Anaesthesia for transvenous transcatheter tricuspid valve-in-valve implantation

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Abstract

The authors report and discuss the anaesthetic management of a transvenous transcatheter tricuspid valve replacement. The conduct of anaesthesia, the challenges encountered and the specific risks associated with the procedure will be discussed. Percutaneous tricuspid valve replacement may be safely performed under general anaesthesia, provided that the procedure is understood and all possible eventualities considered. As the quality of percutaneous prostheses improves, and if long-term follow-up confirms this as a safe option, anaesthesiologists will be expected to provide perioperative care for a growing number of these cases.

Case report

A 39-year-old woman presented with symptoms of worsening dyspnoea due to atrial fibrillation and tricuspid bioprosthesis stenosis. She had a mitral and tricuspid valve replacement (for rheumatic valvular heart disease) 21 years prior to the current admission.

A 29 mm bileaflet mechanical valve (St Jude Medical, St Paul, Minnesota) was initially implanted in the mitral position, together with a 33 mm porcine bioprosthesis (Edwards Lifesciences, Irvine, California) in the tricuspid position. She did well postoperatively and continued anticoagulation at her local community health centre. However, she was lost to follow-up 13 years ago.

Her current symptoms rapidly increased over the past year and she developed New York Heart Association (NYHA) class III dyspnoea and severe peripheral oedema. There was no paroxysmal nocturnal dyspnoea, orthopnoea or angina. Examination revealed an irregular rhythm, raised jugular venous pressure, ascites, hepatomegaly and peripheral oedema.

Electrocardiography confirmed atrial fibrillation. Echo-cardiography showed a well-functioning mitral valve prosthesis but a severely calcified and stenotic tricuspid

bioprosthesis. The peak pressure gradient across the tricuspid valve was 18 mmHg peak, with a 12 mmHg mean. The right atrium was enlarged to 35 cm^2 (normal 9-15 cm^2), the left atrium 17 cm^2 (normal 11-17 cm^2) and the left ventricle ejection fraction mildly impaired at 48%, with a left ventricle end-diastolic dimension of 44 mm (normal 40–55 mm). No thrombus was seen in the atria and there were no echocardiographic or microbiological features of infective endocarditis. The patient was synchronously cardioverted but atrial fibrillation recurred.

She was then assessed at a multidisciplinary team meeting and it was decided to attempt the novel method of percutaneous transcatheter transvenous tricuspid valve implantation of a balloon-expandable bioprosthesis. This decision was based on the fact that the logistic euroSCORE calculation (European System for Cardiac Operative Risk Evaluation, a method of calculating predicted operative mortality for patients) was 8% and literature reported mortality rates up to 27% for repeat tricuspid valve replacement. Another consideration was the treating physicians' growing experience with transcatheter and transapical aortic valve replacement, and the perceived morbidity and mortality benefit.

The procedure

The procedure was performed in a cardiac catheterisation theatre with capabilities for pacing and the availability of emergency cardiopulmonary bypass. This theatre forms part of the theatre complex of a large tertiary university hospital.

A diagnostic right heart catheterisation was performed through the femoral vein. This access could also be used for emergency pacing. Invasive haemodynamic parameters were measured through the femoral artery. The size of the jugular vein was determined with a transfemoral venogram and the jugular vein was entered through a small anterior neck dissection. A large 24–26 French introducer sheath was inserted into the internal jugular vein and secured with a purse string suture. A 20 ml balloon-tipped catheter was inserted into the stenotic tricuspid bioprosthesis under fluoroscopic guidance. The stenotic prosthetic valve was dilated in preparation for implantation of the transcatheter device.

The transcatheter device (Edwards Sapien XT, Edwards Lifesciences, Irvine, California) is a pericardial xenograft bioprosthesis mounted on a stainless steel vascular stent, size 26 mm. The device was crimped onto a balloon-tipped catheter and delivered transvenously under fluoroscopy. It was deployed once the position was confirmed. Rapid ventricular pacing was not required to decrease cardiac output, as is the case with percutaneous aortic valve implantation, where the high transvalvular gradients may cause malposition or embolisation during deployment.

Cardiac and valve function were evaluated by right heart catheterisation and transoesophageal echocardiography (TOE).

