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Review

Sutureless and Trans-catheter Valve Use in Aortic Valve Endocarditis: A Review

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Abstract

New approaches have been developed to treat aortic valve disease, including sutureless and trans-catheter aortic valve replacement (TAVR). Few groups have reported their experience using sutureless and trans-catheter valves for aortic valve endocarditis. We aim to review the current available data on the application of these two approaches in managing aortic valve endocarditis. A literature search was conducted on PubMed, EBSCOhost, and Google scholar databases using the following search terms: "Perceval endocarditis"; "sutureless valve endocarditis"; "Intuity valve endocarditis"; "TAVR endocarditis"; "percutaneous aortic valve endocarditis"; "Trans-catheter valve endocarditis". After filtering, we found 26 articles appropriate for our review including 20 articles about sutureless valves for endocarditis (16 Perceval, 4 Intuity), and 6 articles on trans-catheter aortic valve implantation for endocarditis. The observed early mortality rate of sutureless valve implantation in aortic valve endocarditis ranged between 14–23%, while early mortality rates in a recent national sample of the standard surgical approach were between 8–10%. Additionally, there was an observed increased incidence of peri-valvular aortic regurgitation after sutureless valve implantation for endocarditis. We observed an increased risk of stroke for trans-catheter implantation in aortic valve endocarditis with large vegetations. The current evidence suggests caution for the implantation of trans-catheter and sutureless valves in patients with aortic valve endocarditis. High risk patients for the standard surgical approach or complex endocarditis cases should be evaluated through a multidisciplinary endocarditis team at specialized centers.

Keywords

aortic valve; endocarditis; sutureless valve; trans-catheter valve

Introduction

Infective endocarditis (IE) is an infection of the endocardium that affects native valves and intracardiac devices such as pacemaker leads, prosthetic valves, and ventricular assist devices. Its incidence is rising, affecting at least 3–10/100,000 adults per year. In the United States, 40,000–50,000 new cases are diagnosed every year. The average cost per patient is around $120,000, with no improvement in survival rates over the last 2 decades [1]. Although rheumatic fever is nowadays rare in developed countries, there are emergent risk factors for IE, such as the presence of intra-cardiovascular devices and degenerative valvular disease, which resulted in an increased risk of developing IE in elderly patients [2]. In addition, IE incidence is increasing in young patients with a history of intravenous drug abuse [3].

Staphylococcus, Streptococcus and Enterococci are responsible for 80% of IE cases. These organisms are known for high virulence capabilities, including biofilm formation, toxins, and production of proteolytic enzymes [4]. These unique properties enable these bacteria to evade the host immune response and develop resistance to antibiotics as well as invasion and disintegration of the surrounding tissues. Aortic valve IE can present with an invasive pathology that affects the aortic anulus and root, which may require complex surgical reconstruction [5].

Invasive Aortic Valve Endocarditis

Invasive Aortic Valve Endocarditis (iAVE) is the extension of the infection from the aortic valve leaflets into the valve annulus or beyond, causing abscess or fistula formation (Fig. 1). As described by Pettersson *et al*. [5], invasive disease develops in stages: cellulitis, abscess, abscess cavity, pseudoaneurysm. Internal fistulas, perforations, heart block constitute specific consequences of invasion [5].

Infection begins in a pre-existing endothelial damage site, where sterile aggregates are colonized by bacteria that

