Transcatheter aortic valve implantation: an overview for nurses

Clinical review

Transcatheter aortic valve implantation: an overview for nurses

Asriel Juvenal Chamos, Ulster University, UK. a.chamos@ulster.ac.uk

Abstract

Transcatheter aortic valve implantation is non-inferior to surgical aortic valve replacement in managing severe aortic stenosis. It has been the treatment of choice for those who would be unsuitable for surgical aortic valve replacement. Patient selection and workup involves a rigorous process to ensure a successful outcome, and patient monitoring is crucial during and after the procedure. Nurses play an important role throughout these stages, so developing their understanding of the different processes involved in each step of the procedure is imperative. This article provides an overview of transcatheter aortic valve implantation, from patient selection and workup to peri-procedure, while highlighting considerations for nurses across these stages. It includes the most relevant and recent literature on transcatheter aortic valve implantation for evidence-based nursing care, such as the monitoring of complications, early mobilization and next-day discharge. Furthermore, it includes a discussion on future considerations and research on transcatheter aortic valve implantation.

Key words

Aortic stenosis, Early ambulation, Frailty Patient-centred care, Transcatheter aortic valve replacement

Submitted: 19 August 2022; accepted following double-blind peer review: 19 October 2022

Introduction

Aortic stenosis is a slow, progressive disorder, beginning with mild valve thickening without blood flow obstruction then progressing to severe calcification with impaired leaflet movement (The UK TAVI Trial Investigators, 2022). Its prevalence is rising rapidly as a result of an ageing population, and it is the most common primary valve lesion requiring surgical or transcatheter intervention in developed nations (Browne et al, 2022). Data suggest a high burden of severe aortic stenosis in the UK, with just over 290,000 patients aged 55 years and above being diagnosed with the disease in 2019 (Mack et al, 2019). The primary manifestations of aortic stenosis are exertional dyspnoea or decreased exercise tolerance, angina, syncope or presyncope and, ultimately, heart failure (Popma et al, 2019).

Traditionally, the management options for aortic stenosis were surgical aortic valve replacement or medical therapy (Shehada et al, 2018), with the former remaining the gold-standard treatment for decades (Bagienski et al, 2017). In 2002 Alain Cribier and colleagues performed the first transcatheter aortic valve implantation (TAVI) procedure (Vendrik et al, 2020). Since then, it has been the less invasive option and has shown superiority over standard medical therapy in managing aortic stenosis in inoperable patients (Perl et al, 2021). In their most recent guidelines, the European Society of Cardiology and the European Association for Cardio-Thoracic Surgery recommend TAVI for patients who are aged over 75 years, at high risk or unsuitable for surgery (Browne et al, 2022). Studies, such as the PARTNER 3 and SURTAVI trials have shown that TAVI is non-inferior to surgical aortic valve replacement in terms of all-cause and cardiovascular mortality rates, and superior to surgical aortic valve replacement in reducing hospital stay length and the risk of specific adverse effects, such as significant bleeding, acute kidney injury and atrial fibrillation (Kodali et al, 2015; Vendrik et al, 2020; Avvedimento and Tang, 2021).

This article provides an overview of the TAVI procedure, from patient selection and workup to peri-procedure, while highlighting considerations for nurses across these stages. It will include the most relevant and recent literature on TAVI for evidence-based nursing care, and investigate gaps in the literature for future research recommendations in nursing.

Selection and workup

Optimal patient selection is key to achieving the positive effects of TAVI on mortality and quality of life. Consequently, a heart team was introduced to ensure a rigorous multidisciplinary approach was taken to determine eligibility for the procedure. The components of a heart team will vary between institutions and specific clinical situations, but the literature suggests that it should include a cardiologist, cardiac surgeon, interventional cardiologist, non-invasive imaging specialist, cardiac anaesthetist and nursing specialists or coordinators (Muralidharan et al, 2016). The heart team will diligently evaluate clinical, anatomical and procedural factors, then discuss the team recommendation with the patient, who will make an informed treatment choice (Browne et al, 2022). Shared decision making and patient-centred care are the foundations of a heart team. Nurses, at this point, must advocate for patients. They should ensure that a patient's best interests and preferences are voiced at every heart team meeting. Family members may also be involved with the patient's consent. Additionally, nurses should continually explore the patient's understanding of treatment options and factors considered in the decision-making process. Providing patient decision aids, information leaflets, or directing concerns to appropriate health team members can facilitate this.