Anaesthesia

The cardiac catheterisation theatre is not familiar to most anaesthetists. It is a rather cluttered environment, with a C-arm, TOE machine, cardiologists, cardiac surgeons, an echocardiographer and nursing staff. This makes access to the patient, especially the airway, head and neck areas, challenging at times. A schematic representation of the theatre layout is shown in Figure 1.

Local anaesthesia combined with sedation or general anaesthesia were the options considered. It was decided to carry out the procedure under general anaesthesia for the following reasons: we had no experience with the procedure, TOE was deemed advantageous, and the duration of the procedure was unknown. This approach also secured control of the airway, which may otherwise become difficult during an emergency, given the environment.


Figure 1: Schematic representation of the theatre layout

A1 = anaesthetist 1, A2 = anaesthetist 2, C1 = cardiologist 1, C2 = cardiologist 2, T1 = thoracic surgeon 1, T2 = thoracic surgeon 2, N1 = scrub nurse 1, N2 = scrub nurse 2/ technologist, R = radiographer, Instruments 1 = surgical instruments, Instruments 2 = long trolley used for crimping the valve onto an introducer in a sterile fashion

Anticipated complications included major blood loss due to damage to vascular structures or the heart, cardiac tamponade, dysrhythmias including heart block, malposition or embolism of the implanted valve, paravalvular leak or severe tricuspid regurgitation, contrast-induced nephrotoxicity, pneumothorax related to venous access and need for emergency cardiopulmonary bypass and sternotomy/thoracotomy.

Five-lead electrocardiography, invasive and noninvasive blood pressure monitoring and pulse oximetry were instituted. Intravenous access was secured in the lower extremities. A target-controlled infusion of propofol at plasma concentrations of 2-3 ug/ml and remifentanil 4-6 ng/ml was used.[1-3] Intubation was facilitated with 0.8 mg/kg rocuronium, and 2 g cefazolin was administered for antibiotic prophylaxis. The airway was secured with a 7.5 mm armoured endotracheal tube. The patient was ventilated with a tidal volume of 600 ml, at a rate of 10 ml per minute, and an FiO_2 of 0.5. A TOE probe was inserted.

The patient was positioned with the head elevated 10 degrees, a roll was placed under the shoulders and the head turned to the left-hand side. Heparin was administered to a target-activated clotting time of 300 seconds. The surgical stimulation was minimal at times and intermittent boluses of 50-100 µg phenylephrine were administered to maintain perfusion pressure. The short periods of balloon inflation were remarkably well tolerated. No dysrhythmias were observed (with the exception of the atrial fibrillation with which the patient had presented).
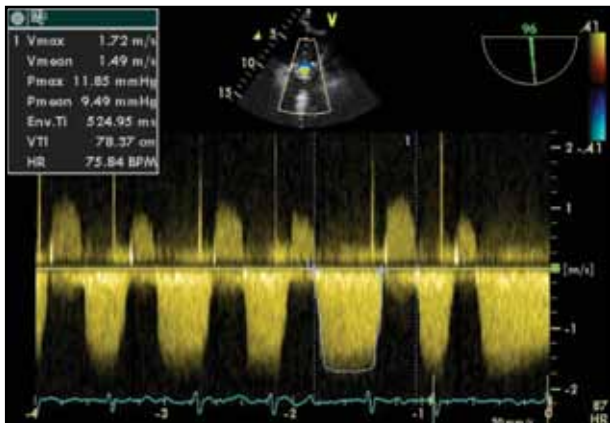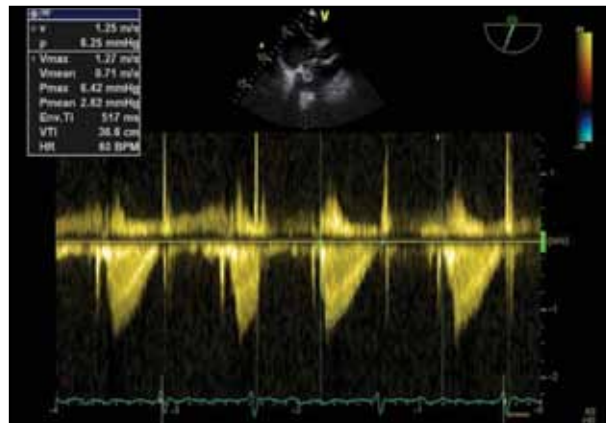
Figure 2: Pre-procedure determination of tricuspid gradients with transoesophageal echocardiography

