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Complications of Recanalization of Chronic Total Occlusion

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Abstract: Percutaneous Coronary Intervention (PCI) of Chronic Total Occlusions (CTO) is an accepted revascularization procedure. These complex procedures carry with them certain risks and potential complications. Complications of PCI such as contrast induced renal dysfunction, radiation, etc, assume more relevance given the length and complexity of these procedures. Further, certain complications such as donor vessel injury, foreign body entrapment are unique to CTO PCI. A thorough understanding of the potential complications is important in mitigating risk during these complex procedures.

Keywords: Chronic total occlusions, complications, percutaneous coronary interventions.

INTRODUCTION

Percutaneous coronary intervention (PCI) of a chronic total coronary artery occlusion (CTO) is an accepted revascularization procedure for coronary artery disease, and is being increasingly utilized. Such interventions account for approximately 10% of patients undergoing PCI [1]**.** Although there are no randomized trials, registry studies suggest that successful revascularization of CTOs is associated with improved outcomes, including survival [2, 3], especially in patients with multivessel coronary artery disease [4].

Revascularization of CTOs are among the most complex procedures that are performed by interventional cardiologists. It is critical to understand the potential complications with these procedures, and steps that could be taken to mitigate risk.

An analysis of 3482 patients and 3493 target CTO lesions from a total of 26 studies [5] revealed the following complications.

Yet another systematic review by Patel and colleagues [6] of 65 studies with 18,061 patients and 18,941 target CTO vessels also revealed consistent results to the above study – i.e. low risk for death (0.2%), emergent CABG (0.1%), stroke (0.01%), MI (2.5%) and contrast nephropathy (3.8%).

Complications can broadly be divided into peri-procedural and long-term –The usual complications of PCI in the peri-procedural and late complications also apply to chronic total occlusion (CTO) interventions, such as periprocedural myocardial infarction and stroke.

Further, there are also complications specific to specialized techniques, such as retrograde crossing and dissection/reentry techniques. Peri-procedural CTO intervention complications can be related to the coronary artery, other cardiac structures, or general complications. In the long term, CTO interventions can be complicated by stent thrombosis, in-stent restenosis or coronary aneurysm formation.

Table 1. Procedural complications in patients undergoing retrograde percutaneous coronary chronic total occlusion interventions [5].

Death	0.7% (95% CI: 0.5% to 1.2%);
Urgent CABG	0.7% (95% CI: 0.4% to 1.2%);
Tamponade	1.4% (95% CI: 1.0% to 2.2%);
Collateral perforation	6.9% (95% CI: 4.6% to 10.4%);
Coronary perforation	4.3% (95% CI: 1.2% to 15.4%);
Donor vessel dissection	2% (95% CI: 0.9% to 4.5%);
Stroke	0.5% (95% CI: 0.2% to 1.0%);
MI Q wave MI	3.1% (95% CI: 0.2% to 5.0%); 0.6% (95% CI: 0.4% to 1.1%);
Vascular access complications	2% (95% CI: 0.9% to 4.5%);
Contrast nephropathy	1.8% (95% CI: 0.8% to 3.7%); and
Wire fracture and equipment entrapment	1.2% (95% CI: 0.6% to 2.5%)

COMPLICATIONS RELATED TO CTO PCI –

General Complications

Radiation

Radiation injury is a potential complication of any PCI. CTO PCI, typically due to longer time involved, is one of the predictors of increased radiation dose [7, 8]. The injury can lead to severe consequences for the patient, including skin injury [9] (see Fig. **1**). It is important for patients and the

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Fig. (1). Radiation skin injury in a patient with prior CTO attempt.

physician to be aware of this potential risk, since if not accurately identified can lead to biopsy and subsequent non-healing ulceration. Further, there are heath hazards as a consequence of long-term exposure to the operating physician and ancillary staff, including tumors [10] and cataracts [11].

