Antegrade Techniques for Chronic Total Occlusions

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Abstract: By convention, a total obstruction of the coronary artery with no flow at the occluded segment that has been present for at least 3 months is termed as chronic total occlusion or CTO. This is to be distinguished from a sudden occlusion of the coronary artery lumen by a thrombus during an acute myocardial infarction. Percutaneous coronary intervention (PCI) of CTO is increasingly being performed by interventional cardiologists with improved success rates. In this article, the focus will be on antegrade techniques that will assist the operator to maximise the success rates and to minimise the complications.

Keywords: Antegrade techniques, chronic total occlusion, percutaneous coronary intervention.

INTRODUCTION

CTO remains one of the most difficult subsets for the interventional cardiologist because of the perceived procedural complexity. Over the past few years, tremendous improvement in PCI materials and equipments, as well as growth of new strategies have enabled us to treat with success even the complex CTO. The antegrade navigation of wires through CTO is dependent on the type of wires used and utilisation of several techniques to enhance procedural success.

INDICATIONS FOR PCI OF CTO

Choosing the appropriate patients for CTO will maximise the benefits for the patient and minimise the complications. The OAT (Occluded Artery Trial) study which randomised more than 2000 patients with subacute myocardial infarction and an occluded infarct-related artery to PCI or to medical therapy provided evidence to demonstrate that PCI of a occluded artery is not beneficial if there is no viable myocardium in the region supplied by the occluded artery [1].

The current indications for PCI of CTO are angina or significant myocardial ischaemia attributable to the CTO. The potential benefits of successful PCI of CTO are improvement in symptoms, improving left ventricular function and improving survival. There are multiple studies demonstrating reduction of angina after successful CTO PCI including an observational study that compared angina symptoms in those with successful and failed CTO PCI which demonstrated that those with successful CTO PCI were more likely to be angina free and have a negative treadmill test [2-4]. Multiple studies have shown that there is an improvement in left ventricular function after successful CTO PCI and the greatest benefit is seen in those with significant left ventricular dysfunction at baseline but with minimal or no evidence of myocardial damage in the region of the distribution of the CTO on cardiac MRI with late gadolinium enhancement studies [5-7]. As regards, the survival benefits of CTO PCI while there are small studies, suggest possible survival benefit, however, there is yet no randomised control data [8]. Another common reason for CTO PCI is the refusal of CABG by the patient and the preference for PCI.

FEASIBILITY OF CTO PCI

Before embarking on a CTO PCI, it is important to assess lesion factors and patient related factors before making a decision to proceed. Favourable anatomic features of the CTO will increase the likelihood of PCI success and reduce the risk of complications.

Predictors of success are : - 1) short duration of occlusion, 2) short length of occlusion, 3) tapered stump at proximal cap (allows guidewire to be directed antegradely), 4) absence of bridging collateral at occluded site (avoids the likelihood of guidewire slipping preferentially into collateral) and 5) the absence of side branch at occluded site (avoids preferential entry of guidewire into side branch where the occlusion is flush with the origin of side branch).

Unfavourable factors that will decrease the likelihood of successful PCI are : - 1) long standing occlusion with calcification (lesion likely to be hardened and not easily penetrable), 2) length of occluded lesion greater than 20 mm (more difficult to cross long lesions), 3) absence of stump (difficulty for the guidewire to find an entry point through the proximal cap) , 4) presence of bridging collateral at occluded site (preferential entry of guidewire into collateral), and 5) presence of side branch at occluded site (preferential entry of guidewire into side branch where the occlusion is flush with the origin of the side branch). An example of an unfavourable CTO where there is no obvious stump is shown in (Figs. **1A & 1B**).

