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HOW-TO-DO-IT

The Prophylactic Chimney Snorkel Technique for the Prevention of Acute Coronary Occlusion in High Risk for Coronary Obstruction Transcatheter Aortic Valve Replacement/Implantation Cases

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Coronary occlusion (immediate or delayed) is an uncommon but potentially devastating complication of transcatheter aortic valve replacement/implantation (TAVR/TAVI). Several patient-related, anatomical, device and procedural risk factors can be assessed to risk-stratify patients and assist in procedural planning. In patients at high risk for coronary occlusion, coronary protection measures should be employed. In the highest risk patients, consideration should be given to prophylactic techniques to prevent coronary occlusion. This how-to-do-it report provides a framework for risk assessment for coronary occlusion followed by a step-wise description of the emerging chimney snorkel coronary stenting technique as a predictable procedural approach for the management of this potentially challenging clinical scenario.

Keywords Transcatheter aortic valve replacement • TAVR • Transcatheter aortic valve implantation • TAVI • Chimney stent • Snorkel stent

Introduction

Transcatheter aortic valve replacement/implantation (TAVR/TAVI) has become a standard of care procedure for patients with symptomatic severe degenerative aortic stenosis who would be at high risk for traditional surgical aortic valve replacement (SAVR). Relatively recent randomised controlled trial data have also pointed to TAVR as an alternative to SAVR in intermediate risk patients with attendant recognition in published guidelines [1–4]. One of the risks associated with TAVR is coronary artery occlusion which can be acute, sub-acute or delayed and carries major morbidity and mortality risk.

Coronary Artery Occlusion Following TAVR

Coronary occlusion is a relatively uncommon but an unfortunately well described complication that occurs in or following <1% of TAVR procedures but carries a 30-day mortality risk in the order of 40 to 50% in published series and registries [5–8]. There are several risk factors for coronary occlusion that can be identified *a priori* to a TAVR procedure. These are outlined in Table 1. Of these, perhaps the most predictive situation is where TAVR is contemplated for a valve-in-valve (VIV) procedure to treat degenerative stentless bioprostheses or stented but with externally

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Table 1 Risk factors for coronary occlusion with TAVR.

Risk Factor	Comment
Gender [6,8,10]	Female > Male
Prior CABG status [8]	Higher risk of clinically relevant occlusion in patients without prior CABG however: • Assessment of graft patency required • Left circulation in particular may not be adequately protected even if grafts patent depending on retrograde coronary flow from distal anastomosis and territory at risk
Coronary height <12 mm [6,8]	Risk further pronounced when <10 mm
Sinus of Valsalva <30 mm [6,8]	Risk augmented by coronary height and degree of leaflet calcification
VIV procedure (TAVR for failed surgical aortic valve bioprosthesis) [6,8,10,11]	Modifying high risk features • VTC distance < 4 mm higher risk (4–6 mm intermediate, >6 mm lower risk) • Stentless bioprostheses and bioprostheses with externally mounted leaflets (especially smaller sizes in smaller aortic roots)
TAVR valve selection [6,8,10,11]	Balloon expandable potentially higher risk than self-expanding for acute occlusion • Delayed occlusion potentially more of an issue with significantly supra-annular leaflet self-expanding devices

Abbreviations: CABG, coronary artery bypass graft; VIV, valve in valve; VTC, valve-to-coronary; TAVR, transcatheter aortic valve replacement.

mounted leaflet bioprostheses failure (particularly stenosis pre-dominate deterioration) [6,9–11]. Examples of the former include the Toronto Stentless Porcine Valve (Abbott, Abbott Park, IL, USA) and the Freestyle Porcine Stentless Valve (Medtronic, Minneapolis, MN, USA). Examples of the latter include the Mitroflow (LivaNova, London, UK) and Trifecta (Abbott, Abbott Park, IL, USA) bioprosthetic valves. Coronary occlusion has been reported to occur in 5% or more of cases involving these prostheses and additional metrics, in particular a valve to coronary (VTC) distance of <4 mm (on computed tomography) has been identified as a potential risk marker for acute occlusion for VIV TAVR (Table 1) [10–12].

