruifang, XU Fangxing, and ZHOU Yujie conceived the study design. All authors participated in procedures, data collection, and analysis. LIU Ruifang and WU Xiaofan drafted the manuscript. LIU Tongku and ZHOU Yujie reviewed and revised the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Note: Figure translations are in progress. See original paper for figures.