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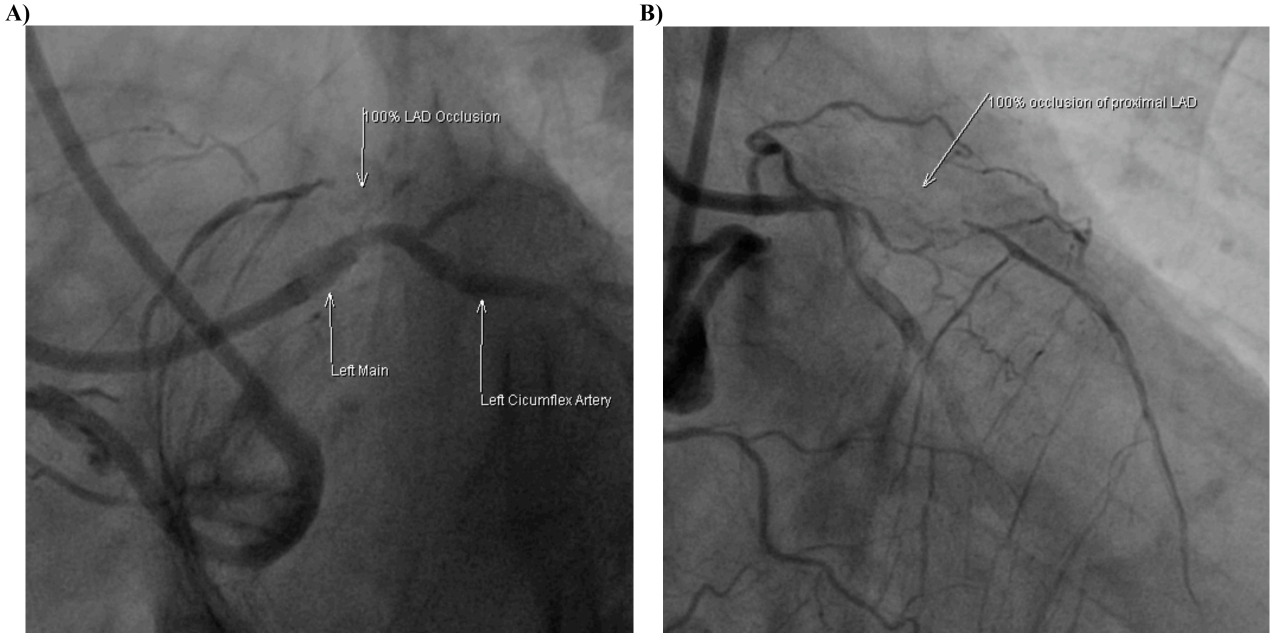

Fig. (1). A). LAO caudal view showing a proximal LAD CTO. **B**). RAO caudal view showing the LAD CTO.

One scoring system used to predict success is the J-CTO score which is used to predict the likelihood of guidewire crossing within 30 minutes. The system attributes one point for each of the following parameters:- presence of blunt stump, calcification in CTO segment, angulation of > 45 degrees in CTO segment, occluded segment > 20 mm in length and previously failed CTO lesion. The system is graded into easy (score 0), intermediate (score 1), difficult (score of 2), and very difficult (score ≥ 3). Generally, a score of 0 predicts successful guidewire crossing of the CTO lesion within 30 minutes in 90% or more [9].

Patient factors include allergy to contrast agents and renal impairment. As CTO PCI may require a higher contrast load, assessment must weigh the risks and benefits of the PCI as there is a risk of contrast induced nephropathy arising from the CTO PCI. Severe peripheral vascular disease and diffuse disease of the aorta may make it impossible to use the femoral route for CTO PCI. Severe tortuosity of the thoracoabdominal aorta or the presence of a thoracic graft may make the angulation impractical to obtain good guiding catheter support. Bilateral iliac or femoral artery occlusion will make femoral access not feasible. When considering the use of a radial route in such a situation where diffuse atherosclerotic disease is present, careful assessment must be made to ensure that there is no significant disease in the radial, brachial, axillary, subclavian and innominate arteries. Presence of atherosclerotic disease in the innominate artery may increase the risk of cerebral embolism during the passage and manipulation of the guiding catheters into the coronary ostia.

PRE-PLANNING FOR CTO PROCEDURE

The key to success in CTO PCI is meticulous planning. Detailed patient preparation is of paramount importance. CTO PCI generally takes a longer time than a routine PCI. There is a tendency to use more contrast media and to expose patients to higher doses of X-ray radiation.

Measures to minimise the risk of contrast induced nephropathy include:- 1) ensuring that the patient is adequately hydrated pre- and intra- procedure by intravenous infusion, 2) giving acetylcysteine pre- and post-procedure, and 3) preplanning the volume of contrast media intended for the procedure. As a rule of thumb, a safe estimate of the contrast volume will be about 4 times the GFR. If there is evidence of mild renal impairment, isosmolar contrast media is less likely to have an impact on renal function should be used, for example, iodixanol.

Understanding the target lesion has been made possible with the easy availability of Coronary Multi-slice Computed Tomography (MSCT) angiography scan. MSCT guided PCI can result in better and safer outcomes by allowing the operator to plan the approach to PCI [10-13].