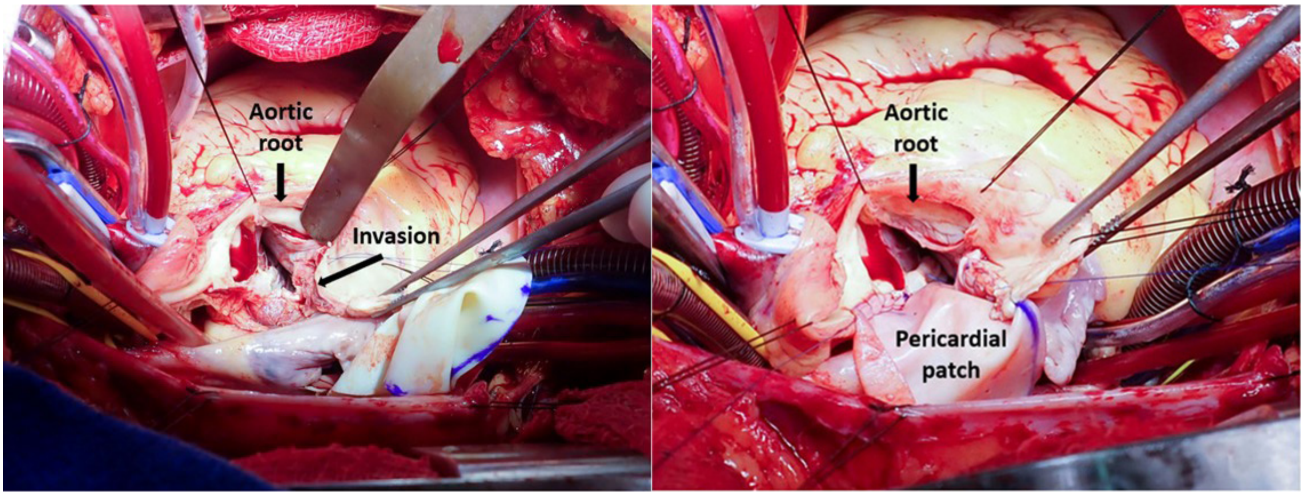

Fig. 1. Native aortic valve endocarditis. Left: Invasive pathology of the non-coronary sinus. Right: Reconstruction with a pericardial patch after debridement.

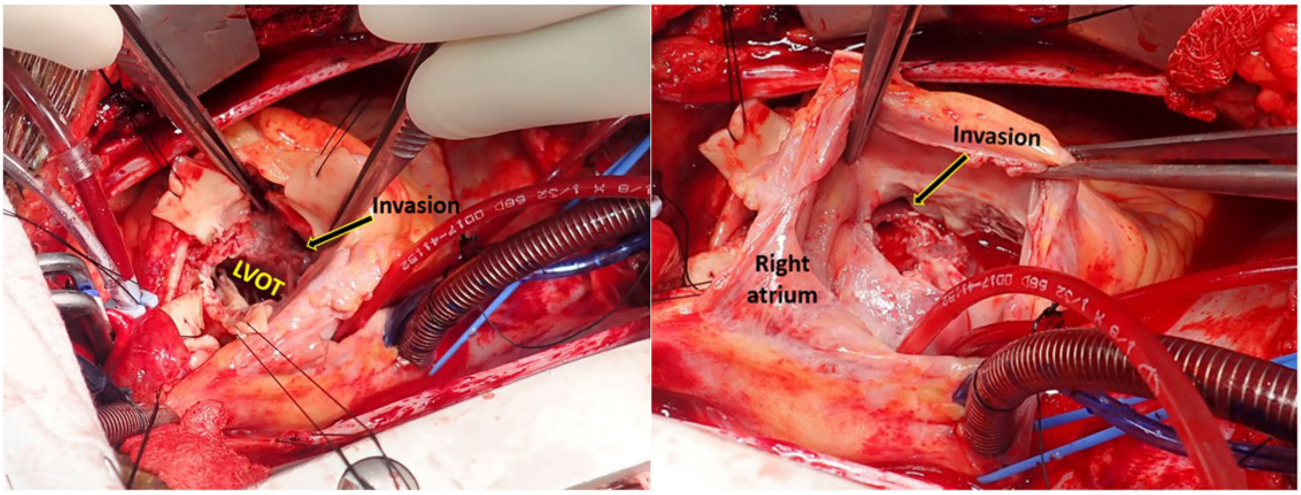

Fig. 2. Prosthetic aortic valve endocarditis. Left: Tissue disintegration underneath the explanted prosthetic aortic valve. Right: Invasion of aortic root abscess into the right atrium across the membranous septum. LVOT, left ventricular outflow tract.