It is critical to follow Air Kerma, and not just the overall fluoroscopy time as had been traditionally done. The air kerma dose is the number that physicians should constantly monitor during the procedure, since this correlates directly with radiation skin injury to the patient [12]. Patients need to have a follow up plan after prolonged procedures [13]. At 2-3 Gy, skin injury can develop at a given site. [Suggest: Specific follow-up for radiation skin injury should be performed when there is >5 Gy air kerma dose exposure]. It is important to have a standardized radiation safety program in place, when embarking on a CTO program. Radiation hand-out to patients who have exceeded thresholds needs to be routine practice. 30 day photographs need to be performed. Also, it is critical to separate CTO attempts by at least 2 months.

Tips and Tricks (Adapted from Chambers [14]

- Pre-procedure planning of CTO PCI.
    - Having a planned approach prior to procedure; Ad hoc CTO PCI is not recommended.
    - Examining the patient's back prior to starting procedure, especially in those that have had prior attempts at fixing the CTO.
    - A Radiation shield such as Radpad (Kansas City, KS) placed over a prior affected area can significantly reduce the radiation over the affected area.
- Constant monitoring of radiation all through the procedure.
- In CTO PCI, it is certainly worthwhile considering stopping the procedure if the CTO is not crossed by 7 Gy.
- Limit fluoroscopy even to what is absolutely required.
    - Avoid the habit of stepping on fluoro when not looking at the screen.
- Utilize low magnification.
- Utilize lowest frame rate.
- Avoid steep angles.
- Changing views.
- Utilizing collimation.
- Utilizing interventional techniques that avoid having to look under fluoroscopy when exchanging equipment - such as having a "trap balloon", and not moving the torquer when not required (to serve as a marker).
- Paying attention to the position of the table and the image intensifier.
- Utilizing fluoro store feature, instead of cine angiography.
- Utilizing additional shielding.
- Have a post procedure follow up plan.
- Separate procedure attempts by adequate time intervals.

VASCULAR ACCESS

Typically, patients with CTO PCI, undergo access in two vessels. Often, larger sheaths are utilized (8 fr). This increases the probability of vascular access injury with CTO PCI than regular PCI, given larger sheaths and dual access.

Tips and Tricks:

- In obese patients, a combination of radial and femoral access can be utilized.
- Bi-radial approaches have also been utilized for PCIs [15].
- Micropuncture technique could be utilized to ensure optimal placement.
- Utilizing fluoroscopic landmarks or ultrasound [16] prior to obtaining femoral access.
- Important to realize the limitations of various access strategies (such as limited use of "trapping" in a 6fr system).

CONTRAST INDUCED NEPHROPATHY

Contrast induced nephropathy (CIN) can occur during PCI. This has adverse consequences on long-term prognosis [17]. High-risk characteristics, and scoring systems such as the Mehran score have been identified as predictors of contrast induced nephropathy [18] in CTO PCI.

Tips and Tricks

- Clearly thinking prior to injection of contrast anytime during the procedure i.e. consider the value of any imaging prior to injecting contrast (this also helps reduce radiation).
- Identify patients at high risk of developing CIN upfront.
    - Utilization of contrast should be monitored closely especially in such patients.
- Contrast utilization should be monitored at regular intervals.

- Injection and opacification of donor artery first followed by target artery minimizes unnecessary contrast use in the latter artery.

CORONARY COMPLICATIONS

Acute Vessel Closure

Donor Vessel Injury

The donor vessel that feeds the collateral supply to the CTO is in most cases visualized by a separate catheter. This donor vessel can be injured when utilized for angiography (during antegrade approach) or when instrumented during retrograde approach. Such a situation can be catastrophic since often there is a large area that is potentially ischemic.

Catheter induced injury can occur especially during equipment withdrawal or at the time of externalization of a snared wire - this may cause the guide to deeply engage the vessel, and potentially lead to a guide induced dissection. Aggressive guides such as Amplatz guides, which are often utilized for extra backup, also predispose to dissection.

Thrombosis of the donor vessel is yet another possibility. Given the typical longer duration of the CTO procedures, and having micro catheters in the vessel make CTO PCIs more susceptible to donor vessel thrombosis.

Donor vessel spasm should also be in the differential when there is compromised flow (see adjoining Fig. **2a** and **2b**). Intracoronary administration of vasodilators such as nitroglycerin often help resolve the spasm.