MSCT scan enables 3 dimensional visualisation of the CTO and also provides information on the presence of calcification and the "hardness" of the plaque. While analysing the MSCT study of the CTO, one should carefully assess the CTO to : - 1) Determine the length of the CTO, 2) Assess the extent of calcification, 3) Assess the density of the plaque by use of the Hounsfield numbers, 4) Assess the distal course of the vessel, 5) Assess the presence of branches in the pre- and post-occlusion segments, 6) Assess the presence and degree of angulation in the CTO segment, 7) Assess the ostium of the occluded vessel in relation to the aortic root anatomy to determine choice of guiding catheter, and 8) Assess the collateral circulation. If no pre-PCI MSCT has been done, a diagnostic coronary angiogram should be performed. Adhoc CTO PCI is generally discouraged as pre-planning will increase the likelihood of success and reduce the likelihood of complications. For the diagnostic coronary angiogram, careful assessment of the coronary anatomy, length of occlusion, proximal and distal cap, presence of side branches and collaterals, presence of calcification, and distal course of the occluded artery. The advantage of MSCT scan over a diagnostic coronary angiogram, is that the MSCT will allow visualisation of the segment distal to the CTO and assessment of the characteristics of the CTO (length of lesion, presence of calcification, severity of calcification) that may otherwise may not be possible from a diagnostic coronary angiogram. Before commencing the procedure, decide on the choice of the guiding catheter that will provide the necessary support, the CTO guidewires required and supporting equipment.

INTRA-PROCEDURAL ANTEGRADE APPROACH FOR CTO

Adequate dual antiplatelet therapy and intra coronary heparin should be given before the commencement of the CTO PCI. For complex CTO procedures, the femoral is generally preferred as larger guiding catheters may have to be used. If the iliac arteries are tortuous, a long sheath should be used.

a). Choice of Guiding Catheter

Based on the MSCT scan or the diagnostic coronary angiogram, an appropriate guiding catheter should be chosen to provide good support. While it is possible to use a 6 F guiding catheter, a 7F size is generally preferred for complex CTO PCI. For PCI of CTO lesions in the left coronary circulation, the guiding catheter of choice is an extra back-up type (EBU, Voda or XB) catheter. Occasionally, an Amplatz left (AL) guiding catheter may be required. For PCI of right coronary artery CTO, a Judkins right (JR) guiding catheter with side holes should be chosen to reduce the risk of dissection during contrast injection. Occasionally, an AL catheter is chosen, especially if there is superior angulation of the right coronary ostium. Routine use of JR, 3-dimensional, or Hockey Stick type catheters may allow better coaxial alignment and wire steerability than Amplatz catheters. Once the guiding catheter has been chosen, orthogonal views should be obtained to ensure that the guiding catheter isco-axial with the coronary artery to get maximal support. Occasionally, if the guiding catheter support in complex PCI is inadequate, the anchor technique may be employed by using a small balloon inflated to a low pressure in a side branch.

One of the important factors that will increase the likelihood of CTO PCI success is the use of a dual coronary injection approach. Bilateral catheterisation with concurrent contrast injection will allow visualization of occluded distal segment of target vessel via collateral flow .The steps to get the best images for CTO PCI include :- 1) injecting contrast into the contralateral artery providing the collateral circulation followed by injection of contrast into the target CTO artery, 2) use a low magnification to enable visualisation of the entire coronary circulation within the cine angiogram image, 3) keeping the position static during cine angiogram to enable clear visualisation of the segment distal to the CTO and the size, number and course of collateral vessels. As CTO PCI procedures generally take a longer time, the radiation exposure of the patient should be reduced by using low magnification and lowest frame rate available when attempting to cross the CTO with a guidewire.

b). Initial Guidewire Choice

The commonest approach is to use a stepwise approach starting with polymer coated floppy wires and progressing gradually to stiffer wires. The initial approach in the CTO PCI is to use guidewires that can allow the safe crossing of microchannels in the CTO. The first choice guidewires are 0.014 inch tapered floppywires with low gram force and low tip stiffness. This includes the polymer coated Fielder XT, XTR, XTA wire (Asahi Intec, Japan), Wizard 78 (Lifeline, Japan), Gaia 1 (Lifeline, Japan) Gentle manipulation of these wires may allow the passage of these guidewires through microchannels in the CTO.