Determining a patient's eligibility for TAVI is very complex, involving an evaluation of risk, frailty and the impact of comorbidities (Patel et al, 2018). The two most widely-used risk stratification models are the Society of Thoracic Surgeons-Predicted Risk of Mortality (STS-PROM) and the European System for Cardiac Operative Risk Evaluation (EuroSCORE II) scales. Both models define operative mortality within 30 days from surgery or later if the patient remains hospitalised (Bagienski et al, 2017). The European Society of Cardiology and the European Association for Cardio-Thoracic Surgery recommend TAVI for patients with a STS-PROM or EuroSCORE II of over 8% (Browne et al, 2022). However, there are criticisms that these current models are not well calibrated for this patient group (Raju et al, 2019). Further developments of these models are needed to include frailty, access approach and outcomes such as quality of life and functional capacity.

To complement the risk models in evaluating eligibility, one of the clinical characteristics that the heart team should consider is frailty. There has been an increase in focus on frailty assessment in recent years, as risk stratification models currently do not incorporate this significant patient characteristic. Frailty is an independent predictor of mortality, peri-procedural complications, prolonged hospital stay, readmissions and total cost among patients undergoing TAVI (Wood et al, 2019). In older adults, frailty also makes it unlikely for TAVI to improve quality of life and survival. There are several assessment tools for frailty, including grip strength, gait speed, 6-minute walk test, albumin levels, the Katz Index of Independence in Activities of Daily Living, the Mini Nutritional Assessment – short form, the Comprehensive Assessment of Frailty and the Multi-Dimensional Geriatric Assessment (Patel et al, 2018; Lauck et al, 2020). Increasing familiarity with these tools among nurses can help to ensure that these assessments are done at the earliest possible opportunity. Nurses may also take this time for health education and promotion, highlighting to patients how frailty can affect their recovery post procedure and how they can maintain or improve their fitness for the procedure.

Some comorbidities need special consideration when evaluating patient eligibility for TAVI; this may be because of their high prevalence, impact or non-representation in risk stratification models. These comorbidities include chronic kidney disease, coronary artery disease, chronic lung disease, concomitant mitral valve disease and systolic dysfunction. Studies have shown that patients

with one of these conditions have higher rates of mortality and adverse post-procedure events (Patel et al, 2018). Nurses must know the patient's medical history, ensuring that this is adequately documented and emphasised when handing over care to other staff members or clinical areas, such as the cardiac catheterisation laboratory or coronary care unit.

A patient undergoes a systematic evaluation before the TAVI procedure to minimise adverse outcomes—this is usually called a workup. A cardiac computed tomography can is the preferred imaging tool for assessing the valve, annulus, aorta and feasibility of vascular access. An operator may also consider transoesophageal echocardiography if the computed tomography results are challenging to interpret or contraindicated, such as in patients with chronic renal failure (Browne et al, 2022). In addition, patients usually undergo further tests in the cardiac catheterisation laboratory to assess coronary and non-coronary anatomy, including haemodynamic status. However, patients with impaired renal function require caution or modifications to minimise contrast-induced nephropathy or further exacerbation of renal impairment (Elbaz-Greener et al, 2017). Withholding nephrotoxic medications, pre-hydration and furosemide with matched hydration are ways to avoid contrast-induced nephropathy (Lilly et al, 2020). Furthermore, nurses can participate in conducting further tests for the holistic assessment of patients for TAVI, such as collecting blood samples for specific tests and electrocardiogram recordings to detect any significant rhythm abnormalities.

Procedure

Some operators prefer to perform the procedure under general anaesthesia in a hybrid operating theatre for a more controlled approach to patient monitoring with the aid of an anaesthetist. This also facilitates transoesophageal echocardiography, which can help with valve placement and monitoring for complications. Other operators prefer conscious sedation in the cardiac catheterisation laboratory for a faster recovery time and avoidance of central or arterial lines and urinary catheterisation. Ultimately, the choice between general anaesthesia or conscious sedation will depend on need, comorbidities and other factors, including patient preference (Okoh et al, 2020; The UK TAVI Trial Investigators, 2022).