It is difficult to estimate what proportion of patients considered for TAVR will require prophylactic steps in order to prevent coronary occlusion although based on the data discussed one would suspect it would be 1% to 5% of all patients. This is because there is enormous geographic heterogeneity in patients at the highest risk (ie the type of SAVR bioprostheses previously used varies heavily by geographic location, even within single countries) in addition to the patient population being managed with TAVR rapidly evolving. In addition, the growing recognition of coronary occlusion risk (and delayed coronary occlusion risk) after TAVR will likely lead to the re-stratification of patients at higher risk of occlusion back to SAVR.

Methods for Prevention of Coronary Occlusion

The first critical step in the prevention of coronary occlusion, as with most TAVR related complications, is careful and fastidious multimodality pre-procedure planning. When coronary occlusion is assessed to be a likely outcome due consideration ought to be given to reassessing the risk equation in determining whether a patient may be more appropriately treated with SAVR. Where a measured decision is made to proceed with TAVR in a patient at high risk of coronary occlusion is confirmed (see Table 1) a coronary protection strategy should be employed. In the setting of failed bioprostheses an approach employing electrosurgery facilitated leaflet laceration (BASILICA) has been described and remains investigational [13].

Where the treating team identify a patient at extreme risk for coronary occlusion (for either native valve TAVR or VIV TAVR), employment of the prophylactic chimney snorkel technique can be considered and is explained in a stepwise how-to-do-it fashion below. As with the BASILICA technique, this approach is also in the investigational phase. The technique has been previously reported in limited case reports in this prophylactic setting [14]. The following modified prophylactic chimney snorkel approach has been adopted by our program (spread across three hospital campuses incorporating the public and private sector) in a pre-emptive prophylactic fashion with successful outcomes (100% 30-day survival), recognising that it is a relatively uncommon scenario (n = 5 cases in a mature program performing >100 cases per year) and longer term follow-up is simply not yet available given the very recent implementation of this procedure (as a prophylactic preventative measure, rather than a bailout option) by our program and world-wide. We would humbly suggest that, at least for the time being, this technique be employed in experienced programs (>100 TAVR cases per year) given the elevated risk in this patient sub-population. It should also be remembered that important limitations in knowledge exist and mechanistic issues such as incalculable comparative radial force dynamics (given the variability in aortic root compliance, radial force variability depending on degree of expansion for both stents and TAVR bioprostheses) and uncertainty around coronary re-access abound. Again, for patients identified as being at high risk of coronary artery occlusion, the re-consideration of re-stratification of patients back to SAVR (if not at prohibitive or extreme surgical risk) is re-emphasised for these reasons.

Step 1: Patient Selection

- Native annulus: Unprotected low coronaries (consider when <10–12 mm, especially with small sinuses and bulky leaflet calcium).
- Valve-in-valve (especially externally stitched leaflet bioprostheses and stentless bioprostheses) where VTC < 4 mm (and coronaries not protected or not adequately protected by previous grafts).
- Where high risk features for coronary artery occlusion are identified, careful assessment and re-weighing of the relative risks of TAVR versus SAVR is strongly recommend. This is to take into account the high morbidity and mortality associated with coronary occlusion and the paucity of data (including a lack of any longer-term follow-up data) around coronary protection techniques (chimney stenting or BASILICA) in TAVR patients (ie the decision may swing back toward a SAVR procedure in non-prohibitive risk potential SAVR candidates).

Step 2: Access and Equipment

- Three points of arterial access that typically involves:
  - Radial (for pigtail in non-coronary cusp [NCC]).
  - Arterial access for TAVR deployment (femoral, axillary or other access as required).
  - Arterial access for percutaneous coronary intervention (PCI) guide catheter(s), ideally 7-French with a guide for left coronary artery (LCA), right coronary artery (RCA) or both depending on vessel(s) at risk.

