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TRANSAXILLARY AORTIC VALVE REPLACEMENT AS AN ALTERNATIVE TO CURRENT TREATMENT METHODS

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ABSTRACT

Introduction and aim: The aortic valve consists of three lobes, often presenting as a bilobed congenital heart defect. It is responsible for the outflow of blood from the left ventricle into the aorta by preventing backflow of blood into the heart during left ventricular diastole. The most common health problems associated with the aortic valve include stenosis and regurgitation. In minor defects, regular pharmacological treatment may be sufficient. In larger defects, these are available and necessary for treatment; they often require a mechanical valve. The aim of this paper is to review the availability of transaxillary access for aortic valve replacement as an emergency treatment method and its compatibility with current alternatives. The advantages and disadvantages of this treatment are highlighted.

Materials and Methods: This narrative review was based on a structured analysis of published clinical trials, extension studies, and review articles evaluating, clinical efficacy, complications in patients with surgical methods for aortic stenosis defects.

Results: A significant number of people with aortic valve disease can be managed with minimally invasive monitoring and do not require radical treatment. However, if the defect is severe, surgical treatment is necessary. Aortic valve replacement is currently treated using three basic methods. The first is a classic sternotomy, which involves opening the chest by splitting the sternum. The second method is percutaneous valve implantation: TAVI. Recently, thanks to the use of modern equipment, minimally invasive surgical techniques have become available, including: partial upper sternotomy, mini-sternotomy, and right anterior mini-thoracotomy. During surgery, two types of valves can be implanted: mechanical or biological. Each is preferred by different groups of patients and carries different consequences. Therefore, when qualifying for the procedure, it is crucial to consider the patient's preferences, as well as a thorough analysis of the clinical situation by a team of experts.

Conclusions: The transaxillary approach is a more invasive method than TAVI, but less invasive than the sternotomy approach. This allows for shorter recovery times after the procedure, with more thorough cleaning and valve adjustment than with TAVI. At the same time, this method requires greater operator dexterity, as access is limited compared to traditional incisions, both in terms of space for instruments and visibility.

KEYWORDS

Cardiac Surgery, Aortic Valve, Valve Replacement, Transaxillary Approach, Heart, TAVI, Sternotomy

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1. Introduction

The aortic valve is an arterial valve whose primary purpose is to prevent backflow of blood from the aorta into the left ventricle. Its function allows the heart to function properly, ensuring unilateral blood flow. This valve consists of three semilunar leaflets: posterior, right, and left. During left ventricular systole, the aortic valve leaflets part toward the aorta, and then blood flows from the left ventricle into the aorta. After blood escapes, the heart relaxes. At the same time, blood remaining in the aorta, attempting to flow back toward the heart, fills the semilunar leaflets, closing them and preventing backflow into the left ventricle. Proper aortic valve function maintains the heart in good condition. However, as the aortic valve's efficiency declines, the left ventricle becomes increasingly overloaded. This carries numerous health implications, such as heart failure, arrhythmias, and hypertension.

2. Aortic Valve Disease

Aortic Valve Stenosis Aortic valve stenosis can have various causes, the most common of which include thickening of the leaflets, loss of elasticity, calcium deposition, and adhesions within the commissures. Aortic valve stenosis resembles an atherosclerotic process, which, with progression, reduces the aortic valve area, resulting in increased resistance to blood outflow from the heart. The degenerative process includes endothelial damage, inflammatory infiltration, fibroblast activation, and mineralization and calcification of the aortic valve. As a result of degenerative changes, resistance to blood flow increases, resulting in increased systolic pressure in the left ventricle and an increased pressure gradient between the left ventricle and the aorta. This has consequences for the heart's adaptation as the disease progresses. This can lead to enlargement of the heart and thickening of its wall. In the long term, diastolic relaxation is impaired, the ventricle stiffens, and end-diastolic pressure increases. Diastolic dysfunction of the heart muscle can cause cardiac fibrosis and reduced ejection fraction. Furthermore, aortic stenosis can reduce myocardial blood flow in the long term, even despite significant coronary artery stenosis. Patients with aortic stenosis may experience shortness of breath, chest pain, and syncope on exertion. This is due to the body's circulatory failure, especially during times of increased oxygen demand. As the degree of valve stenosis increases, the disease progresses and the body's ability to adapt to various conditions during physical exertion decreases.