Figure 3: Post-procedure determination of tricuspid gradients with transoesophageal echocardiography

On completion of the procedure, the tricuspid valve was interrogated with right heart catheterisation, as well as TOE. Both showed a well-functioning bioprosthesis with minimal paravalvular leakage, and revealed a 6.5 mmHg peak gradient and 2.6 mmHg mean gradient (mild residual stenosis). Figures 2 and 3 show pre-procedure and post-procedure determinations of tricuspid gradients with TOE respectively.

After removal of the sheath the transfemoral jugular venogram confirmed a patent right jugular vein. Surgical haemostasis was achieved. On completion of the procedure significant facial oedema was observed and, therefore, the airway was inspected before reversing the neuromuscular blockade. The patient was extubated in theatre, awake and alert, and nursed in the 30-degree upright position. Postoperatively the patient recovered in the cardiac intensive care unit. There were no signs of right heart failure or airway compromise and the facial swelling improved markedly over the next 24 hours.

The patient had an uncomplicated recovery after the procedure. She remained in hospital for five days, while awaiting therapeutic anticoagulation with warfarin for atrial fibrillation and the mechanical mitral prosthesis. At time of discharge she had diuresed well on furosemide and spironolactone and lost about 10 kg of oedema fluid. Dyspnoea improved to NYHA class II. At three-month follow-up she remained well, with NYHA class II dyspnoea and no orthopnoea or paroxysmal nocturnal dyspnoea. She had no ascites, tender hepatomegaly or other signs suggestive of recurrent tricuspid stenosis. The transthoracic echocardiogram was mostly unchanged, with a 12 mmHg peak gradient and 6 mmHg mean gradient, and no regurgitation or leaks.

Discussion

Tricuspid disease

The tricuspid valve has three leaflets (anterior, posterior and septal) and is attached to the fibrous skeleton of the heart. The leaflets are attached to the right ventricle, chordae tendineae and papillary muscles. The normal valve area is 7.6 ± 1.4 cm.[2,4] Anatomically, the tricuspid valve is closely related to the coronary sinus, atrioventricular nodal conduction tissue and the right coronary artery.

Tricuspid stenosis is a rare entity and is mostly caused by rheumatic heart disease, although the mitral and aortic valves are affected more commonly by the rheumatic process. Isolated tricuspid stenosis is rare and raises the possibility of carcinoid heart disease, atrial myxoma, atrial thrombus or methysergide use, or congenital causes such as tricuspid atresia and Ebstein's anomaly.[5–7]

Pathologically, there is fusion and shortening of the chordae tendineae and leaflet thickening. Fusion and calcification of the leaflets is a late sign.

Clinically, patients present with symptoms of limited cardiac output such as tiredness, fatigue and dyspnoea. Right-sided signs such as peripheral oedema, ascites and non-pulsatile hepatomegaly are common, and even anasarca can occur. Atrial dysrhythmias, especially atrial fibrillation, are common. The jugular venous pressure is increased and prominent "a" waves can be noted, which increase with inspiration (provided that the patient is in sinus rhythm). The murmur is typically mid-diastolic, maximal along the left sternal border, and often of high-pitched character. Electrocardiography and chest radiology confirm an enlarged right atrium, echocardiography is useful to define valvular anatomy, and catheterisation will confirm a diastolic gradient in excess of 4 mmHg across the valve.

Generally a large prosthesis can be implanted into the tricuspid position and hence haemodynamic consequences are minimal. The choice of prosthesis for tricuspid replacement is controversial: tricuspid mechanical valve replacement is associated with a higher incidence of thrombosis than replacement in the aortic and mitral positions. However, reports on newer bileaflet valves suggest a lower incidence of this complication.[8] Tricuspid tissue valve replacements are prone to valve degeneration, but the performance is better in young patients when the replacement is done in the tricuspid position compared to the mitral and aortic positions.[9] Despite this controversy, the survival is probably similar for mechanical and bioprostheses.[8,10,11] Overall, the tricuspid valve is more prone to thrombosis and pannus formation, irrespective of whether a bioprosthesis or a mechanical valve is used. Pannus formation occurs mostly on the ventricular side and has a 35% incidence at five years' follow-up.[12] Pannus is the most frequent reason for reoperation.[13]