can grow as a biofilm within the cardiac vegetations [6–8]. In cases of prosthetic valve endocarditis (PVE), bacteria can colonize both leaflets and sewing ring, then invade the surrounding tissues (Fig. 2). PVE is commonly associated with a more aggressive pathology [8,9]. The extent of pathology is related to several factors, including the virulence of the causative organism, the duration of infection, and the presence of intra-cardiac devices [10]. Modified Duke criteria are the clinical parameters widely used to diagnose IE. Their sensitivity could be reduced in the presence of prosthetic valves that require advanced imaging tools [11–13]. Echocardiography, both transthoracic (TTE) and transesophageal (TEE), is the initial imaging tool to diagnose IE [14]. However, in cases of iAVE, a cardiac CT scan can be helpful in the diagnosis of aortic root pathology [15]. Antibiotic therapy remains the first-line treatment for IE, which may alter (false-negatively) the result of intra-operative specimen cultures [16].

Standard surgical management of IE consists of aggressive debridement of all infected tissues and removal of previous implants and materials [17]. At least 50% of surgical procedures for aortic IE are associated with invasive pathology, which requires complex high-risk procedures [18]. Root abscess formation in PVE reaches up to 42% in different reports [19]. In the American Association for Thoracic Surgery (AATS) guidelines, replacement/reconstruction of the aortic root with an allograft or a biological tissue root is preferable to a prosthetic valved conduit for cases of invasive PVE [20]. Allograft may have a theoretical advantage against early recurrent infection, being a biological conduit with no sewing ring [18,21]. More importantly, the allograft en-bloc includes the donor left ventricular muscle and the anterior mitral leaflet, which allows for reconstruction of the aortic root in cases of circumferential abscess.

There has been continuous improvement of surgery outcomes for IE at specialized centers [22]. This success is multi-factorial, related to institution and surgeon experience, aggressive debridement, improved myocardial protection, and, in our experience, the utilization of aortic allografts. In a study published in 2012 by our group, the operative mortality for 428 patients who underwent surgery for valve endocarditis during the period 2003–2007 was 10%, higher for PVE (13%) than native valve IE (5.6%) [23]. Long-term survival was not significantly different between prosthetic and native aortic valve endocarditis (35% versus 29%). *Staphylococcus aureus* endocarditis had a higher mortality compared to other organisms [24]. In a subsequent cohort of 775 patients who underwent surgery for left-sided endocarditis during the period 2002–2011, our group analyzed the outcomes of surgery for iAVE. PVE had a higher incidence of invasive pathology compared to native valve endocarditis. The 30-day survival was 92%, which was similar for native and prosthetic valve endocarditis. Invasive pathology had higher hospital mortality rates versus non-invasive (11% versus 4%) [24]. In a recent study of The Society of Thoracic Surgeons (STS) Database, the incidence of PVE has increased during the study period (2011–2019) but operative mortality had decreased (PVE: 22.5% to 10.4%, $p < 0.001$; native valves: 10.9% to 8.5%, $p < 0.001$) [25].

Given the complexity of standard surgery for IE, there has been a recent utilization of sutureless and trans-catheter valves to treat aortic valve endocarditis. The rationale of this review is to examine the current available data regarding the use of sutureless valves (Perceval, Corcym, London, UK; Intuity, Edwards Lifesciences, Irvine, CA, USA) and trans-catheter aortic valve implantation (TAVI) in patients with active IE.

Material and Methods

Study Design and Search Strategy

We performed a literature search using three databases: PubMed, EBSCOhost, Google scholar. We have chosen articles published between January 2013 and December 2023. The following keywords have been used for the detailed research: “Perceval endocarditis”; “sutureless valve endocarditis”; “Intuity valve endocarditis”; “trans-catheter aortic valve replacement (TAVR) endocarditis”; “percutaneous aortic valve endocarditis”; “Transcatheter valve endocarditis”. Only full articles available in the English language were considered for this review. The search was conducted between January 2024 and April 2024. The review was conducted without any funding support.

