

# Anaesthesia for transcatheter aortic valve implantation (TAVI): An anaesthetist's perspective

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## INTRODUCTION

Transcatheter aortic valve implantation (TAVI) is being hailed by some as “transformational technology” for valvular heart disease, i.e. technology that radically changes markets, creates new markets or eliminates existing markets for older technology.<sup>(1)</sup> Others question how a procedure with an increased risk of neurological incident over current treatment, i.e. surgical aortic valve replacement (SAVR), could be adopted so widely and rapidly.<sup>(2)</sup> With the publication of the first prospective randomised trial (PARTNER), some of the answers are emerging and patients can make informed decisions, given the relative risk of available treatments.<sup>(3,4)</sup>

The Mediclinic team has performed 70 TAVI procedures to date, with a procedural mortality of 4.3%. The team was sent for training before the programme started and was assisted by a proctor for the first 20 cases. All our cases thus far have been with the balloon-expandable Edwards SAPIEN valve, a bovine pericardium tri-leaflet valve, crimped on an 18-19 F delivery device (a 23mm or 26mm valve). The valve can be introduced transfemorally (TF) (via the femoral artery), transapically (TA) (via the left ventricle) or transaortic (TAo) (in the ascending aortic via a mini-sternotomy). The Medtronic CoreValve (self-expanding) is either a TF or a transaxillary artery (TAX) approach. Presently a third of TAVI procedures are performed as TA-TAVI and two-thirds as TF-TAVI.

Anaesthesia for TAVI is of interest to the anaesthesiologist for the unique patient subset and the novel procedure.

## ABSTRACT

**There are several reviews of anaesthesia for transcatheter aortic valve implantation (TAVI) in the literature. This article reflects the practice of one South African TAVI unit (Cape Mediclinic unit) based on our experience with 70 TAVI procedures. TAVI should never be regarded as a minor procedure. Patients selected for TAVI all have severe aortic stenosis (AS) and, by selection criteria, represent high risk for surgical aortic valve replacement. The salient points of anaesthesia management for TAVI are pre-operative assessment, haemodynamic management, anti-coagulation management and the detection of procedural complications.**

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In the absence of long term outcome data and in the presence of only one randomised trial to date, the selected cohort is a frail subset of octogenarians with severe aortic stenosis (AS). They frequently have been declined for surgery and have multiple co-morbidities. The short term prognosis for these patients without intervention is poor. In the PARTNER trial, the group regarded as inoperable and who were randomised to standard treatment, had a 1-year mortality of 51% (standard treatment included balloon valvuloplasty (BVP) in 85% of patients).<sup>(3)</sup>

This ingenious and non-invasive procedure (when compared to sternotomy, cardio-pulmonary bypass and SAVR) should by no means be regarded as minor. Its procedural complications include aortic dissection, acute free aortic regurgitation, limb ischaemia, large blood loss and stroke. Furthermore, it carries a 30-day mortality of 3.4% to 8.5% and a 1-year mortality of 25%.

The intra-operative management is mainly complication detection, coagulation management and haemodynamic manipulation. These goals change during the procedure. To this end, it is best to organise the procedure in stages.<sup>(5)</sup>

## ASSESSMENT

The pre-operative assessment of these patients is key to the success of the procedure. No less important, is the principle of management by a multidisciplinary team, who knows the routine and can work together. All patients are presented and discussed at a meeting, a week or two prior to the procedure.

The assessment evaluates admissibility for the procedure (and, unfortunately funding), annulus size and prosthesis size, approach (apical or femoral) and optimisation. Patients have a standard work-up, as for cardiac surgery, and in addition, all undergo transthoracic and transoesophageal echocardiography, a CT scan, coronary angiography and femoral vessel angiography.