Tips and Tricks

- Attention to wave forms constantly.
- Removal of contralateral catheter when not needed.
- The importance of understanding the various forces that would act in antegrade and retrograde systems when equipment is being manipulated is critical – pulling and pushing equipment should be done after giving some thought about what would happen to wires, equipment, antegrade and retrograde guide catheters.
- No catheter with side holes to engage the donor vessel.
- There should be back bleeding done after removal of any gear, and good flushing.
- Avoid or be extremely meticulous when utilizing left internal mammary artery for retrograde access. Extremely tortuous LIMAs should be avoided.
- Monitoring ACTs at least every 30 minutes (the authors recommend an ACT of > 350 during retrograde procedures and > 300 during ante grade procedures).
- If there is an issue with the donor vessel, it is critical to take a step back, and look at the overall condition of the patient. Hemodynamic status of the patient might quickly deteriorate, often necessitating an Intra-aortic balloon pump or an Impella device.
- Fixing the donor vessel should be of the highest priority at this point. In the case of dissection, the authors

a)

b)

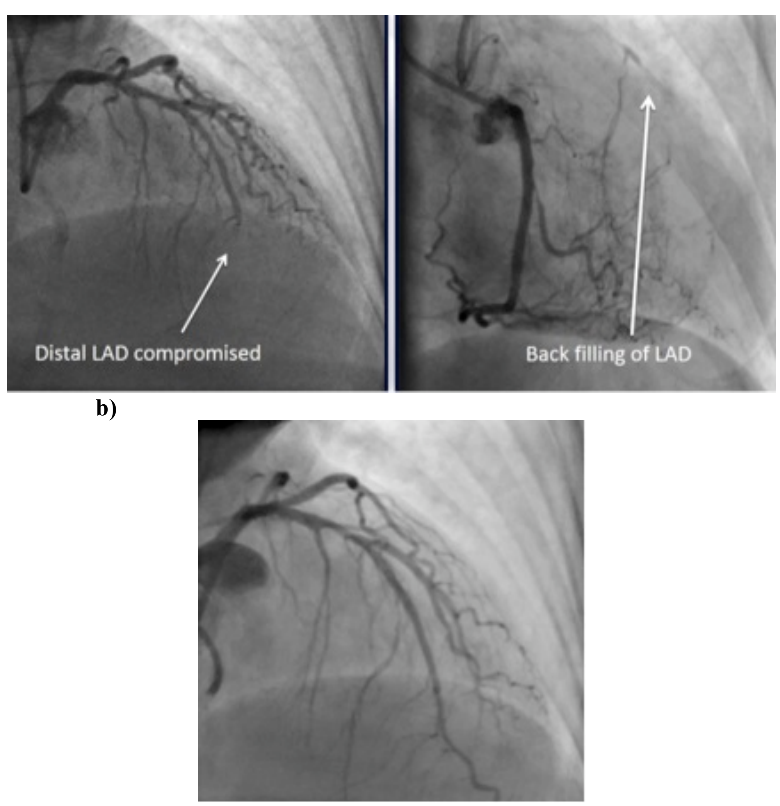


Fig. (2). a and **b**: LAD spasm during PCI of CTO of RCA; subsequently resolved post IC nitroglycerin.

favor exchanging the retrograde wire for a workhorse wire across the microcatheter, and then stenting the donor vessel.

- o Unless the CTO procedure is virtually completed, the authors favor aborting the CTO PCI, and focusing on treating the donor vessel.

- With donor vessel thrombosis, aspiration thrombectomy and additional IIb/IIIa inhibitors might be required. It is also important to recheck ACTs to ensure that adequate anticoagulation is on board.

DISSECTION

Aortocoronary Dissection

Dissection occurs more commonly in the RCA (Fig. **3**), and occurs more frequently in CTO PCIs than normal PCIs. Dissection might be limited to the sinus, but might extend to the aorta. Aortic dissection is usually a hydraulic event, although other causes include aggressive predilation of the coronary ostium and/or balloon rupture.

Tips and Tricks

- In RCA CTOs, guides with side holes are preferred to reduce barotraumas.
- Avoid injections when pressure is dampened.
- Careful injection when guide extensions such as Guideliner is utilized (these should be much gentler than a regular injection).
- Avoiding power injectors.
- Avoid injections antegrade when wire passage is subintimal.
- Understand forces at play when manipulating equipment.