Selection Criteria

To be a potentially selected study, inclusion criteria had to be met as follows: a study reporting the use of Perceval, Intuity sutureless valves, or TAVI implantation in patients with active aortic valve IE; the study had to be a case report, a case series, or a cohort study. Exclusion criteria were letters to editors, comments on other studies, and published videos. Studies were analyzed by three reviewers (HE, HS, SP) first by reading titles and abstracts. Selected articles were then fully read to check their eligibility; their references were revised for potential new studies to add. We did not exclude any article based on quality.

Data Collection and Analysis

Data collection was conducted by two reviewers independently (HS, SP). Outcomes were post-procedure survival, recurrence of aortic IE, echocardiographic findings (aortic stenosis, aortic regurgitation (AR), paravalvular leak, prosthesis dehiscence, aortic root abscess or fistula), incidence of re-operation, major complications (stroke, acute kidney failure), and length of follow-up. The final analysis of the collected data and outcomes was supervised by the principal investigator (HE).

Results

Our research identified 273 potentially relevant articles. After excluding duplicates, letters to editors, comments, non-English articles, and after reviewing the abstracts of the original studies, we identified 171 studies potentially suitable papers to include in this review article. After reviewing the full reports, 26 articles met the criteria for this review, including 16 studies of Perceval valve use in IE, 4 studies of Intuity valve use in IE, and 6 studies of TAVI in IE.

Sutureless Surgical Valves for Aortic IE

The Perceval sutureless valve is designed for implantation in the native aortic annulus after debridement of calcification and is not indicated for use in IE per the manufacturer’s instructions [26]. However, it has been used off-label to treat 97 cases of IE presented in 16 publications (Table 1, [27–46]). Nguyen *et al*. [40] reported three cases of PVE that were treated with a Perceval prosthesis implantation inside a previous aortic root prosthesis: one FreeStyle (Medtronic, Minneapolis, MN, USA) and two bioprosthetic valved conduits. During the surgery, the leaflets were excised and the Perceval valve was implanted inside the previous prosthesis frame. The patient had preoperative positive blood cultures. At 1 year follow-up, there was no recurrent IE nor reoperation. Echocardiography showed mild paravalvular leak and trace aortic regurgitation (AR) in one

Table 1. Case reports and series of sutureless valves for IE.

Study	No. of patients	Type of IE	Causative organism(s)	Valve type	Follow-up	Outcome
Lio *et al.* 2015 [27]	5	PVE	—	Perceval L 4 Perceval M 1	1 mo.	1 hospital death No IE recurrence
Konertz *et al.* 2016 [28]	1	PVE	Streptococcus gallolyticus	Perceval L	6 mo.	No IE recurrence
Weymann *et al.* 2017 [29]	9	Native 4 PVE 5	Streptococci Enterococci Staphylococci species (3 S. aureus)	Perceval L 7 Perceval XL 2	7 mo.	100% survival at 30 days 1 patient died during follow-up
Roselló-Díez *et al.* 2018 [30]	9	PVE	2 Enterococcus faecalis 2 Staphylococcus epidermidis 3 Streptococcus 1 Candida albicans	Perceval S 2 Perceval M 1 Perceval L 5 Perceval XL 1	6 mo.	2 patients died in perioperative period No IE recurrence 2 mild AR
Ruchonnet *et al.* 2019 [31]	1	PVE	Staphylococcus aureus	Perceval L	1 year	Heart block required pacemaker No IE recurrence
Cummings *et al.* 2019 [32]	8	PVE	—	Perceval S 3 Perceval M 5	Not specified	1 hospital death 1 required pacemaker
Hammond *et al.* 2020 [33]	1	PVE	Streptococcus constellatus	Perceval S	44 mo.	No complications
Goto *et al.* 2021 [34]	1	PVE	MSSA	Perceval S	6 mo.	No IE recurrence
Karangelis *et al.* 2021 [35]	1	PVE	Staphylococcus aureus	Perceval L	2 years	Mild-to-moderate aortic stenosis
Piperata *et al.* 2021 [36]	1	PVE	Enterococcus faecalis	Perceval XL	7 years	No IE recurrence
Zubarevich *et al.* 2022 [37]	13	Native 5 PVE 8	4 Staphylococcus aureus 3 Enterococcus faecalis	Perceval S 3 Perceval M 6 Perceval XL 4	1 year	3 deaths at 30 days 6 deaths at 6 mo.
Smith *et al.* 2022 [38]	1	PVE	Propionibacterium acnes	—	3 mo.	No IE recurrence
Bociański *et al.* 2022 [39]	7	Native 4 PVE 1 1 thrombus of mechanical valve 1 diffuse aortitis	—	Perceval S 1 Perceval M 1 Perceval L 2 Perceval XL 3	40 mo.	2 in-hospital mortality No IE recurrence
Nguyen *et al.* 2022 [40]	3	PVE	Streptococcus mutans Enterococcus Streptococcus sanguinis	—-	1 year	No IE recurrence 1 mild AR
Mosquera *et al.* 2023 [41]	36	Native 25 PVE 11	Streptococci 12 Staphylococci 11 Enterococci 8 Mycoplasma pneumoniae Propionibacterium acnes Tropherima whipplei Candida albicans	Perceval S 2 Perceval M 9 Perceval L 15 Perceval XL 10	5 years	No IE recurrence