### Risk stratification

Risk scores are used in the TAVI program to identify patients that are at high risk for SAVR (a 15% risk of death at 30 days after SAVR). Inclusion criteria are:

- STS score >10% (Society of Thoracic Surgeons)
- EuroSCORE >20% (European System Cardiac Operative Risk Evaluation)

The above-mentioned surgical risk scores have limited capability to predict outcome of TAVI, as they have been devised for surgical intervention. Note that a previous coronary artery bypass graft operation (CABG) with a patent LIMA imparts protection against occlusion of the left coronary ostium, and as such is beneficial. In contrast, it can be damaged by the left trans-axillary approach (Medtronic CoreValve).

The frailty score, as introduced by the American College of Surgeons in 2010, is an attempt to define the risk that the elderly present that is not defined by other means. The score assesses weight loss, grip strength, exhaustion, low activity and slow walking speed by means of questionnaires and physical tests, including a hand-held dynamometer. The frail group had double the complications and length of stay in hospital (non-cardiac procedures) as compared to non-frail counterparts. Importantly, if used concurrently, the score improved the predictive power of other risk scores.<sup>(6)</sup> It is, however, not a simple score to apply, which detracts from its usefulness for routine application.

Post-procedural risk stratification of TAVI with Trop-T has recently been described.<sup>(7)</sup> Pro-BNP has not been used for risk stratification, but should be of value as all these patients have left ventricle (LV) dysfunction.

For lack of reproducible outcome stratification, the team discussion and effort in finding potential complications remains invaluable.

Having had a comprehensive workup and a waiting period for medical aid authorisation, patients are admitted the afternoon before surgery. A blood group and screen specimen is sent to blood bank or blood components ordered as indicated.

TAVI is performed under general anaesthesia (GA) in most units. GA affords control of oxygenation and ventilation, makes the use of

TEE possible (an indispensable monitor) and also makes the supine position possible in patients with LV dysfunction. It is, however, possible to perform TAVI with sedation only and operators then rely on radiographic screening for placement and monitoring. The contrast dose is increased with this approach.