Many a time avoiding further injections will be sufficient to avoid extension of the dissection plane - the urge to keep injecting contrast to 'see' should be controlled. Ostium of aorta should be covered by stent prior to injecting antegrade. Intravascular ultrasound is a useful imaging modality to ensure ostial coverage when stenting. If there is a large dissection, serial non-invasive imaging (with computed tomography or transesophageal echocardiography) to ensure the dissection is not progressing should be considered. Emergency surgery is rarely needed.

Thrombus or Air Injection

Given the frequent exchange of devices, and prolonged duration of procedures, the possibility of thrombus forming in the guide is higher than regular PCI.

Tips and Tricks

- Avoiding aspiration especially in setting of trap balloon (sucks in air).
- When in doubt, it is important to bleed back.
- During CTO PCI, often times, there are several devices in the guide. It is important to bleed back routinely after removal of any device.
- Monitoring ACTs at least every 30 minutes – empowering ancillary staff and educating them about the importance of this will often reduce the burden on the interventional cardiologist, and make the team more involved.

When in doubt, bleed back. This should be done after removal of any gear, to avoid air or clot from being embolized during subsequent injections. Also it is critical to keep ACT >300 during ante grade PCIs and ACT > 350 during retrograde PCIs

PERFORATION

Coronary perforation occurs when a dissection or intimal tear propagates outward to completely penetrate the arterial wall.

Main Vessel Perforation

CTO PCI in general involves the use of stiffer wires for penetrating the proximal and distal caps of the total occlusion compared to routine PCIs. Wire perforations are typically benign except in a collateral (see perforation from looped wire and stenting in Fig. **4**). A caveat to remember is that device perforations are usually with more catastrophic consequences, than just a wire perforation. Balloon dilation or following a wire with a micro catheter or Crossboss should be avoided unless the operator is confident that the wire is in the architecture of the vessel (see perforation secondary to Crossboss in Fig. **5**). Such a maneuver would considerably enlarge the size of the perforation. Atherectomy, balloon angioplasty or stent placement could all potentially lead to perforation, especially when oversized, or with aggressive post-dilation.

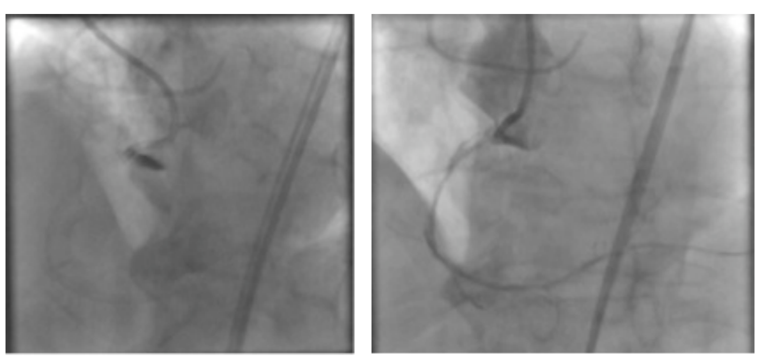


Fig. (3). Aortocoronary dissection likely due to aggressive AL guide catheter.

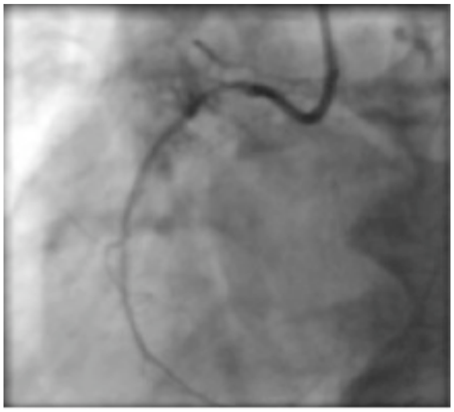


Fig. (4). Perforation of the RCA following successful PCI after having utilized a looped wire.