3. Surgical Treatment Methods

There are three basic surgical methods for aortic valve replacement: open surgery, keyhole surgery, and TAVI. Two types of valves are used during the procedure: mechanical and biological. The mechanical valve is more durable and therefore usually requires no reoperation, but it requires the patient to take medications for the rest of their life. A biological valve, on the other hand, usually made from animal tissue, allows the patient to live without medications, but its drawback is its shorter lifespan and gradual degradation. The effectiveness and durability of such a valve is approximately 15 years.

SAVR

This method is performed under general anesthesia, required because the patient is placed on extracorporeal circulation during the procedure and undergoes an extensive incision. After inserting the necessary surgical catheters and patient monitoring systems, the patient is placed under general anesthesia, and the surgeon performs a sternotomy. This is the fundamental difference that distinguishes this method from other methods. This allows unimpeded access to the heart. After widening the sternum, the surgeon has a relatively large operating field, allowing for precise execution of subsequent stages of the procedure. After incising the pericardial sac, the heart is exposed. The next steps involve preparing the heart to be placed on extracorporeal circulation. This is essential to opening the heart without causing hypoxia to other organs after the heart is immobilized. After activating the heart-lung machine and stopping the heart with cardioplegia, the surgeon opens the aorta, thoroughly cleans, and removes the diseased valve. This is crucial, as it determines the integrity and durability of the valve that will later be implanted. Both mechanical and biological valves are available for this method. In this part of the procedure, the cardiac surgeon places and secures the artificial valve. After the aorta is tightly closed, the heart is slowly restarted and the integrity of the closure is checked. If no undesirable bleeding occurs, the cardiopulmonary bypass is discontinued, the surgeon closes the pericardial sac, and the incision is closed. The sternum is sutured using metal wires, which remain in the patient for the rest of their life; they are not removed. Due to the extensive incision, recovery is relatively long. Full recovery can take up to several months, while the hospital stay following the procedure lasts approximately 7-10 days. This is a highly invasive and taxing procedure, which is why some patients cannot be considered for this procedure and must be managed with less invasive methods.

MIAVR

With this procedure, the patient is placed under general anesthesia, similar to a classic sternotomy. Additionally, a special endotracheal tube is inserted, which allows for separate ventilation of the right and left lungs, thus increasing the surgical space. The incision can be performed using a mini-sternotomy or a mini-thoracotomy. A mini-thoracotomy involves making an incision approximately 5 cm between the ribs on the right side of the chest, under the armpit. After making the incision and spreading the ribs with a special instrument, access to the center of the chest is gained. A cardiopulmonary bypass is then initiated, allowing for temporary cardiac arrest using cardioplegia. Using special instruments, often using magnifying glasses, the cardiac surgeon carefully removes the aortic valve and then cleans the area. After this step, a mechanical or biological valve is implanted. To facilitate attachment from such a small access point, sutureless or self-expanding valves are typically used. Once the valve is properly positioned, the heart is restarted and the cardiopulmonary bypass is discontinued. The intercostal incision is sutured. This method eliminates the need for metal wires, as the incision is less invasive to the ribs and sternum than a traditional sternotomy. Patients currently considered for this method primarily include those with isolated severe aortic stenosis and those who do not require concomitant cardiac surgery procedures such as CABG.