### CARDIAC CATHETERISATION LABORATORY ORGANISATION

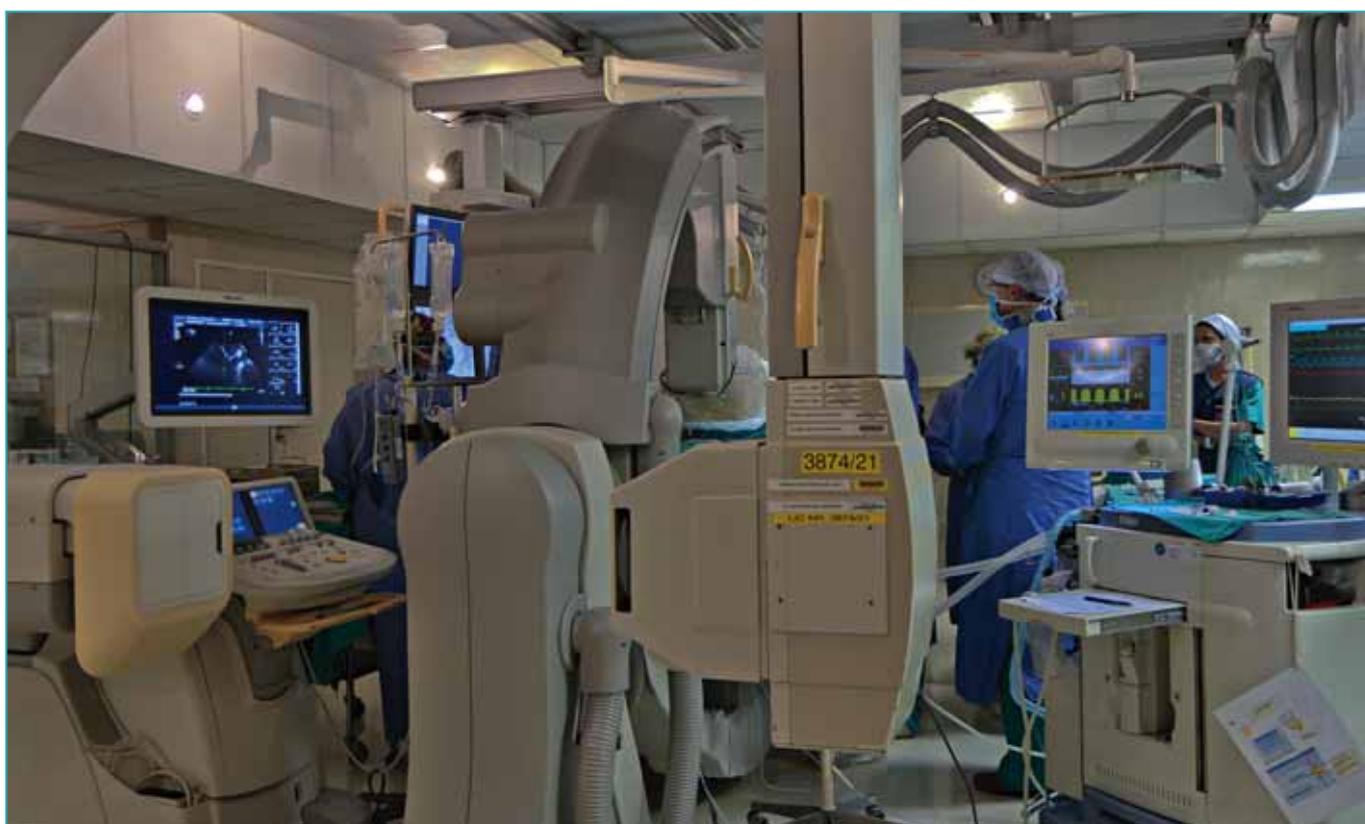
TAVI is done in an adapted cardiac catheterisation laboratory (cath lab). The cath lab is often crowded as the procedure requires a large team and a variety of equipment (Figure 1). The laboratories used by our team are used for endovascular surgery and are large enough to accommodate the team and all the necessary equipment. A true hybrid theatre is considered ideal.

A primed cardio-pulmonary bypass (CPB) machine is set up and kept at the cath lab entry. Any team attempting TAVI would be well advised to run through the drill of setting the bypass machine up in the cath lab e.g. through which door to enter, the gas points, the length of circuitry versus the position of the bypass machine, cannula for femoral bypass, etc. The perfusionist is present in theatre.

### ANAESTHETIC INDUCTION AND MAINTENANCE

A pre-med of the anaesthesiologist's choice is prescribed. Patients do not get a loading dose of Clopidogrel 300mg and aspirin 300mg for TAVI with the Edwards SAPIEN valve. Clopidogrel is instituted in the post-operative period and dual anti-platelet therapy is continued for 6 months. Statins are continued as per routine. The pre-operative use of dobutamine in patients with AS and LV systolic dysfunction is discouraged, and its (or other inotrope) use should be limited to after prosthesis deployment. BVP is a preferable temporising measure.

Consideration may be given to prophylaxis for contrast-induced nephrotoxicity, although the amount of contrast is less than a 100ml in the majority of cases. TEE limits the amount of contrast necessary for evaluation – the procedure has also been described with echocardiography guidance and no contrast. Acute kidney injury (AKI) after TAVI is reported to occur in 12% of patients (defined as a decrease of 25% in baseline estimated GFR). The incidence of AKI in patients with chronic renal dysfunction is reported as three times less with TAVI than after SAVR, and renal replacement therapy was similarly reduced.<sup>(8)</sup> Renal dysfunction, presently an exclusion criterion, may become a future indication for TAVI.



**FIGURE 1:** The TAVI cardiac catheterisation laboratory is often crowded as the procedure requires a large team and a variety of equipment is used.