Step 3: Procedure Sequence

- Guidance pigtail placed in the NCC (or LCA guide if dual coronary protection required). Radial guide is acceptable but guide stability for the RCA in particular is potentially better from the femoral approach.
- Cross aortic valve and position TAVR procedural guidewire into left ventricle.
- Position guide(s), wire(s) and stent(s) prior to percutaneous balloon aortic valvuloplasty (PBAV) or TAVR deployment (Figure 1A and 1 B):
  - Single wire for RCA with long stent in vessel (prepared and undeployed).
  - Dual wires for LCA (wire in left anterior descending [LAD] and left circumflex [LCX]) with long and appropriately sized stent in the vessel where deployment desired (eg, if circulation partially protected by patent LIMA-LAD then position stent in the left circumflex artery).
  - The length of the selected stent should be selected so as to ensure that the stent comes above the height of the pre-existing bioprosthesis in situ (with enough stent in the proximal part of the coronary artery to allow for adequate anchoring) and above the most superior portion of the TAVR bioprosthesis leaflet or commissural attachment point. This will usually require a long stent >35 mm in length to allow for venting above the tube created by strutting open of the previous bioprosthesis and/or the sealing effect of the TAVR bioprosthesis and varies by vendor.
- If performing pre-implantation PBAV proceed with this and then deploy TAVR prosthesis while leaving guide[s], wire[s] and stent[s] all in situ (Figure 1C and Figure 1D).
- Assessing coronary artery patency with an inflated PBAV balloon or at near complete (but not no-return deployment) with a recapturable TAVR prosthesis has been advocated by some to assess for the possibility of coronary occlusion [15]. However, these techniques are not reliable predictors of subsequent coronary occlusion and should not be relied upon.
- If post-dilatation of the TAVR is contemplated or decided upon, this should proceed prior to deployment of coronary artery stents.
- A low threshold for deploying the coronary artery stent(s) is recommended, ideally with a substantial portion of the stent hanging into the aorta, and ideally at least enough to come above the highest portion of the sealed portion of the TAVR bioprosthesis. For VIV cases, coming above the level of highest point of the open bioprosthetic leaflet is also recommended (Figure 1E). Even if the flow into the coronary artery/arteries seem satisfactory, especially for VIV cases where occlusion risk has been assessed as substantial, proceeding with chimney-snorkel PCI is recommended because:
  - Withdrawal of the stent with the wire left in-situ will not reliably clarify the risk of coronary occlusion (the coronary wire can be enough to keep the coronary artery open) and re-advancement of the stent may not be possible.
  - Delayed coronary occlusion (DCO) after VIV TAVR cases with high risk features have been well reported and so a low threshold for stent deployment is recommended. The presence of adequate coronary flow after deployment cannot be relied upon to decide against coronary protection. A recently reported series demonstrating that 23.7% of patients presenting with DCO actually had coronary guidewire protection and 18.4% had an ostial (non-chimney / non-snorkel) stent deployed [10].
  - Withdrawal of the stent and wire has a high risk of leading to an inability to re-access the vessel if occlusion occurs and should not be done unless the risk of occlusion appears unequivocally low (Figure 6) and taking into account the inability to accurately predict DCO as described.
- Coronary stent deployment should then proceed with subsequent use of the stent balloon pulled back away from the distal edge to higher pressures. Flaring the proximal