TAVI

This method can be performed under both general anesthesia and local anesthesia with sedation. This allows it to be performed on patients who would not be considered suitable for general anesthesia by anesthesiologists. Therefore, it is recommended for patients with significant chronic illnesses. During the procedure, access to the valve is achieved through a vascular access. The most convenient access for the operator is the femoral artery, but in cases of significant atherosclerotic lesions, the procedure can be performed through the subclavian artery. The access site should be locally anesthetized, followed by a skin incision and arterial access. After inserting the guidewire into the artery, the valve is fitted into place under X-ray guidance. In this method, the site of the original valve is not thoroughly cleaned; a new prosthesis is implanted in place of the old one. Once the valve is properly positioned, it expands. Pressure expands the original valve to its maximum capacity, allowing the new valve to function at its best. The physician then checks the valve for leaks and blood flow, particularly for proper positioning and adjustment. After these checks, the guidewires are removed, the vascular catheter is removed, and the artery is sutured. The culmination of this method is the moment of valve expansion, as it temporarily stops blood flow through the body, potentially causing sudden cardiac arrest. This procedure is significantly shorter than the traditional aortic valve replacement method and is less invasive. Short-term studies in increasingly younger patients show that TAVI does not cause any major complications compared to the traditional method over a 5-year follow-up (Desaj & Goel & Kleiman & Reardon, 2023). However, it should be emphasized that most defects and the need for reoperation become apparent after this time, especially after 15 years of valve placement. Further studies will be necessary in the future on a larger group of young patients undergoing this procedure to accurately assess the effectiveness of the intervention and long-term prospects.

4. Overview of Complications in Specific Methods

SAVR

The most important complication that may occur with this method is mortality, although it should be noted that this has been significantly reduced with medical progress. In 1990, it was 6.2%, while thanks to the development of postoperative care, refinement of the procedure, and improvement of surgical conditions, in 2010 it was 4.2% (Langanay & Rouze & Tomasi, 2018). In another study by Dell'Amore et al., mortality was 4.3% in patients with an average age of 82 years (Smith et al., 2011). A significant complication may be the occurrence of stroke; the incidence of this complication in the open method is 1.6% within the first year (Holzhey et al., 2016). In another study, the incidence of this complication was as high as 6.6% within the first 7 days, conducted on a group of 383 patients (Messe et al., 2022). The most common reported events were hemiplegic stroke or loss of consciousness, while approximately 70% of neurological symptoms resolved within the first weeks and months after surgery (Jensen et al., 2024). In the same study, among patients who experienced a stroke, the mortality rate within 30 days of the procedure was 7.7%. The frequency of complications correlates with patient age; the older the patient, the more frequent the complications. A similar relationship was observed in patients who were classified as high-risk before the procedure (Agarwal et al., 2015). Analyzing age-matched groups of patients, the incidence of neurological complications in patients under 70 years of age was 1.3%, increasing to 3.2% in patients over 85 years of age (Agarwal et al., 2015). An unusual complication identified in the study was postoperative delirium, which was noted in 28.5% of patients.