### Pre-induction

Radial arterial pressure monitoring and a large bore (14 - 16 G) peripheral venous line are placed. An under-body Bair Hugger is placed for all patients, irrespective of anticipated duration of the procedure, as this is unpredictable.

Mini-thoracotomy is debilitating in this frail, geriatric group, therefore if TA-TAVI is planned, 0.2mg sub-arachnoid morphine is administered with a 26 G pencil point spinal needle. A combination of granisetron 1 - 3mg and dexamethasone 4 - 8mg is effective prophylaxis for post-operative nausea and vomiting. Other possible regional techniques include intra-operative paravertebral catheter placement, intercostal nerve block (ICB) and thoracic paravertebral block. Our surgeons had difficulty in placing the paravertebral catheters far enough posterior from the mini-thoracotomy incision. ICB has the disadvantage of limited duration and needs post-operative follow-up ICB. Thoracic paravertebral catheter placement requires experience with the technique.

Post-operative care is in an intensive care unit, giving the monitoring necessary after intrathecal opioid administration.

TF-TAVI has bupivacaine wound infiltration at the end of surgery, and requires minimal systemic analgesia.

### Induction

Any combination of drugs that the cardiac anaesthetist is familiar with will suffice, as long as they serve the haemodynamic goals of AS and make early extubation possible. For example, the induction could include etomidate, remifentanyl, and rocuronium. A remifentanyl bolus of 0.5 - 1mcg/kg is given prior to intubation and continued with an infusion of 0.1 to 0.3mcg/kg/min. Bradycardia can occur with this combination of drugs – the prophylactic use of atropine or glycopyrrolate in AS is avoided, and utilised as treatment only. Patients with severe AS may have been subjected to aggressive diuresis pre-operatively and be hypovolaemic on induction. Fluid administration is conservative until the TEE is placed, especially if LV dysfunction is present.

Sevoflurane at 0.5 to 1 MAC in a 50% air/oxygen mixture is used for maintenance. As there are 3 periods of ischaemia during rapid ventricular pacing (RVP) (albeit of short duration – 10 to 15 seconds), sevoflurane's preconditioning is beneficial. Intubation is with an ordinary endotracheal tube. Double lumen intubation is not necessary for the apical approach.

Patients receive antibiotic prophylaxis (2 grams of cephazolin intravenously, and an additional 3 doses in the first 24 hours). If a hospital, and notably an ICU stay, has preceded the procedure, a

review of the microbiological data, antibiotic history is done. Microbiology consultation is often used.

### Vasopressor use

Cardiac arrest in aortic stenosis is difficult to resuscitate and has a poor outcome. Most TAVI patients need vasopressor administration. In Columbia University's review, 86% patients received a vasopressor intra-operatively.<sup>(9)</sup> Vasopressors can be administered as a bolus as necessary approach, or a constant infusion. The alpha agonist effect is distal to a "fixed" stenosis and as such does little further harm to ventricular function. It maintains diastolic perfusion pressure to the hypertrophied left ventricle (LV). For example, a background infusion of phenylephrine at 0.25 - 1mcg/kg/min could be started at induction. Vasopressors are titrated to pre-operative baseline arterial pressure. Phenylephrine also contributes to a slower heart rate; an alternative should be considered if the patient has bradycardia e.g. noradrenaline. With an infusion, the need for an anticipatory bolus before RVP for valve deployment is avoided.

### Transoesophageal echocardiography

Central vein cannulation is performed and the transoesophageal echocardiography (TEE) probe is placed. The baseline TEE examination is done. Though TEE evaluation of AS is beyond the scope of this article it is a central part of the intra-operative management. Aside from haemodynamic information, it is important to note: the valve morphology and distribution of calcification; the origin of the coronary arteries; confirm annular size; sinotubular diameter and length; ascending aorta size and calcification; pre-existing aortic regurgitation (AR); pre-existing mitral regurgitation; LA appendage for thrombus; LV apex; LV function; LV end-diastolic dimension and wall dimension; LV diastolic dysfunction; regional wall motion abnormalities (RWMA) as ischaemic heart disease is common; the descending aorta; and as much of the arch as possible for atheroma.