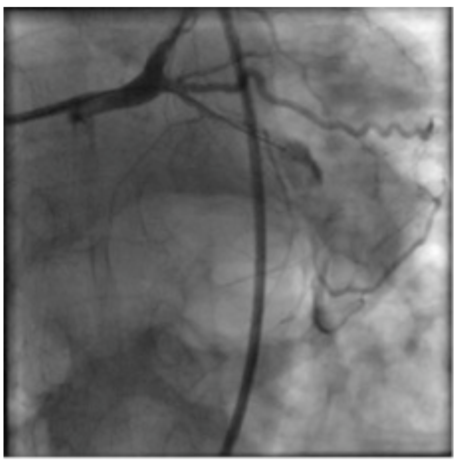


Fig. (5). Perforation due to CrossBoss catheter exiting the Circumflex vessel.

Tips and Tricks

- Perhaps the most important rule to remember is not to advance equipment without confirming position of the wire.
- Dilation of the vessel during reverse CART needs to be done after assessment of the vessel size either by angiographic estimate (such as knuckle-loop size) or by IVUS guidance (preferred).
    - Avoid over sizing balloons and stents.
- Inflation of a balloon proximal of the perforation to arrest the bleeding, and possibly using a covered stent, utilizing the dual catheter technique [19] helps minimize extravascular bleeding.

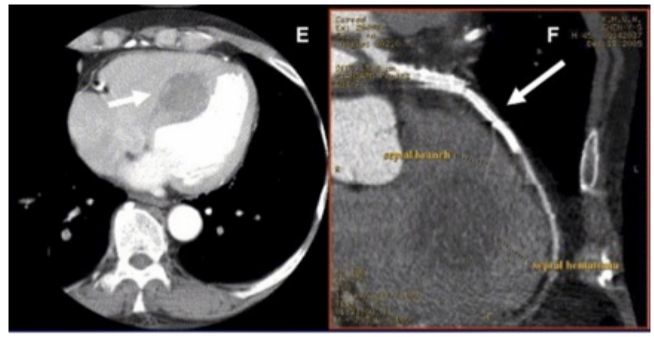
COLLATERAL PERFORATIONS

The Ellis classification [20] predated much of the advances in CTO PCI, and hence is not particularly helpful in collateral perforations. With collateral perforations, the following are worthwhile considerations:

Septal Versus Epicardial Collaterals

Septal perforations usually do not result in adverse consequences, although septal hematomas and ventricular dysrhythmias have been reported (see Figs. **6a, b** and **7a, b**). Epicardial collateral perforation can lead to rapid tamponade (see Fig. **8**), or local collection of fluid that might lead to compression of cardiac chambers [21, 22] (see Fig. **10a** and **b**).

a)



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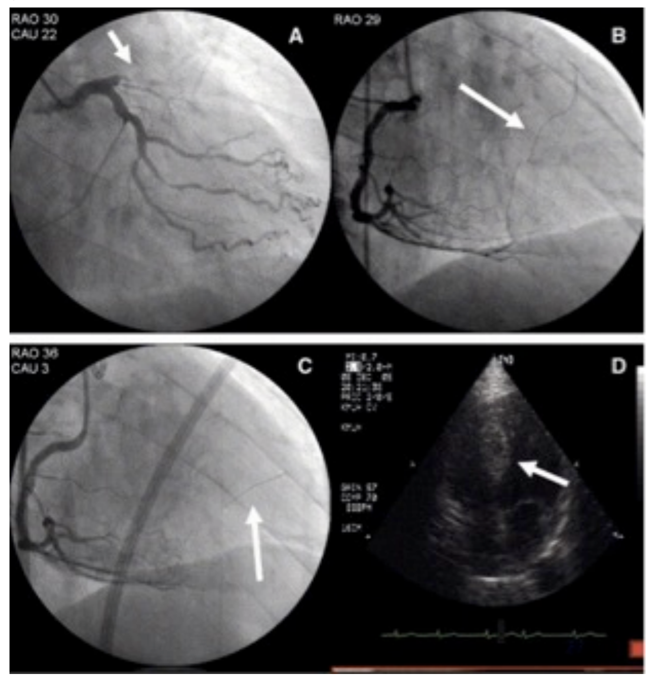

Fig. (6). a: Septal hematoma after a septal perforation during attempted CTO PCI (Courtesy: Colm Hanratty MD, ctofundamentals.org). **b**: Septal hematoma noted (Courtesy: Colm Hanratty MD, ctofundamentals.org).