Furthermore, depression was noted in 5.3% of patients within 90 days (Messe et al., 2022). A preoperative and postoperative assessment using the Mini-Mental State Examination (MMSE) demonstrated that cognitive impairment, initially present in 3.2% of patients, increased to 8.8% (Auensen et al., 2017). These results demonstrate the significant burden of surgery on individuals and its potential neurological consequences. At the same time, it has been shown that patients who do not undergo surgery are associated with more frequent and more serious complications than those who do undergo surgery (Auensen et al., 2017). Acute kidney injury is a serious problem after SAVR, which can occur in 30.7% of patients. This includes patients whose glomerular filtration rate (eGFR) decreased by at least 25% (Deblier & Dossche & Vanermen & Mistiaen, 2025). The occurrence of AKI is associated with a longer hospital stay compared to patients without renal problems. Postoperative AKI also affects long-term survival, shortening it. The need for renal replacement therapy, in particular, negatively impacts patient prognosis, impacting both the length of hospital stay and survival. A study analyzing nephrological problems in 462 patients who underwent SAVR showed AKI in 16.5%, and 23 patients died, most of whom required renal replacement therapy (Lacquanti et al., 2024). Postoperative cardiac arrhythmias may occur in patients undergoing surgical aortic valve replacement; a retrospective study showed that 44.5% of patients developed postoperative atrial fibrillation (Rezk et al., 2023). Postoperative atrial fibrillation increases the long-term risk of death by 1.21 (Rezk et al., 2023). Postoperative atrial fibrillation also increases the risk of stroke. Postoperative cardiac monitoring and early detection of arrhythmias are important. Heart failure may develop early after surgery, which may result from left ventricular dysfunction or insufficient adaptation of the heart to new hemodynamic conditions. An additional factor increasing this risk is complications related to the mismatch of the prosthesis to the patient. However, this factor has been significantly reduced with the development of diagnostic and imaging methods. In the case of patients who received bioprostheses, some required reintervention. Reintervention, however, is associated with a significantly higher risk of death than the initial intervention. The risk of death ratio was 2.53 compared to those who did not require such intervention (Shi et al., 2023). The need for reoperation, which is also associated with a higher risk of death, occurs particularly in younger patients, due to the fact that they are more likely to live to the point where the valve degrades and requires replacement, compared to those who die earlier from other causes. However, another study noted a significant decrease in complications after reoperation, concluding that mortality is currently similar to that of patients who underwent initial surgery. A possible complication after surgical valve replacement is Prosthetic valve endocarditis (PVE), which affects 1.6% of patients (Habib et al., 2009). This is a serious complication because it significantly affects mortality. In patients who experienced this complication, the mortality rate was 21% (Wang et al., 2007). Osteomediastinitis of the sternum is also possible, occurring in 1-3% of patients. Mortality can be as high as 29% (Berdajs et al., 2011). This inflammation is detected by computed tomography, which shows bone destruction and tissue separation. In the first few days after surgery, it is difficult to distinguish between abscess formation and hematoma accumulation; therefore, it is important to monitor the area. If changes persist for more than two weeks and fluid continues to accumulate, inflammation should be suspected.

MIAVR

Minimally invasive aortic valve replacement is characterized by a similar incidence of serious complications such as stroke and arrhythmia (Nelly et al., 2015). An analysis of 1,691 patients showed that the duration of aortic clamping, the incidence of atrial fibrillation, and the length of stay in the intensive care unit did not differ significantly from that of full sternotomy (Sajid et al., 2025). The mortality rate for this procedure is approximately 3%. Analysis of patients showed that stroke occurred in 4% of the operated patients (Elbardissi & Shekar & Couper & Cohn, 2010). Long-term survival beyond 5 years is also similar to that observed with the open method (Gilmanov et al., 2015). Analysis of data with a median follow-up of 29.1 months showed survival rates at 1 and 5 years of 96% and 80%, respectively. New cardiac arrhythmias, such as atrial fibrillation, occurring after surgery were noted in 243 of the 853 patients (Gilmanov et al., 2014). A serious complication of the keyhole procedure is the need to convert the operation to a full sternotomy in some cases. The incidence of this complication is as high as 14% (Foghsgaard & Schmidt & Kjaergard, 2009), primarily due to technical difficulties encountered during the procedure. Another study describes the need to convert the operation to a full sternotomy in 0.8-8% of cases (Laduena & Rastan, 2014). Converting this procedure carries significant complications, primarily due to a significant increase in operative time, which impacts the level of trauma to the body, but also the overall larger area of incision. Therefore, careful selection of patients undergoing this procedure is necessary to minimize this risk. In minimally invasive techniques, late bleeding can be a complication; it occurs more frequently than in classic sternotomy. For this reason, reoperation may be required. When distinguishing between a minithoracotomy and a right anterior minithoracotomy, bleeding is more common in minithoracotomy, as well as the longer operative time (Starvidis et al., 2924). A study of 194 patients demonstrated the need for reoperation due to bleeding in 3.6% of patients (Stoliński et al. 2016). The minimally invasive approach, due to the limited surgical field, also affects the duration of cardiopulmonary bypass. This time is statistically significant and longer than that required for full sternotomy (Kowalówka et al., 2025). The median cardiopulmonary bypass time and aortic clamping time are 108 minutes and 75 minutes, respectively (Gilmanov et al. 2015). This method can cause AKI; of the 334 patients undergoing surgery, this complication was observed in 12% Squiccimarro at el., 2024). Most of these (39 of 40 patients who developed AKI) were complications following partial sternotomy, and only one patient underwent right mini-thoracotomy.