Early mortality with tricuspid valve replacement together with another valve is 6%.[14,15] However, mortality of up to 27% has been reported for repeat operations, advanced NYHA status, and complex congenital heart disease.[16] Reported complications are complete heart block (6%), thromboembolism and thrombosis (1% per patient per year).[15] Survival after tricuspid valve replacement at 10 years' follow-up is 55%.[16] Mortality is related to right ventricular dysfunction, dysrhythmias, endocarditis, other valve disease, stenosis or malfunction of implanted devices.[17]

Transcatheter valve implantation

Cribier et al performed the first transcatheter aortic valve implantation (TAVI) in 2002.[18] Transcatheter valve implantation techniques have become an accepted alternative to conventional surgery in high-risk [euroSCORE greater than 20, Society of Thoracic Surgeons (STS) score greater than 10] and inoperable patients, especially for aortic valve disease.[19] This technique has also found application as an alternative to conventional surgery in patients with failed bioprostheses in the aortic, mitral, tricuspid and pulmonary positions.[20] Transapical and transarterial aortic valve replacements are well described for both degenerative native and bioprosthetic valves, but implantation of the first tricuspid case has only recently been described.[21]

Peripheral arterial disease is an indication to utilise the transapical approach to TAVI, where a small anterior thoracotomy is performed and the device is applied through a small ventriculotomy reinforced with purse string sutures.

At present there is limited availability of valve sizes and a patient with too large or small an annulus will not be suitable for transcatheter device placement. Furthermore, valve sizes are not standardised.[22]

Regardless of the approach, the transcatheter device should be placed in plane with the in situ prosthesis to align the outflow during deployment. This requires perpendicular radiographic imaging and little movement from the patient, ventilation or the heart, and can be best achieved with fast ventricular pacing, interrupting ventilation periodically and anaesthesia with paralysis.

When implanting a conventional prosthetic heart valve, the size is chosen according to the external diameter. When a valve-in-valve implantation is done, the internal diameter should be assessed to determine valve sizing. Inadequate expansion of a transcatheter device that is too large because of residual stenosis or pannus may give suboptimal results.[21] This might necessitate re-expanding the balloon to achieve a better seal.

Paravalvular leak is defined as a leak between a native valve and a prosthetic valve. The term intervalvular leak is new, and refers to a leak between the prosthetic valve and the transcatheter valve.[20]

Preliminary early follow-up for transcatheter aortic valve replacement in native aortic valves appears encouraging,[23] but only time will tell how favourable valve-in-valve implantation will compare to conventional valve replacement. The results of the PARTNER trial (Placement of AoRTic TraNscathetER Valve trial) are eagerly awaited.[24]

Issues to be considered by the anaesthetist

There are several issues that need to be considered by the anaethetist. The patients qualifying for transcatheter valve implantation have increased perioperative risk compared to patients presenting for conventional valve replacement, and this should be kept in mind when formulating the anaesthetic plan.

The ideal location to carry out this procedure is a hybrid theatre. This is a theatre that has the features of both a normal operating theatre as well as those of a catheterisation laboratory. When designing such a theatre the needs of the multidisciplinary team of cardiovascular anaesthesiologists, cardiac surgeons, interventional cardiologists, perfusionists, technologists, radiographers and surgical scrub team should be taken into account.

Having so many team members makes excellent communication and a team approach mandatory. Everybody involved should have a thorough understanding of the procedure and their role. The anaesthetist should play an indispensible role in the pre-, intra- and postoperative periods.[25]

Monitoring, ventilator and infusion devices are placed at the patient's feet, allowing the surgeons maximal access to the large sterile field. The position of electrical outlets, oxygen

supply and suction should be considered. Equipment should be compact to maximise the use of space.

Access to the patient's airway is difficult once the procedure has started. The procedure has the potential for severe haemodynamic compromise, necessitating resuscitation and more invasive procedures. In light of this, in our opinion it is safest to secure the airway with an armoured endotracheal tube before commencing with the procedure. A supraglottic airway device could be an alternative, although it does not guarantee a secure airway. One-lung ventilation could become necessary if sternotomy or thoracotomy needs to be performed.