The transfemoral approach is the most commonly used access site for valve implantation. It is the least invasive and only actual percutaneous method, which does not require surgical preparation and can be performed under local anaesthesia. However, other access sites will be considered if the femoral vascular anatomy is problematic. Alternative access routes include subclavian, direct aortic, transapical and transcarotid. Access route selection will depend on operator preference, local experience and patient needs, with the latter remaining the only recommended way to improve outcomes in TAVI (Dekany et al, 2021). The replacement valve is deployed using a guidewire and specialised devices under fluoroscopy. The new valve will push the native valve against the aortic wall through balloon-expandable or self-expanding mechanisms. Aortography or transoesophageal echocardiography is performed immediately to assess for the presence of paravalvular aortic regurgitation, which has remained a significant concern in TAVI because of its negative impact on patient survival. A single-centre prospective observational study found that haemodynamic assessment using the regurgitation index demonstrated the highest added predictive value for survival compared to the other two modalities (Khan et al, 2019). Once the valve is successfully deployed, the guidewire is removed and the access site is closed using a vascular closure device for haemostasis (The UK TAVI Trial Investigators, 2022).

Nurses play an essential role in monitoring and reassuring patients, maintaining equipment sterility and keeping accurate documentation throughout the procedure. Monitoring of continuous cardiac rhythm and vital signs is required to identify potential rhythm disturbances and ensure haemodynamic stability. These should be documented precisely, including the timing of events and medications administered to facilitate communication and continuity of care. Some cardiac centres have specialist nurses who are trained to perform valve preparation or loading and nurse-led

sedation. Browne et al (2022) indicated that nurse-led sedation is safe and can deliver significant savings in anaesthetic resources, which can lead to greater flexibility in scheduling, increased capacity and improved patient access (Branny et al, 2017).

Post-procedure management

Figure 1 provides a summary of the patient journey, from pre-assessment to discharge and follow up. The main focus of post-procedure management is monitoring for complications. The most common complications encountered are conduction disturbances, vascular complications, paravalvular leak and stroke. These complications contribute to a prolonged hospital stay, complex post-procedure care and elevated healthcare costs. Nevertheless, the literature suggests a decreasing trend in the incidence of these complications, which could be attributed to improved patient selection, procedural protocol and techniques and operator skills (Chau and Williams, 2016; Estes and Kalra, 2018). That said, patients who undergo TAVI are typically older and more unwell, often with multiple comorbidities, so it is essential to acknowledge that efforts to decrease these complications may be limited (Estes and Kalra, 2018).

Figure 1. Journey of the patient undergoing transcatheter aortic valve implantation, from pre-admission to discharge and follow up

<table>
<tr><td rowspan="6">Pre-admission</td><td rowspan="6">Heart Team</td><td rowspan="6">Cardiologist, cardiac surgeon, interventional cardiologist, cardiac anaesthetist, nursing specialists or coordinators</td><td rowspan="4">Patient selection and workup</td><td>Aged ≥75 years

Unsuitable /High risk for surgical aortic valve replacement (STS-PROM or EuroSCORE II of >8%)

Suitable for transfemoral transcatheter aortic valve implantation</td><td>European Society of Cardiology and European Association for Cardio-Thoracic Surgery guidelines*</td></tr>
<tr><td colspan="2">Cardiac computed tomography or transoesophageal echocardiography

Cardiac catheterisation</td></tr>
<tr><td colspan="2">Frailty assessment

Comorbidities review</td></tr>
<tr><td colspan="3">Multidisciplinary meeting</td></tr>
<tr><td>Procedure</td><td colspan="2">Conscious sedation in cardiac catheterisation laboratory or under general anaesthesia in hybrid operating theatre

Preferred site: transfemoral

Other sites: subclavian, direct aortic, transapical, transcarotid

Site closure with vascular closure device

Continuous cardiac rhythm and vital signs monitoring</td></tr>
</table>

Discharge and follow up			Post-procedure	Monitor for common complications: conduction disturbances, vascular complications, paravalvular leak, stroke Early mobilisation Discharge and follow-up planning

*(Browne et al, 2022). EuroSCORE=European System for Cardiac Operative Risk Evaluation; STS-PROM=Society of Thoracic Surgeons-predicted risk of mortality.