TAVI

TAVI can cause atrioventricular (AV) block, which requires pacemaker implantation; this complication occurs on average in 10-50% of patients (Schroeter et al., 2012). The incidence of this complication also depends on the type of valve used. 44.4% of patients using the CoreValve System required pacemaker implantation, and 7.1% with the Edwards Sapiens System (Erkapic et al., 2010). In a study analyzing 5,258 patients, the incidence of permanent pacemaker implantation was 15%, and attention was paid to the timing of this need. Follow-up during the first 7 days after the procedure is most important, as this is when AV block becomes apparent (Erkapic et al., 2012). At the same time, in approximately half of patients who developed AV block immediately after the procedure, it may resolve within 7 days (Roten et al., 2012). A pacemaker was implanted in 67% of patients who had RBBB before the procedure, a factor significantly increasing this risk (Koos et al., 2011). The incidence of AV block after TAVI is higher than after the open method using a classic sternotomy (Roten et al., 2012). Stroke is a serious complication after TAVI, and it occurs more frequently than after the traditional method. In the first 30 days after the procedure, 3.8% of patients experienced stroke (Smith et al., 2011). A similar incidence of this complication, 3.6%, was observed in a 2009 study Eltchaninoff et al., 2011). Stroke significantly impacted post-procedure mortality. In the first 30 days after TAVI, in the group of patients who experienced stroke, the mortality rate was 38.4%, compared to 4.6% in patients without stroke (Storecky et al., 2012). The occurrence of this complication may be related to the specific group of patients qualified for the procedure, as patients often have extensive atherosclerotic lesions, and embolic material is detached during the procedure. However, this risk can be reduced approximately fourfold by conservative stroke treatment, by implanting a protective device that captures material that could potentially reach the brain (Naber et al., 2012). Vascular complications may also occur after TAVI, with a frequency of up to 20% (Hayashida et al., 2012). With technological advancements, the frequency of these complications is decreasing, primarily due to the reduction in the diameter of the catheters inserted for the procedure. Stortecky and co-authors demonstrated a similar rate of vascular complications in their study, approximately 18%, while these complications had no long-term impact on the patency and blood flow in the artery that served as vascular access (Stortecky et al., 2012). A hemorrhagic complication highlighted in TAVI-related articles is the need for blood transfusion in some patients, which may result in increased mortality and other complications, such as kidney damage (Tchetche et al., 2012). Acute kidney injury is a common complication of TAVI. Depending on the studies, it ranges from 12.5% (Thomas et al. 2011) to 35.9% (Khawaja et al., 2012). Additionally, the occurrence of AKI significantly increased mortality, from 3.8% to 13.5% (Khawaja et al., 2012). The highest mortality occurred in the group of patients who developed stage 3 AKI (Saia et al., 2012). The widespread use of TAVI in an increasing number of patients allowed for studies on larger groups of patients and longer follow-up. Analysis of patients who required TAVI-in-TAVI surgery for various reasons showed a mortality rate of 3.7% during hospitalization, 3.9% within 30 days of the procedure, and as much as 12.5% within the first year (Ktenopoulos et al., 2024). While the first TAVI procedure does not result in higher mortality, the need for a second procedure is characterized by a significantly higher mortality rate than the full sternotomy procedure.