It is also important to recognize intra-coronary bridging collaterals. Crossing these tiny channels instead of true CTO crossing may cause rupture especially during micro-catheter or balloon crossing.

Persistent Staining

Despite that the visual appearance, stain staying on typically is a good sign given that it is in a contained space. Contrast that disappears is usually into a cardiac chamber, pericardium or free space.

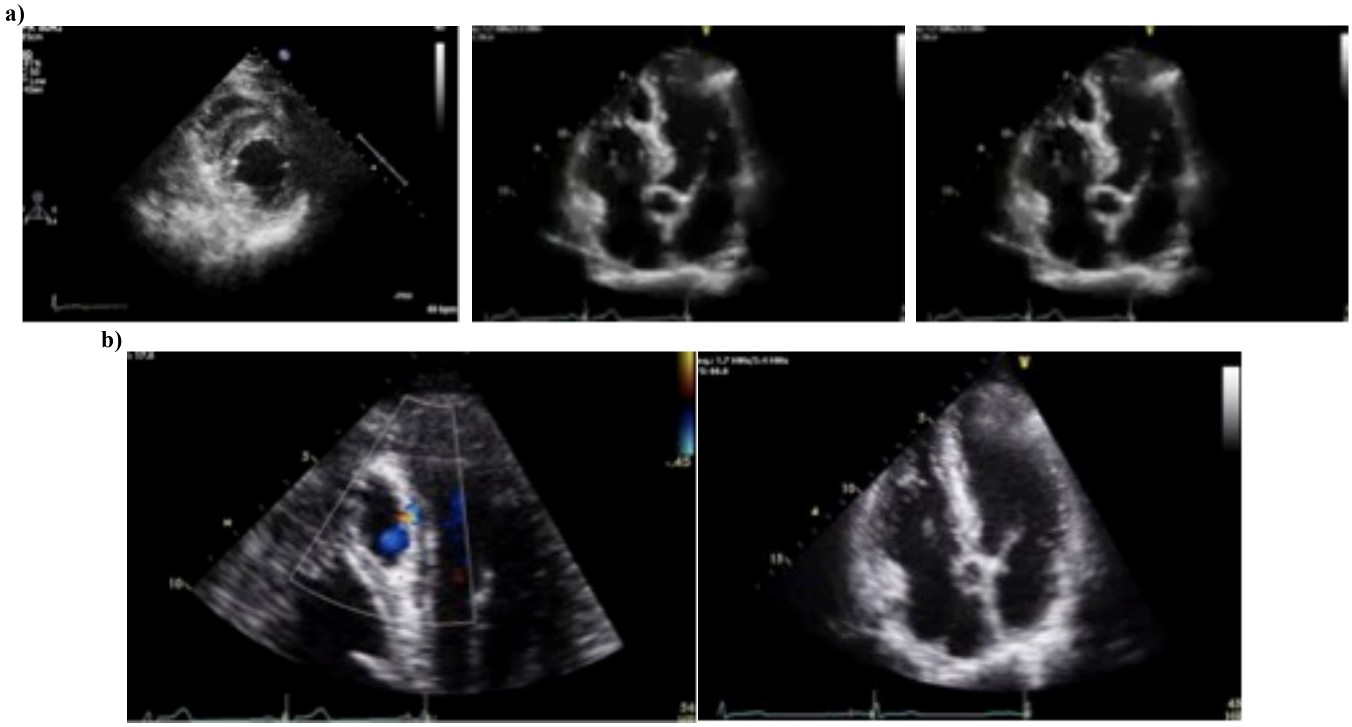

Fig. (7). a: Large Septal hematoma noted after a septal perforation (echolucency In septum) (Courtesy: Colm Hanratty MD, ctofundamentals.org). **b**: Subsquent formation of Interventricular septal defect, that results in decompression and resolution with time (Courtesy: Colm Hanratty MD, ctofundamentals.org).