Although TOE is used extensively in the modern era of cardiothoracic anaesthesia, it is not indispensible for transvenous transatrial tricuspid replacement, as contrast cineradiography is also used. TOE may be performed by a second anaesthetist or cardiologist. The avoidance of TOE, maintaining haemodynamic stability and limiting the duration of balloon dilatation of the stenotic tricuspid prosthesis will make local anaesthesia and sedation a feasible option for this procedure. Sedation and local anaesthesia might offer advantages in this high-risk population. Further experience might enhance safety and make a local procedure, coupled with light sedation, an option. Bispectral index (BIS) or entropy monitoring could guide the level of anaesthesia or sedation. If sedation is chosen, the anaesthetist must be aware that access to the airway will be difficult and disruptive to the procedure being performed.

The method of general anaesthesia is probably not as important as the maintenance of stable haemodynamics and rapid postoperative recovery. Patient movement during expansion of the stent may cause malpositioning or embolisation of the prosthesis, with haemodynamic consequences. The advantages and disadvantages of TOE are listed in Table I.

For long procedures, attention should be given to urinary catheterisation. Temperature regulation for such procedures should be accomplished by increasing the ambient temperature.

Care should be taken when positioning the patient. Excessive turning of the head to the contralateral side, accompanied by ipsilateral obstruction caused by the introducer catheter, may impede venous return and cause intracranial hypertension and facial and airway oedema. Intraoperative venography of the internal jugular veins confirms patency. Air embolism is a risk, given the head-up position and large bore cannulas. TOE is sensitive for the detection of air embolism. Although high jugular venous pressure limits this risk, excessive head-up positioning should be avoided.

Haemodynamic instability is mainly related to injury to major vascular structures or to the heart, cardiac tamponade, dysrhythmias (including heart block), malpositioning or embolism of the implanted device, paravalvular leak or severe tricuspid incompetence and tension pneumothorax. Adequate intravenous access should be secured and haemodynamic status continuously monitored. Owing to the nature of the intervention and the underlying pathology, it is not practical to use central venous or pulmonary artery catheters. The anaesthetist relies on invasive arterial pressure monitoring, TOE and catheterisation data to monitor haemodynamic stability. Cross-matched blood should be made available. Facilities for transvenous pacing should be readily available and facilities for conversion to cardiopulmonary bypass and sternotomy or thoracotomy should be on standby.

Patient movement during deployment of the device could result in malpositioning and resultant haemodynamic compromise. Furthermore, preoxygenation and interrupting the ventilation for a short period, fast cardiac pacing or intravenous adenosine could improve conditions for successful device placement.

All staff should be adequately protected from the high levels of radiation in the catheterisation theatre at all times.

Care should be taken when renal function is abnormal or concomitant nephrotoxins are being used. Renal function might be affected if large doses of intravenous contrast are used. Attention to fluid status is mandatory and the use of

Table I: Advantages and disadvantages of transoesophageal echocardiography

Advantages	Disadvantages
Useful for pre-procedure evaluation of baseline Relatively noninvasive Provides additional information to catheterisation data when central venous catheter or pulmonary artery catheter cannot be used Continuous assessment of structures of interest No intravenous contrast needed and might decrease total amount of contrast required Useful for monitoring internal diameter of degenerative valve post-dilatation Can be used to determine size of valve to be implanted	Need for general anaesthesia increases In some cases of tricuspid stenosis, worsening of upper airway oedema may be experienced (For specific contraindications and complications the reader is referred to standard textbooks)

N-acetylcysteine, furosemide and inotropic support prior to the procedure should be considered.

Postoperative care should be individualised in these high-risk patients. Early extubation may be attempted, provided the patient is haemodynamically stable, normothermic, pain free and awake.[26]

Conclusion

Percutaneous tricuspid valve replacement can be safely performed under general anaesthesia, provided that the procedure is understood and all possible eventualities have been considered. As the quality of percutaneous prostheses improves, and if long-term follow-up confirms this as a safe option, anaesthesiologists will be expected to provide perioperative care for an increasing number of cases.

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