5. Discussion

Each of the presented methods is dedicated to a different group of patients. Currently, TAVI works best in the oldest group of patients because it is the least invasive, facilitating recovery and carrying the least intraoperative burden on the patient. It involves the least amount of intervention in the patient's body. Minimizing skin incisions and their extensiveness ensures less trauma to the body. However, it should be remembered that this method does not allow for precise cleaning of the site where the valve will be placed, which will significantly affect its size and capacity. The size of the secondary valve will be smaller than the primary valve. In patients who may require secondary valve implantation, a full sternotomy is a better option during the initial procedure, while the second valve can be placed using the TAVI method (Curio et al., 2025). This should be considered primarily in patients with a longer survival rate. Patients potentially eligible for repeat surgery in the future are younger, with a survival prognosis of over 15 years. TAVI-in-TAVI surgery is characterized by a higher mortality rate and lower effectiveness. Classic sternotomy is intended for patients with significantly fewer other ailments. The procedure requires extracorporeal circulation and the extensive nature of the procedure is highly traumatic. Therefore, a significant number of patients may be excluded from this procedure. It also provides the surgeon with the best visibility and access to clean the site where the valve will be implanted. Minimally invasive sternotomy is a middle ground between the methods described above. It can be used in a wider range of patients. This method also allows for a relatively short stay in both the intensive care unit and the general hospital setting, with these times being 1.3 days and 5.7 days, respectively (Stoliński et al., 2016) Using this method allows professionally active individuals to return to work sooner than patients after a full sternotomy, significantly shortening recovery time. MIAVR minimizes the risk of sternal instability in the long term. Long-term follow-up shows that the most lasting results are achieved with the classic sternotomy method. The valve will function properly for the longest time, and the patient will remain in good health. However, it should be remembered that the patient's estimated life expectancy should also be taken into account when choosing a method. For elderly patients, this factor may not be the dominant factor. The length of time the valve will function properly may be less important than the patient's burden from the surgery itself. Analyzing various studies, it can be seen that mini-sternotomy is characterized by a lower incidence of stroke, while TAVI provides better protection against acute kidney injury. Studies show that the incidence of complications decreases with both open and TAVI methods, although a more significant decrease was observed with the transcatheter method. The rate of serious complications decreased with TAVI from 41% to 19%, compared to a decrease with SAVR from 51% to 47% (Harvey et al., 2024). This decrease was noted in both absolute and relative terms. A review of articles indicated the advantage of TAVI over the surgical method in terms of postoperative quality of life, with patients undergoing the transcatheter method declaring greater improvement in this parameter (Cordeiro & Goncalves & Santana & Santos, 2021).

6. Conclusion

Minimal access aortic valve replacement may become the leading method in the future, combining the advantages of the open method and TAVI. Patient recovery will be significantly faster than with a full sternotomy, and the valve will be more precisely attached than with TAVI. Direct surgical intervention at the aortic valve site will allow for precise removal of the remaining valve to create space for the implant. However, this method will be limited to highly specialized centers with modern equipment, which may limit patient access. MIAVR presents challenges with a learning curve and the procedure itself, with only a small number of centers performing it. However, the greatest limitation will be technical difficulties. Therefore, patients from specific groups should be selected for minimally invasive surgery to avoid the need to convert the procedure to a full sternotomy. Improved methods and instruments that allow for better imaging of the surgical field and shorten the procedure through advances in suturing and valve fixation techniques. However, it should not be used when patients require additional cardiac surgical interventions.

Author's Contribution
Mateusz Taranowicz: Conceptualization, writing, rough preparation, investigation
Olga Kowalczyk: Conceptualization, supervision
Dominika Zdobylak: Formal analysis, supervision
Monika Kowalska: Visualization, data curation
Anita Zięba: Conceptualization, data curation
Michał Domin: Methodology, project administration
Justyna Całka: Conceptualization, methodology, supervision
Katarzyna Ścibisz: Resources, writing rough preparation
Karolina Ollik: project administration, data curation
Kamil Harenza: methodology, supervision

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