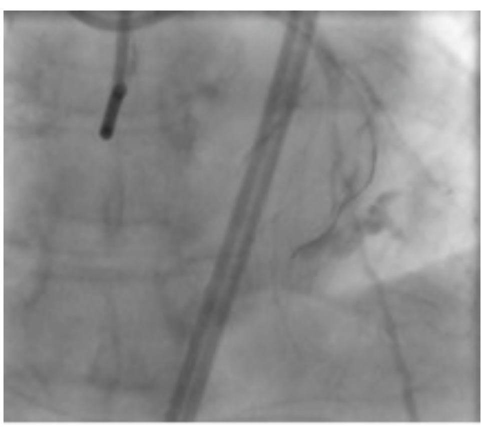

Fig. (8). Wire perforation in an intact perciardium (epicardial collateral).

Intact Pericardium

Presence of intact versus non-intact pericardium can be a crucial determinant in how catastrophic the perforation is. Epicardial collateral wiring is safer in patients with prior coronary artery bypass grafting or other surgery where the pericardial sac has been accessed before. Typically, bleeding is contained in spaces due to prior adhesions and surgical scarring, and is more contained, although tamponade or local chamber compression can still occur in post-CABG patients [22, 23].

Tips and Tricks

- Guide wire manipulation through collaterals should be performed meticulously with finesse.
- Ensure position of guide wire prior to advancement of microcatheter.
- Cautious injection of contrast through tip of Corsair microcatheter. Ensuring that 'back bleeding' is possible prior to injection of contrast. Careful withdrawal of the catheter should be performed if there is no back bleeding when corsair is in the collateral.
- Withdrawing collateral wire should be performed after ascertaining there are no perforations i.e. maintain wire position across collateral prior to ensuring no perforation at end of procedure, especially for epicardial collaterals.
- Avoid 'surfing' epicardial collaterals.
- Negative pressure from wedging microcatheter might occasionally be sufficient to seal the rupture.
- Advancing microcatheter might be another strategy employed.
- Coiling from both sides that feed the collateral might be required to seal perforations.
- Occasionally, additional treatment, such as injection of autologous clots, macerated fat (see Fig. **9a** and **9**), fibrin glue [24] might be required to obtain hemostasis [25].
- Dual injections from both sides should be performed to confirm that there is no bleeding from the antegrade or retrograde side.
- Echocardiographic contrast imaging to confirm or exclude active bleeding into the pericardial space

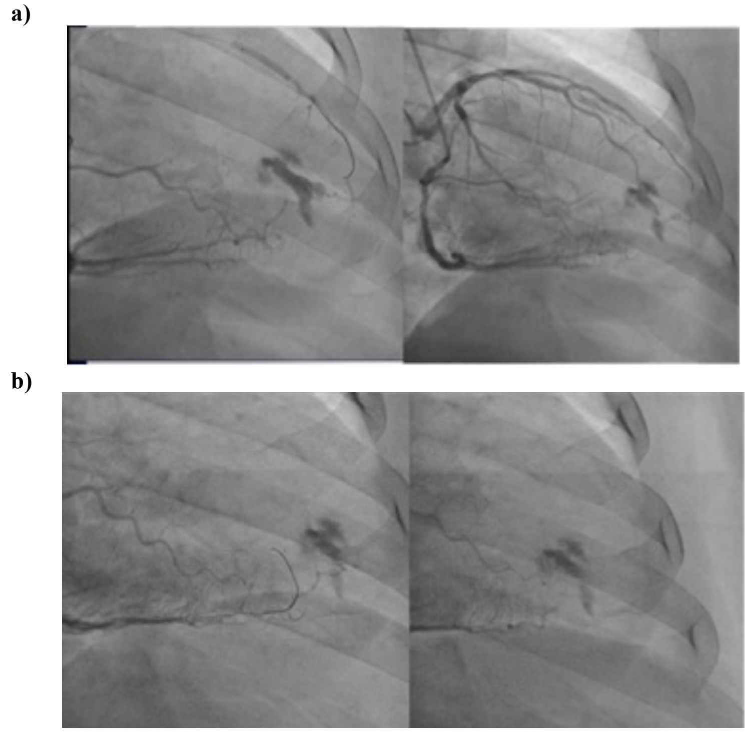

Fig. (9). a: Epicardial perforation showing bidirectional flow (Courtesy: Colm Hanratty MD, ctofundamentals.org). **b**: Post injection of adipose tissue via corsair through both antegrade and retrograde Corsairs (Courtesy: Colm Hanratty MD, ctofundamentals.org).