Conduction disturbances are caused by the proximity of the left ventricular outflow tract to the aortic valve and either trauma or compression by the bioprosthetic valve of the native conduction system. These conduction disturbances range from bundle branch blocks to atrioventricular blocks, with some patients requiring a permanent pacemaker (Bagienski et al, 2017; The UK TAVI Trial Investigators, 2022). Patients with a new first or second degree atrioventricular block, new bundle branch block or prolongation of the QRS complex that is equal to or greater than 10% will require telemetry monitoring until conduction is stable for 48 hours or more. Outpatient monitoring using an implantable loop recorder may also be considered if the patient has a new rhythm disturbance, such as atrial fibrillation, progression of the baseline conduction system, or if the operator believes that monitoring is warranted (Zaman et al, 2015).

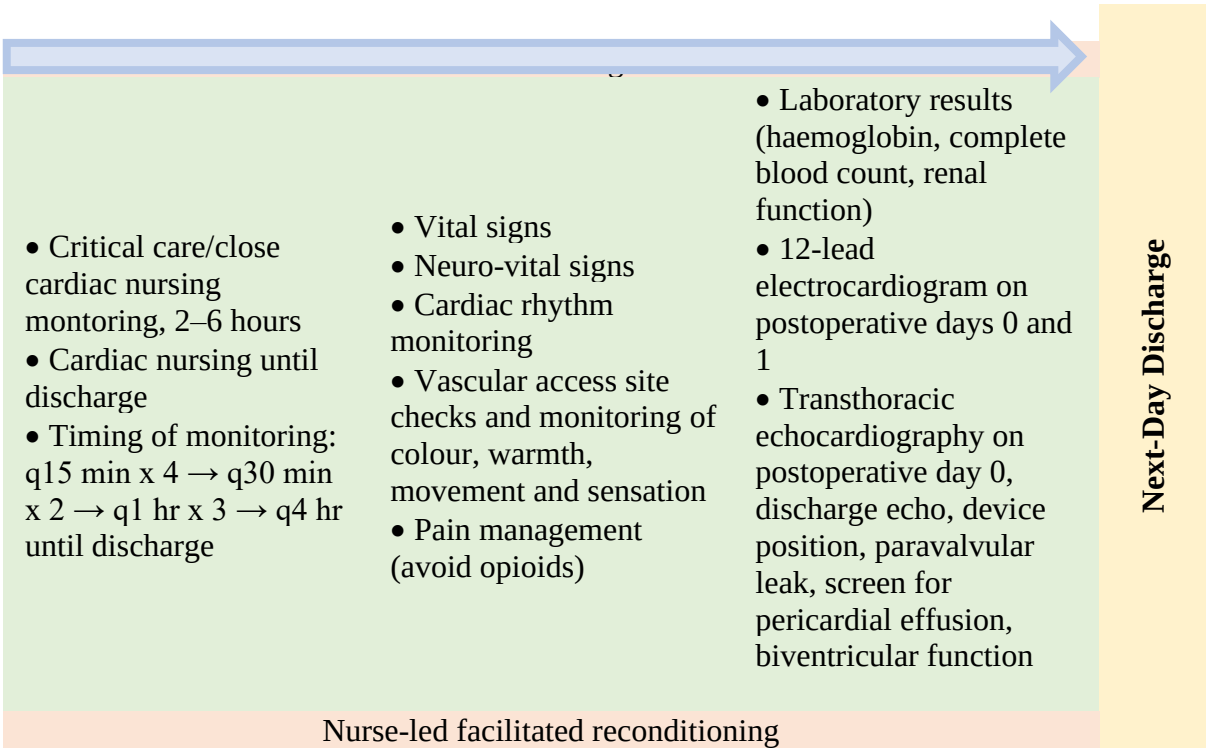
Significant clinical trials have shown that the incidence of major vascular complications ranges from 2.2% to 6% at 30 days post procedure (Avvedimento and Tang, 2021; Van de Velde-Van De Ginste et al, 2021). Vascular complications include aortic dissection or rupture, vascular injury, distal embolisation, unplanned endovascular or surgical intervention and closure device failure (Abugroun et al, 2022). In a single-centre retrospective cohort study, researchers found that two-dimensional ultrasonography guidance was effective in reducing access-related vascular complications (Xue, 2011). Furthermore, developments in TAVI technology, such as the downsizing of delivery systems from 24–25 French to 14–18 French and newer generation devices, were found to reduce vascular complications dramatically (Holmes et al, 2013). Early involvement of the vascular surgical team for recommendations concerning access site, side preference and anatomical considerations may also be beneficial (Sintek and Zajarias, 2014). Vigilant monitoring of vascular access haemostasis is crucial after the procedure. Bed rest for at least 4–6 hours is proven safe, with the patient in a supine position for the first 2 hours and then the head of the bed elevated to 30 degrees for the next 2 hours. Standardised nursing care protocols and operators' orders should guide monitoring frequency (Braunwald et al, 2021).