When shaping the curve of a guidewire tip, the aim is to shape the curve just slightly longer than the vessel lumen diameter. However, as a CTO has no lumen, the guidewire tip curve should be shaped such that the bend should be about 1 to 2 mm from the tip at an angle that is less than 45 degrees. A secondary bend can be made few mm from the tip with a very slight angulation of not more than 15 degrees.

c). Microcatheter

The CTO PCI success can further be enhanced by the concomitant use of microcatheter which can provide support to the guidewire while attempting to manipulate across the CTO. The microcatheter can also allow injection of contrast when the guidewire is removed. It also allows the guidewire to be exchanged for an atraumatic guidewire after crossing the CTO. It can also straighten a tortuous coronary artery proximal to CTO and increase the guidewire torque. The most commonly used microcatheter presently is the Finecross (130 cm, 150cm, Terumo, Japan) whose small tip and and M-coating enables it to navigate smoothly through a narrow space in CTO. The recently introduced Finecross MG (130 cm, 150 cm, Terumo, Japan) is better for tracking tortous vessels as it is hydrophilic coated and tapered from 2.6 F proximally to 1.8 F distally. The Corsair (135 cm, 150 cm, Asahi Intec, Aichi, Japan) microcatheter designed for collateral channel tracking, can also be used antegradely. It has more support, even beyond a calcified segment. Certain precautions need to be observed when handling the microcatheter. Before injecting contrast through the microcatheter, back bleeding should be present. When the microcatheter has to be removed without removal of the guidewire, the sideport of the microcatheter can be connected to an inflation device which is inflated to about 6 to 10 atmospheres of pressure or connected to a contrast filled syringe. The microcatheter is then removed with the guidewire in situ by injecting contrast at an elevated pressure through the sideport. Another technique for the removal of the microcatheter is the trapping technique where the microcatheter is withdrawn into the guiding catheter and a small balloon catheter is passed beyond the distal tip of the microcatheter and inflated to trap the guidewire within the guiding catheter. The microcatheter is removed while the guidewire is securely held in place. After removal of the microcatheter, the balloon catheter is deflated and also removed, leaving the guidewire in place.

d). Single Wire Antegrade CTO Techniques

Using a hydrophilic floppy wire with tapered tip supported by a microcatheter, the guidewire tip with a short curve is gently advanced and rotated to find microchannels which offer no resistance (Fig. **2**). While performing this sliding technique, as there is no tactile response to guide the operator, the wire position has to be observed in 2 orthogonal planes to look for evidence of entry into subintimal space. When performing this technique, the proximal end of the guidewire should be lightly held with the left hand and the distal end where the torque device is should be rotated clockwise and anti-clockwise alternatively. Tapered polymer coated guidewires that are generally preferred are the Fielder XT (Asahi Intec, Aichi, Japan) series wires (Fielder XT with tip load of 0.8 gm, Fielder XT-R with tip load of 0.6 gm and Fielder XT-A with tip load of 1.0 gm). The operator should attempt crossing the CTO with the Fielder XT wire for at least 10 to 15 minutes before changing the wire. Tapered hydrophilic wires like Runthrough NS (Terumo, Japan) wire and non-tapered polymer coated low tip stiffness wires such as Fielder FC (Asahi Intec, Aichi, Japan), Whisper (Abbott Vascular, USA) and Choice PT (Boston Scientific, USA). Floppy wires are alternative choices. If these wires are unable to make any penetration into the CTO lesion, a polymer coated non-tapered high tip stiffness wire can be considered such as the PT II (Boston Scientific, USA) Moderate Support (tip stiffness of 2.9 gm) or PT Graphix (Boston Scientific, USA) Intermediate (tip stiffness of 1.7 gm). Extreme caution must be exercised when using these high tip stiffness guidewires as subintimal dissection and even perforation can occur if the guidewire is advanced despite the presence of resistance.