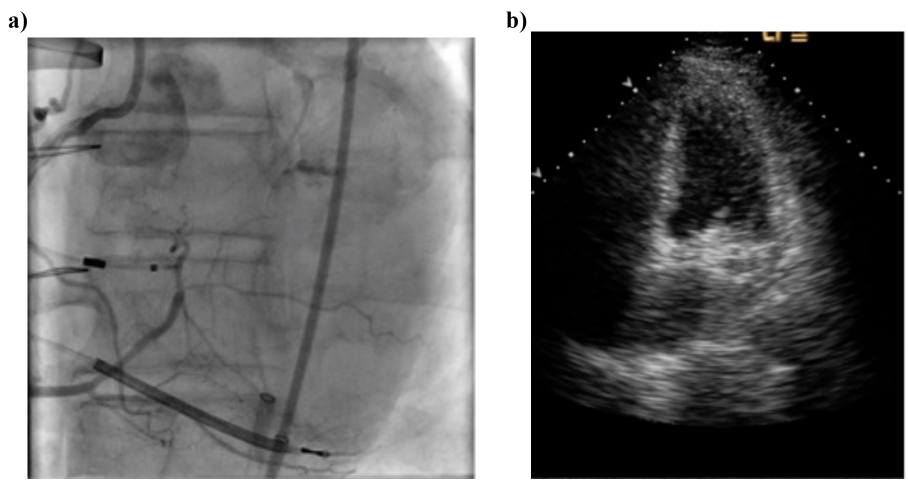

Fig. (10). a: Wire perforation in a patient post-CABG. **b**: Echocardiogram showing localized compression of Left atrium.

when not otherwise visible by conventional imaging measures [26].

- It is critical that interventionists be facile with emergent pericardiocentesis.
    - This might need to be performed in an emergent basis when required.
- Also, avoid protamine if at all possible.

GEAR ENTRAPMENT

Equipment delivery is often challenging in CTO PCI, given the extensive disease, calcification, and tortuousity often in these interventions. Attempting to deliver equipment via collaterals can predispose to both stent loss and wire entrapment. Wires can get kinked and/or entrapped [27].

Tips and Tricks

- Knuckled wires have the potential of getting knotted - it is critical to avoid trying to torque a knuckled wire. Truly, the only maneuver should be to push the knocked wire, or pull back, reform knuckle and then push again.
- Adequate vessel preparation is critical prior to attempting to deliver stents.
- Avoiding 'overtorquing' microcatheters.

- Avoiding tip of antegrade and retrograde microcatheters over the same wire to "kiss" - this could lead to entrapment.
- Avoiding extremely tortuous epicardial collaterals that might predispose to entrapment of wire.
- Techniques such as small balloon technique, whereby a balloon is inflated distally and withdrawn together with the lost stent into the guide catheter can be utilized.
- Snares can also be utilized in the right setting.
- Often crushing the lost equipment is more time efficient than trying to retrieve stents.

LONG TERM COMPLICATIONS

Patients who undergo PCI of chronic total occlusions can have the same late complications that patients with non-CTO PCI might have. These include in-stent restenosis and stent thrombosis. Coronary aneurysms [28] have been reported as a late complication after CTO PCI.

CONCLUSION

While CTO PCI can significantly improve patient symptoms and is correlated with decreased mortality [3], it is critical that the improved success rates be in conjunction with the least possible risk of complications. Having a thorough understanding of potential complications is the first step in taking steps to mitigate risk of complications. Finally, it is important to obtain consent upfront that includes the potential risks of CTO PCIs prior to the procedure.

TIPS AND TRICKS:

- Plan, plan and plan prior to the procedure.
- Works in pairs if possible.
- Proctors are available.
- PCI Consent should detail CTO specific risks – this needs to be documented clearly and all questions that patients have should be addressed upfront.
- Have a CTO cart ready with several required devices including covered stents, and a pericardiocentesis kit.

CONFLICT OF INTEREST

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

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Declared none.

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