A paravalvular leak occurs when there is inappropriate valve sealing against the aortic root anatomy and depends on specific transcatheter heart valve designs (Swift et al, 2021). It can be classified as mild/moderate or severe, with both being associated with higher 1-year mortality rates after TAVI (Leon et al, 2010). A meta-analysis of observational and randomised control studies revealed a significant decrease in paravalvular leak among next-generation devices compared to previous designs. Furthermore, improved prosthesis design, valve architecture, imaging techniques with enhanced sizing and superior delivery techniques with partially to fully repositionable prostheses are potential links to substantial overall improvement (Holmes et al, 2013). Assessment for the presence of a paravalvular leak is done through echocardiography during or after the procedure, before the patient is discharged (Cribier et al, 2002). If a clinically significant paravalvular leak is detected, surgery or transcatheter paravalvular leak closure will be considered (Joseph et al, 2017).

The incidence of stroke after TAVI is currently <5% (Adams et al, 2019), but is associated with a 6-fold greater mortality risk at 30 days in this population (Strange et al, 2022). Approximately 50% of strokes occur within 24 hours after the TAVI procedure, followed by a gradually decreasing incidence in the next 30 days (Boland and Muller, 2019). Strokes can be caused by procedural and non-procedural factors. Procedural factors may include atheromatous and calcific emboli from wire, catheter and valve manipulation through a calcific aortic valve. Non-procedural factors include new and chronic atrial fibrillation, previous stroke, diabetes mellitus, atheromatous arterial disease and chronic hypertension (Adams et al, 2019). This highlights the importance of considering cerebral embolic protection devices, adequate intraoperative anticoagulation, individualised antithrombotic therapy, aggressive management of new-onset atrial fibrillation and careful neurologic assessment in all patients (Adams et al, 2019; Boland and Muller, 2019). It also emphasises the crucial role of nurses in the consistent neurological assessment and cardiac rhythm monitoring of patients throughout their post-procedure hospital stay. Nurses will need to include the importance of adhering to antithrombotic medications in their patient education.

Post-procedural immobilisation was previously the standard of care to prevent vascular and bleeding complications after TAVI. However, prolonged immobilisation may also increase other post-procedure complications, such as delirium and infections (Vahanian et al, 2022). A recent trial of 150 patients showed that early mobilisation (4–6 hours post procedure) following transfemoral TAVI is safe and feasible. It also decreased the combined incidence of delirium, infections, pain and unplanned urinary catheter use post-procedure. Similarly, Wood et al (2019) reported that early mobilization is a safe and effective strategy to facilitate next-day discharge after TAVI. This study developed a rapid reconditioning post-procedure protocol, specifying 4–6 hours of bed rest, with the head of the bed flat for the first 2 hours, then elevated to a 30-degree angle for the next 2 hours (Figure 2). Following this, two nurses should assist the patient with the first mobilisation. In this protocol, nurses provide all direct care in collaboration with the multidisciplinary team (Braunwald et al, 2021).

Figure 2. Protocol for next-day discharge after transcatheter aortic valve implantation



Bedrest		
• Rapid removal of invasive lines	• Head of bed flat, 2 hours • 30^{o} elevation, 2 hours • Total bedrest: 4–6 hours • Two nurses assist for first mobilisation • Mobilisation on post-operative day 0 (including walking to toilet)	• Hydration • Nutrition: resume/encourage regular meals after mobilisation • Elimination: avoid urinary catheterisation
Communication, patient teaching and discharge planning		
• Individualised plan • Communication of early alerts with medical team • Patient education	Discharge criteria: • Absence of persistent (>3 hours) intraventricular conduction delays • Absence of laboratory contraindications (haemoglobin and estimate glomerular filtration rate) • Return to baseline mobilisation • Availability of a family member for 24 hours to remain with the patient	

Future considerations and research

Current risk stratification tools used to determine eligibility criteria must include frailty, as this can have a significant impact on TAVI outcomes. There are numerous frailty assessment tools available, but more research is needed to determine which of these tools are appropriate for patients undergoing TAVI. Once standardised, it will also be beneficial for nurses to perform these assessments to maximise and mobilise every member of the heart team.