Table 1. Continued.

Study	No. of patients	Type of IE	Causative organism(s)	Valve type	Follow-up	Outcome
Cabrucci *et al.* 2023 [42]	1	PVE	Staphylococcus aureus	Perceval S	15 mo.	No complications
Piperata *et al.* 2020 [43]	8	Native 1 PVE 7	—	Intuity Elite	2.7 years	1 in-hospital death 1 leak 2+ 2 Pacemaker implants No IE recurrence
Öner *et al.* 2022 [44]	7	Native 4 PVE 2 post-Ross 1	S. epidermidis 2 S. salivarius 1 E. faecalis 1 A. aphrophilus 1 R. dentocariosa 1	Intuity	29 mo.	1 in-hospital death 1 pacemaker implant 1 acute kidney failure No IE recurrence
Belyaev *et al.* 2022 [45]	25	Native 9 PVE 16	Staphylococci 8 Streptococci 5 Enterococci 3 E. coli 1 C. acnes 3 T. whipplei 1	Intuity	11 mo.	1 death at day 24 No IE recurrence
Benke *et al.* 2024 [46]	8	Native 8	S. aureus 1 S. epidermidis 1 S. salivarius 1 S. bovis 1 E. coli 1	Intuity	—	2 pacemaker implants 2 acute kidney failure No IE recurrence

PVE, Prosthetic Valve Endocarditis; IE, Infective Endocarditis; AR, Aortic Regurgitation.

Table 2. Case reports of trans-catheter aortic valve replacement for IE.

Study	No. of patients	Type of IE	Causative organism	Valve type	Follow-up	Outcome
Albu *et al.* 2013 [47]	1	PVE	Staphylococcus aureus	CoreValve 1	6 mo.	No IE recurrence
Nguyen *et al.* 2015 [48]	1	PVE	Staphylococcus sanguinis	CoreValve 1	12 mo.	Early stroke
Naqvi *et al.* 2018 [49]	1	PVE	Corynebacterium	Edwards Sapien 1	12 mo.	Normal functioning prosthetic valve
Fathi *et al.* 2020 [50]	1	PVE	Staphylococcus sanguinis	Edwards Sapien 1	18 mo.	No IE recurrence
Brankovic *et al.* 2022 [51]	1	PVE	Diphtheroids, Enterococcus faecalis	Edwards Sapien 1	6 mo.	No leak No IE recurrence
Shen *et al.* 2022 [52]	1	Native	Staphylococcus epidermidis	Edwards Sapien 2	6 mo.	No leak No IE recurrence

patient, trace AR in the second patient, while follow-up echocardiography was not completed in the third patient [40].