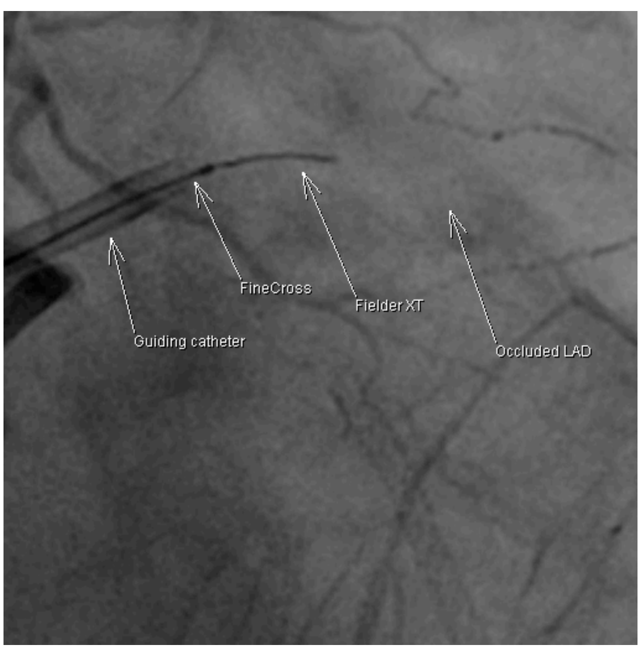

Fig. (2). Using a hydrophilic floppy wire with tapered tip (Fielder XT wire) supported by a microcatheter (FineCross) to cross the LAD CTO.

If the above steps fail, polymer coated or hydrophilic non-tapered wires with tip stiffness of 3 to 6 gm should be used. These will include the Miracle 3, Miracle 6, Ultimate Bros 3 (Asahi Intec, Aichi, Japan) and Cross IT 100, 200 (Abbott Vascular, USA) guidewires. These wires are suitable for the drilling technique which can be employed if there is a discrete entry point. Compared to the sliding technique mentioned above, the curve at the wire tip should not only be short (2 mm) but the angulation is greater at between 45 to 60 degrees. Generally, these wires should not be continuously torqued and advanced in the same direction continuously. Instead, the guidewire should be rotated clockwise and counter-clockwise alternately. Rapid rotation of the tip with gentle probing as the guidewire is gradually advanced is complemented by a stepwise increase in the stiffness of the wire to achieve crossing of the CTO. Caution must be exercised to detect passage into the false lumen where the operator can feel the resistance and the tactile sensation when moving the wire. Another approach is to use a non-tapered wire with tip stiffness of 3 to 6 gm (such as Ultimate Bros 3) if the lesion cannot be crossed with a tapered polymer coated guidewire such as Fielder XT (Fig. **3**). In the example given, the ostial LAD CTO was successfully crossed and stented with good results (Fig. **4**).

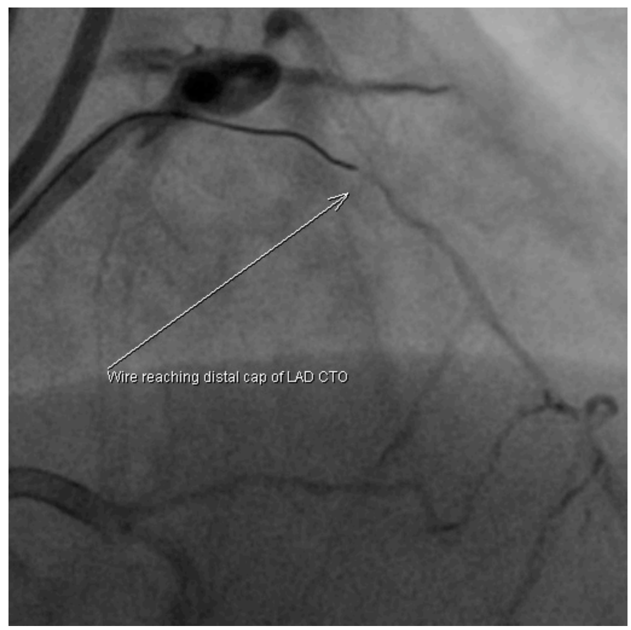

Fig. (3). Using a Ultimate Bros 3 wire supported by a FineCross catheter to cross the LAD CTO.

If the drilling technique is not successful or not practical, the penetration technique will have to be considered especially where the proximal cap is blunt, hardened and calcified. This technique is associated with a higher risk of perforation and hence should be avoided if the CTO lesion is angulated or has the presence of bridging collaterals. It should only be used if the course of the CTO is evident. The stiff guidewire should be pushed gradually and slowly advanced with minimal rotation towards the direction of the distal lumen. The guidewires are tapered with tip loads of 9 to 12 gm and include Conquest Pro 9 and 12 (Asahi Intec, Aichi, Japan), Progress 200 (Abbott Vascular, USA). Miracle series or Gaia 2 (Asahi Intec, Aichi, Japan) wires are better than Conquest wires for crossing a CTO in tortuous artery.