Clinical trials have suggested that TAVI may now be extended to younger, low-risk patients. With these findings, various issues emerged which require further research, such as long-term valve durability and performance, coronary re-access and optimum pharmacological management post procedure. Progress in these areas may consequently prompt recommending bodies to update their position on patient selection for TAVI in the near future. Because of its non-inferiority to surgical aortic valve replacement and superiority in reducing hospital length of stay and some adverse effects, TAVI will potentially be routinely offered to most patients with aortic stenosis. If this happens, there will be a reallocation of resources and a potential restructuring of the cardiac surgical and interventional environment. Regardless of these possibilities, patient needs and preferences will remain a priority when deciding between TAVI and surgical aortic valve replacement.

Early mobilisation and discharge are safe, but protocols for these are not standardised and there is no evidence of their universal use. The clinical pathway developed by Wood et al (2019) uses a multidisciplinary approach, facilitating safe monitoring, rapid mobilisation and reconditioning, as well as promoting the involvement of family members. More research should be carried out on the implementation or influence of this model in developing local standards of care in different centres and different countries.

Conclusions

Current guidelines recommend TAVI for patients at high surgical risk, but recent findings may influence these guidelines to include those at low risk in the near future. Further research is required, as there are concerns surrounding long-term valve durability and performance, coronary reaccess and optimal pharmacological treatment in younger and low-risk populations. To ensure the optimal selection and systematic evaluation of patients, centres should have their own heart team, maintaining shared decision making and patient-centred care throughout. TAVI could be performed under general anaesthesia or conscious sedation, and various access sites can be considered. When deciding between these, individual needs and patient preferences should guide decision making. Nurses play a crucial role throughout a patient's TAVI journey, especially during the post-procedure phase, where the focus is on monitoring for common complications such as conduction disturbances, vascular issues and stroke. It is imperative that nurses are trained to perform these assessments for early identification and timely management of these complications. Early mobilisation (4–6 hours post-procedure) is safe and effective in facilitating early discharge; however, there is not enough evidence of its standardisation and broad implementation. More research needs to be conducted to explore its adoption or integration in local protocols.

Key points

- Transcatheter aortic valve implantation is non-inferior to surgical aortic valve replacement in all-cause and cardiovascular mortality, and superior in reducing hospital stay length and the risk of specific adverse effects such as significant bleeding, acute kidney injury and atrial fibrillation.
- A heart team is essential for rigorous patient selection and workup while maintaining shared decision-making and patient-centredness, resulting in favourable outcomes.
- Early mobilisation (4–6 hours post procedure) following transfemoral transcatheter aortic valve implantation is safe, feasible and can facilitate next-day discharge.
- Guidelines may soon change on patient eligibility to include younger patients and those with low surgical risks, but further research is needed to explore long-term valve durability and performance, coronary re-access and optimal pharmacological treatment in these populations.

Reflective questions

- How can nurses contribute to decision making within the heart team?
- How can nurses contribute to the successful outcomes of TAVI procedures?
- How will the inclusion of younger and low-risk patients impact the health service?
- What potential nursing research can you carry out to contribute to TAVI's evidence base?

Conflicts of interest statement

The author declares that there are no conflicts of interest.

Declaration of funding

None to declare.

References

Abugroun A, Daoud H, Hallak O, Abdel-Rahman ME et al. Frailty predicts adverse outcomes in older patients undergoing transcatheter aortic valve replacement (TAVR): from the national inpatient sample. Cardiovasc Revascularization Med. 2022;34:56–60. https://doi.org/10.1016/j.carrev.2021.02.004

Adams HSL, Ashokkumar S, Newcomb A et al. Contemporary review of severe aortic stenosis. Intern Med J. 2019;49(3):297–305. https://doi.org/10.1111/imj.14071

Avvedimento M, Tang GHL. Transcatheter aortic valve replacement (TAVR): recent updates. Progr Cardiovasc Dis. 2021;69:73–83. https://doi.org/10.1016/j.pcad.2021.11.003

Bagienski M, Kleczynski P, Dziewierz A et al. Incidence of postoperative delirium and its impact on outcomes after transcatheter aortic valve implantation. Am J Cardiol. 2017;120(7):1187–1192. https://doi.org/10.1016/j.amjcard.2017.06.068