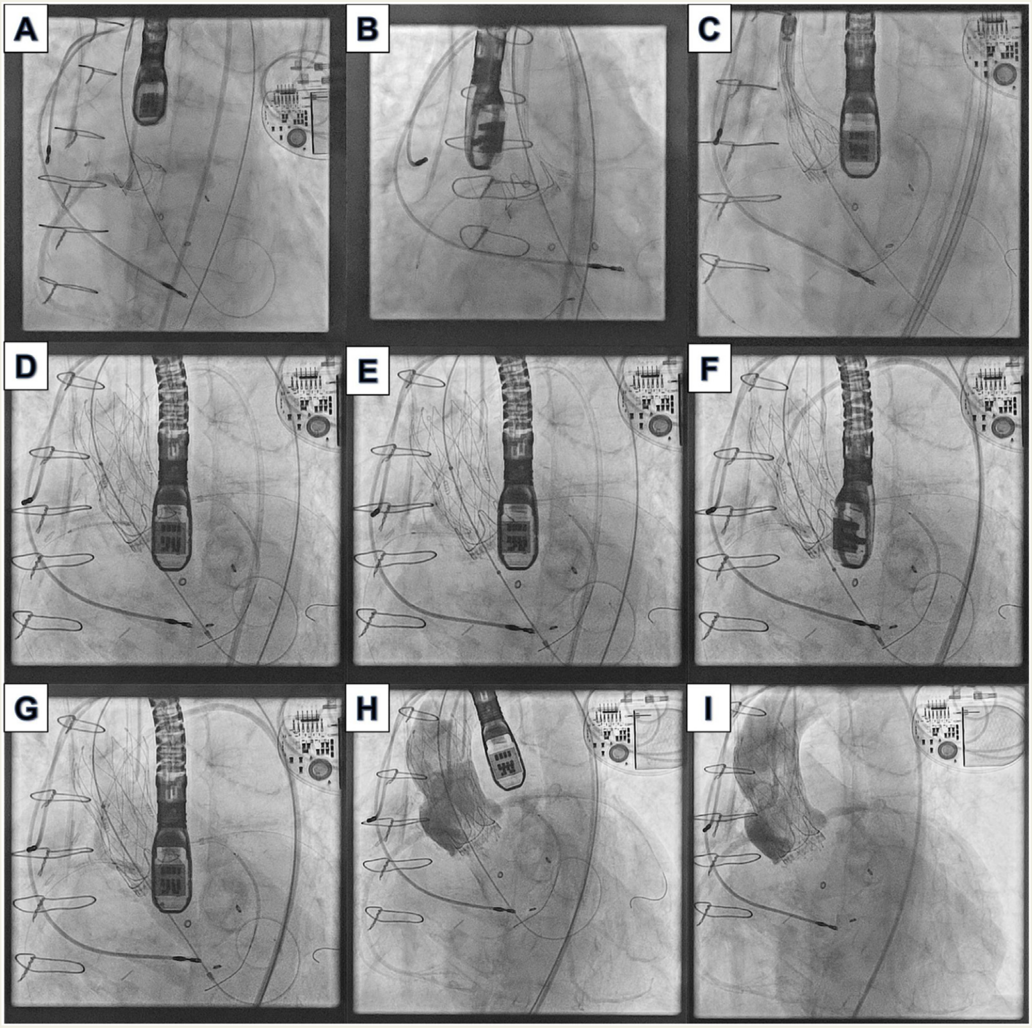

Figure 1 Image panel of the chimney snorkel prophylactic coronary protection technique.
Figure 1A-I Description: A: Correlating invasively with computed tomography (CT) for final plan for coronary obstruction prophylaxis; B: Guides, wires and undeployed stents delivered; C: Valve deployed as usual; D: Withdrawing stent so proximal end is above prosthesis skirt and native valve leaflets. Valve post dilated before stent deployed; E: Deploying stent; F: Proximal end of stent flared; G: Kissing balloon inflation with stent balloon and post-dilatation balloon; H: Assessing the result in stent (guide can be redelivered over deflating stent balloon) and risk of obstruction of left coronary ostia (in this case minimal valve tissue near ostium and valve to ostium distance sufficient); I: Final result.

stent may improve the chances of re-access if required later (Figure 1F).

- The final inflation should be one that involves the coronary stent balloon. A kissing technique can be performed with simultaneous inflation of the TAVR post-dilation PBAV balloon and the coronary stent balloon (Figure 1H) but is not mandatory.
- Final aortography is then performed (Figure 1I).

Step 4: Antiplatelet Therapy Recommendations

- In the absence of any specific trial data, recommendations in relation to antiplatelet therapy are based on extrapolation of standard guidelines and recommendations and clinical reasoning.
- Recommendations will also vary dependent upon the stent used (vendor specific) and bleeding risk of the patient in addition to requirements for anticoagulation for comorbid atrial fibrillation or other indications for anticoagulation.
- The current approach adopted by our program is 3 to 6 months of dual antiplatelet therapy.

Conclusions

Coronary occlusion following TAVR is, to a large extent, an avoidable complication. Careful peri-procedural multimodality imaging assessment and planning with an understanding of the risk factors for coronary occlusion can then be used to either re-stratify patients at high risk for coronary occlusion to SAVR or employ active coronary protection measures. The prophylactic chimney snorkel stent technique offers a potential predictable stepwise method of coronary protection that can be employed in the highest coronary occlusion risk patients to facilitate their safe management with a TAVR procedure. Long-term outcome data from the technique are of course pending and are required to give a perspective of the long-term durability of the technique.

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