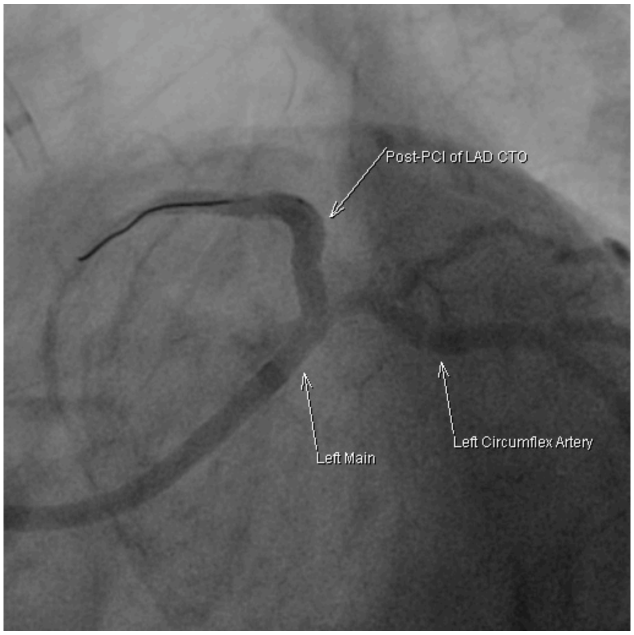

Fig. (4). Post- Stenting of the proximal LAD.

e). Dual Wire Antegrade CTO Techniques

This technique, also called parallel wire technique, can be employed if the guidewire causes a sub-intimal dissection and is in the false lumen. Once sub-intimal dissection is seen, the wire should not be advanced further and should be left in its position and the single wire technique can be converted to a dual wire technique. Using the track created by the initial guidewire, a stiffer second guidewire (such as Miracle 12 or Conquest Pro) is manipulated along the same course and under orthogonal views, an attempt to gain entry into the true lumen distally by puncturing the distal cap of the CTO. The operator must avoid twisting of the 2 wires by careful observation in 2 orthogonal planes when advancing the second guidewire.

f). Complex Antegrade CTO Techniques

Complex antegrade CTO techniques are used by experienced operators when the usual techniques are unsuccessful. Intravascular ultrasound (IVUS) guided CTO PCI can be used if the initial guidewire fails to cross the CTO and causes a sub-intimal dissection. If this technique is a possible option in the preplanning phase when the CTO lesion is calcified and has a blunt stump, a 8F guiding catheter should be used at the commencement of the procedure. A small 1.5 mm balloon is inflated in the sub-intimal space to allow passage of the IVUS catheter. The IVUS catheter can help provide imaging guidance for the entry of the second stiff guidewire and orientation in the right direction. The second guidewire is supported by a microcatheter and entry into the true lumen attempted. Contrast injection should be minimized or avoided till access to the distal true lumen is obtained. This is to avoid further dissection when contrast is injected into the passage created by the balloon dilatation [14]. Other sub-intimal dissection reentry techniques include the "knuckle wire" technique and the "subintimal tracking and reentry" (STAR) technique. In the "knuckle wire" technique, a polymer coated wire such as Fielder XT is allowed to form a wire loop distally and the wire loop is advanced distally past the CTO length. Reentry into the distal true lumen is attempted with a stiff guidewire supported by a microcatheter. The STAR technique is a variation in which a hydrophilic wire with J configration is used to create a subintimal dissection pass the CTO length instead of a wire loop and the J tip is orientated to try to obtain reentry into the distal true lumen [15]. Additional iterations of this technique including contrast enhanced and mini-STAR techniques also have suboptimal control over reentry site location and lower rates of successful reentry [16]. Devices that are available to assist reentry from the sub-intimal plane into the distal true lumen include the CrossBoss catheter and the Stingray balloon system (BridgePoint Medical, Plymouth, MN). All these complex techniques are associated with an increased of perforation and hence have to be performed by experienced operators with careful observation of the orthogonal images to avoid this complication.

CONCLUSION

With improved technological advances, PCI CTO can be performed with high success and low complication rates. However, pre-planning especially with CT, can potentially increase success rates, reduce complication and shorten procedural times. Being experienced with the techniques and the PCI CTO equipment are essential for high success rates. Last but not least, the operator must always be alert to any signs of complications and be well trained to manage the complications.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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