Boland JE, Muller DWM. Interventional cardiology and cardiac catheterisation. Milton: CRC Press; 2019

Branny M, Branny P, Hudec M et al. Alternative access routes for transcatheter aortic valve implantation (TAVI). Cor Vasa. 2017;59(1):e10-6–e16. https://doi.org/10.1016/j.crvasa.2017.01.024

Braunwald E, Libby P, Bhatt D et al. Braunwald's heart disease: a textbook of cardiovascular medicine. London: Elsevier; 2021

Browne S, Smith D, Adams D et al. 75 Nurse-led sedation is safe and effective, shortening procedure times, and improving access for selected transcatheter aortic valve implantation (TAVI) patients. Heart. 2022;108(Suppl 1):A56

Chau CH, Williams DO. Prevention of contrast-induced renal failure for the interventional cardiologist. Circulation. 2016;9(6):e004122. https://doi.org/10.1161/CIRCINTERVENTIONS.116.004122

Cribier A, Eltchaninoff H, Bash A et al. Percutaneous transcatheter implantation of an aortic valve prosthesis for calcific aortic stenosis. Circulation. 2002;106(24):3006–3008. https://doi.org/10.1161/01.CIR.0000047200.36165.B8

Dekany G, Fontos G, Satish S et al. The prognostic value of immediate post-TAVI hemodynamic evaluation is superior to aortography and transoesophageal echocardiography in predicting patient survival. Int J Cardiol. 2021;329:153–161. https://doi.org/10.1016/j.ijcard.2020.12.058

Elbaz-Greener G, Zivkovic N, Arbel Y et al. Use of two-dimensional ultrasonographically guided access to reduce access-related complications for transcatheter aortic valve replacement. Can J Cardiol. 2017;33(7):918–924. https://doi.org/10.1016/j.cjca.2017.03.025

Estes BA, Kalra A. Contemporary nursing care in transcatheter aortic valve replacement. J Vasc Nurs. 2018;36(4):186–188. https://doi.org/10.1016/j.jvn.2018.08.001

Holmes DR, Rich JB, Zoghbi WA et al. The heart team of cardiovascular care. J Am Coll Cardiol. 2013;61(9):903–907. https://doi.org/10.1016/j.jacc.2012.08.1034

Joseph J, Naqvi SY, Giri J et al. Aortic stenosis: pathophysiology, diagnosis, and therapy. Am J Med. 2017;130(3):253–263. https://doi.org/10.1016/j.amjmed.2016.10.005

Khan AA, Murtaza G, Khalid MF et al. Risk stratification for transcatheter aortic valve replacement. Cardiol Res. 2019;10(6):323–330. https://doi.org/10.14740/cr966

Kodali S, Pibarot P, Douglas PS et al. Paravalvular regurgitation after transcatheter aortic valve replacement with the edwards sapien valve in the PARTNER trial: characterizing patients and impact on outcomes. Eur Heart J. 2015;36(7):449–456. https://doi.org/10.1093/eurheartj/ehu384

Lauck SB, Sathananthan J, Park J et al. Post-procedure protocol to facilitate next-day discharge: Results of the multidisciplinary, multimodality but minimalist TAVR study. Catheter Cardiovasc Interv. 2020;96(2):450–458. https://doi.org/10.1002/ccd.28617

Leon MB, Smith CR, Mack M et al. Transcatheter aortic-valve implantation for aortic stenosis in patients who cannot undergo surgery. N Engl J Med. 2010;363(17):1597–1607. https://doi.org/10.1056/NEJMoa1008232

Lilly SM, Deshmukh AJ, Epstein AE et al. 2020 ACC expert consensus decision pathway on management of conduction disturbances in patients undergoing transcatheter aortic valve replacement: a report of the American College of Cardiology solution set oversight committee. J Am Coll Cardiol. 2020;76(20):2391–2411. https://doi.org/10.1016/j.jacc.2020.08.050

Mack MJ, Leon MB, Thourani VH et al. Transcatheter aortic-valve replacement with a balloon-expandable valve in low-risk patients. N Engl J Med. 2019;380(18):1695–1705. https://doi.org/10.1056/NEJMoa1814052