With TA-TAVI, the apex is marked with the aid of transthoracic echocardiography, prior to prepping and draping.

## VASCULAR ACCESS

### Complications

- Pacemaker perforation (and tamponade);
- Ileo-femoral dissection (and retrograde "endarterectomy" embolism);
- Plaque embolisation;
- Air embolisation (TA approach);
- Occlusion of patent LIMA (TAx left); and
- Occlusion of innominate artery (TAx right).

The cardiologist places an arterial pigtail catheter and a femoral transvenous pacemaker. As soon as the pacemaker has been placed, it is tested for the first of the 3 rapid pacing periods. It is the shortest run of the 3. Ideally, pacing must be possible at 180 beats per minute, but a lower rate is acceptable if the mean arterial pressure decreases to below 50mmHg. Recovery from RVP is noted.

## Anti-coagulation

Unfractionated heparin, 1mg/kg is administered, to a target ACT of 250 seconds. Alternatively, heparin 5 000 IU is administered and adjusted once the first ACT has been done. With TF-TAVI, surgeons prefer the heparin to be given once the exposure of the femoral artery is complete; it should not be given later than before placement of the introducer sheath for the delivery device. With TA-TAVI it is given once the purse string is in place, but again not later than just before the introducer sheath is placed. A documented ACT is essential before the device is introduced. On average, the procedure takes 90 minutes, and a follow-up dose is not necessary, but the ACT should be repeated if the procedure is prolonged. Surgeons request protamine reversal of heparin, when they are satisfied with their closure of the femoral artery and angiography confirms good outflow or having closed the thoracotomy. Sheaths are removed in the ICU once an ACT <150 sec is recorded, with the exception of the temporary pacemaker that remains in-situ for 24 hours.

TF access is still obtained with surgical exposure at present and TA with a mini-thoracotomy. With surgical access to the LV, pressure control is essential, bearing in mind that the peak intra-ventricular pressure is the sum of the arterial systolic pressure and the peak pressure gradient. There are no literature guidelines on an absolute value that is safe – we use a mean arterial pressure of 65mmHg.

## RAPID VENTRICULAR PACING (RVP) AND BALLOON VALVULOPLASTY (BVP)

### Complications

- Dissection/rupture of the aorta or annulus;
- Embolism;
- Myocardial ischaemia;
- AV block; and
- Acute severe AR.

Access is gained and a guide wire is passed over the aortic valve. The TF wire can tether the anterior MV leaflet, causing MR (mitral regurgitation).

The second RVP run is initiated for BVP. The duration is 10 - 15 seconds. The mean arterial pressure goal is below 50mmHg. The arterial curve should also show minimal ejection for the balloon not to be displaced during valvuloplasty. It is important that there be silence so that the operator's orders can be clearly heard and confirmed, i.e. pacemaker on – balloon up – balloon down – pacemaker off. (TAVI theatres are often crowded and the noise can be distracting). Observation of the patient's haemodynamic response gives the opportunity to anticipate what the response will be to device deployment.

TEE after balloon valvuloplasty assesses the degree of AR (it can lead to acute, severe AR) and hence the success of the valvuloplasty. Aortic dissection can occur and should be looked for.

## VALVE DEPLOYMENT

### Complications

- LVOT obstruction by delivery system;
- Coronary artery occlusion;
- AR (paravalvular or valvular);
- MV damage (or temporary dysfunction if wires impinge);
- Prosthesis positioning;
- Patient-prosthesis mismatch;
- Aorta/annular rupture; and
- AV block.