Muralidharan A, Thiagarajan K, Van Ham R et al. Meta-analysis of perioperative stroke and mortality in transcatheter aortic valve implantation. Amer J Cardiol. 2016;118(7):1031–1045. https://doi.org/10.1016/j.amjcard.2016.07.011

Okoh AK, Haik N, Haik B et al. Periprocedural complications after transcatheter aortic valve replacement and their impact on resource utilization. Cardiovasc Revascularization Med. 2020;21(9):1086–1090. https://doi.org/10.1016/j.carrev.2020.01.025

Patel PA, Patel S, Feinman JW et al. Stroke after transcatheter aortic valve replacement: incidence, definitions, etiologies and management options. J Cardiothoracic Vasc Anesthesia. 2018;32(2):968–981. https://doi.org/10.1053/j.jvca.2017.08.034

Perl L, Cohen A, Dadashev A et al. Long-term outcomes of catheter-based intervention for clinically significant paravalvular leak. EuroIntervention. 2021;17(9):736–743. https://doi.org/10.4244/EIJ-D-20-01206

Popma JJ, Deeb GM, Yakubov SJ et al. Transcatheter aortic-valve replacement with a self-expanding valve in low-risk patients. N Engl J Med. 2019;380(18):1706–1715. https://doi.org/10.1056/NEJMoa1816885

Raju S, Eisenberg N, Montbriand J et al. Vascular complications and procedures following transcatheter aortic valve implantation. Eur J Vasc Endovasc Surg. 2019;58(3):437–444. https://doi.org/10.1016/j.ejvs.2019.03.014

Shehada S, Wendt D, Peters D et al. Infections after transcatheter versus surgical aortic valve replacement: mid-term results of 200 consecutive patients. J Thorac Dis. 2018;10(7):4342–4352. https://doi.org/10.21037/jtd.2018.06.54

Sintek M, Zajarias A. Patient evaluation and selection for transcatheter aortic valve replacement: the heart team approach. Prog Cardiovasc Dis. 2014;56(6):572–582. https://doi.org/10.1016/j.pcad.2014.02.003

Strange GA, Stewart S, Curzen N et al. Uncovering the treatable burden of severe aortic stenosis in the UK. Open Heart. 2022;9(1):e001783. https://doi.org/10.1136/openhrt-2021-001783

Swift SL, Puehler T, Misso K et al. Transcatheter aortic valve implantation versus surgical aortic valve replacement in patients with severe aortic stenosis: a systematic review and meta-analysis. BMJ Open. 2021;11(12):e054222. https://doi.org/10.1136/bmjopen-2021-054222

The UK TAVI Trial Investigators. Effect of transcatheter aortic valve implantation vs surgical aortic valve replacement on all-cause mortality in patients with aortic stenosis: a randomized clinical trial. JAMA. 2022;327(19):1875–1887

Vahanian A, Beyersdorf F, Praz F et al. ESC/EACTS guidelines for the management of valvular heart disease. Eur Heart J. 2022;43(7):561–632. https://doi.org/10.1093/eurheartj/ehab395

Van de Velde-Van De Ginste S, Perkisas S, Vermeersch P, Vandewoude M et al. Physical components of frailty in predicting mortality after transcatheter aortic valve implantation (TAVI). Acta Cardiol. 2021;76(7):681–688. https://doi.org/10.1080/00015385.2020.1769346

Vendrik J, Vlastra W, van Mourik MS et al. Early mobilisation after transfemoral transcatheter aortic valve implantation: results of the MobiTAVI trial. Neth Heart J. 2020;28(5):240–248. https://doi.org/10.1007/s12471-020-01374-5

Wood DA, Lauck SB, Cairns JA et al. The Vancouver 3M (multidisciplinary, multimodality, but minimalist) clinical pathway facilitates safe next-day discharge home at low-, medium-, and high-volume transfemoral transcatheter aortic valve replacement centers: the 3M TAVR study. Cardiovasc Interven. 2019;12(5):459–469. https://doi.org/10.1016/j.jcin.2018.12.020

Xue Q. The frailty syndrome: definition and natural history. Clin Geriatr Med. 2011;27(1):1–15. https://doi.org/10.1016/j.cger.2010.08.009

Zaman S, Gooley R, McCormick L et al. Pre - transcatheter aortic valve implantation workup in the cardiac catheterisation laboratory. Heart Lung Circul. 2015;24(12):1162–1170. https://doi.org/10.1016/j.hlc.2015.07.018