The points discussed for BVP applies to valve deployment as well. Note that the Edwards delivery system's French gauge refers to internal diameter. For illustrative purposes the crimped valve, if we assume the same diameter as the introducer sheath, has an area of 0.28cm<sup>2</sup>. Most patients with severe AS have an AVA of 0.4 to 0.8cm<sup>2</sup>. The positioning of the device across the valve, albeit after BVP, and the subsequent debate about positioning, leaves the patient with significant obstruction at valvular level. Patients with impaired LV systolic function are at risk at this point. It is soon to be followed by a (brief) period of ischaemia.

As mentioned, the anticipatory vasopressor bolus has rarely been necessary. The recommended correct position of the Edwards prosthesis on TEE<sup>(9)</sup> is that the end of the prosthesis is 2 - 3mm from the origin of the anterior MV on the mid-oesophageal aortic valve long axis (ME AV LAX) view. AR is not uncommon and needs to be identified as paravalvular or transvalvular, quantified and a decision made by the surgical team on further intervention. The guide wire, while in position, causes transvalvular regurgitation, and should be recognised as such.

## VASCULAR/APICAL REPAIR

### Complications

- Blood loss;
- Rupture of LV; and
- Limb ischaemia.

The blood loss of TAVI occurs during this stage. Average blood loss amounts to 200 - 300ml for both TA-TAVI and TF-TAVI, but large variability is noted, and major blood loss is possible.

### Femoral artery

Surgeons make a decision as to primary repair, prosthetic patch, prosthetic bypass or stent. If the repair is complicated, it is necessary to note ischaemic time, especially if proximal control means total occlusion of the femoral artery. All femoral artery repairs are checked angiographically before the patient leaves the cath lab. Foot pulses are documented with Doppler in ICU, if not palpable. Ischaemic limb complications are severe and carry a high morbidity and mortality.

### LV apex

Using the pacemaker for pressure control during suturing of the apex has been effective, being of short duration. Alternatively, an intravenous bolus of magnesium sulphate (30mg/kg) has also been successful. In patients with ischaemic heart disease a nitrate infusion can be the initial choice.

## POST-OPERATIVE CARE

The care for these cases is as for cardiac surgical patients. ICU stay differs for TA and TF cases and is dictated by complications, but on average is about 2 - 3 days. The patients then go to a ward.

### Routine orders

- Oral Clopidogrel is administered as soon as possible (post-procedure anti-coagulation is an area of ongoing controversy and investigation);
- Aspirin is continued;
- Temporary transvenous pacemaker is left in place for 24 hours – this decision is left to the cardiologist;
- Cephalosporin prophylaxis for an additional 3 doses; and
- Vascular sheaths are removed as soon as the ACT <150 sec.

### Extubation

Extubation is possible immediately in the cath lab or within an hour in ICU. The patient must be evaluated for focal neurological signs. The patients with TA-TAVI who have had intrathecal morphine are extubated once their PaCO<sub>2</sub> is below 6.5 kPa on pressure support

ventilation (PSV) of 10cm H<sub>2</sub>O. These patients need serial PaCO<sub>2</sub> monitoring, and low dose naloxone is employed as necessary.

### Hypertension

The patients' usual anti-hypertensive regimens are continued post-operatively. Hypertension is managed in the same manner as after CABG.

### Acute kidney injury

The literature cites the incidence of this complication at 11.7%. It is also lower than an equivalent population undergoing SAVR (9.2% vs 25.9%), needs renal replacement therapy less often than SAVR, but, when it occurs, it is a marker of decreased survival (4-fold increase in mortality). The risk was increased in patients with hypertension, COPD and those requiring intra-operative blood transfusion.<sup>(6)</sup>

### Post-operative risk stratification

All TAVI procedures have an increase in Troponin T post-operatively, peaking at about 48 hours and decreasing thereafter, with elevations after TA procedures greater than after TF procedures. This increase is more pronounced in the presence of renal dysfunction. There was predictive value in the degree of increase and post-operative systolic function and outcome.<sup>(7)</sup>

**Conflict of interest: none declared.**

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