Mosquera *et al*. [41] reported midterm outcomes of Perceval implantation in 36 cases of aortic valve IE; 11 were PVE. There was perivalvular invasive pathology in 60% of cases including 5 cases with aortic root pseudoaneurysm, 17 cases with aortic root abscess, and 3 patients with aortic root fistula. Aggressive debridement of the infection was followed by reconstruction with pericardial patch before deploying the Perceval valve. The 30-day mortality was 14%. Postoperative echocardiograms showed 3 cases with residual AR >1+. At 1-year follow-up, echocardiography showed 2 cases with residual AR >1+. Survival at 1-year and 5-year was 72% and 61%, respectively. There was no recurrent IE reported during follow-up [41].

Roselló-Díez *et al*. [30] reported the use of a Perceval valve in 9 patients with PVE. Surgery included removal of the previous prosthetic valves followed by debridement of abscess cavities. Tissue defects were closed with interrupted pledget sutures or a pericardial patch. In-hospital mortality was 22%. At 6 months follow-up, one patient had mild intra-valvular regurgitation, and one patient had mild peri-valvular regurgitation [30]. Zubarevich *et al*. [37] implanted Perceval in 13 IE patients, including 8 patients with PVE. The 30-day mortality was 23%, as one patient died intra-operatively due to severe sepsis and two patients died secondary to pulmonary hemorrhage. The mortality was 46% at 6 months. No echocardiographic follow-up data were presented [37]. Another study reported 7 patients who underwent Perceval implantation with unexpected operative findings, including active endocarditis in 4 patients (one case of PVE). Two patients suffered death secondary to multi-system organ failure [39].

The use of Intuity rapid-deployment valve in IE has been reported by a few groups as well [43–46]. Piperata *et al*. [43] described 8 cases (7 PVE) with a 2.7 year follow-up; there was one in-hospital death, one patient with 2+ paravalvular leaks postoperatively, but no IE recurrence. Öner *et al*. [44] presented the use of the Intuity valve in 7 patients undergoing surgery for aortic valve IE, including 2 patients with PVE. They reported one in-hospital death and one death during follow-up, but no IE recurrence [44]. Belyaev *et al*. [45] reported the use of the Intuity valve in 25 patients (9 native IE, 16 PVE) with one operative mortality but no IE recurrence during follow-up. Benke and colleagues [46] showed no recurrence of IE after use of an Intuity valve in 8 patients with native aortic valve IE.

Trans-catheter Aortic Valve Implantation for IE

Off-label TAVI has been suggested for aortic valve IE as a destination therapy or a bridge to surgery to control acute heart failure in prohibitive-risk surgical candidates (Table 2, Ref. [47–52]). In a systematic review, Brankovic *et al*. [53] have analyzed the outcomes of 6 case reports of TAVI implantation (off-label) for IE (including 5 reports of PVE). All patients had significant AR with a median STS score and EuroSCORE of 27% and 56%, respectively. The primary indication for intervention was cardiogenic shock. There was no in-hospital death nor myocardial infarction, but one patient suffered a stroke. Median follow-up was 9 months; no recurrent IE or valve-related re-hospitalization were reported [53]. Albu *et al*. [47] described a case of IE in a 51-year-old patient who had previous aortic root replacement using an aortic allograft. Blood cultures were positive for *Staphylococcus aureus.* TEE showed vegetations on the aortic valve leaflets and the patient suffered a stroke during hospitalization. The patient was considered high risk for *redo* aortic valve surgery and underwent TAVI inside the infected homograft. The authors reported a good recovery and no signs of recurrent endocarditis at 6-month follow-up [47].

Nguyen *et al*. [48] reported a case of TAVI PVE diagnosed a year later after having valve-in-valve TAVI using a 31 mm CoreValve System (Medtronic, Minneapolis, MN, USA) for a degenerated bioprosthetic (FreeStyle) valve. The isolated organism was penicillin-sensitive *Streptococcus sanguis*. There were no vegetations on the prosthetic valve, but the patient developed severe AR and acute heart failure. The patient was not deemed an appropriate surgical candidate and was treated with another TAVI implantation (TAVI-in-TAVI-in-FreeStyle). The patient developed recurrent acute strokes postoperatively secondary to mycotic aneurysms. Postoperative echocardiography showed mild paravalvular leak, and the patient required a prolonged course of antibiotics up to 13 weeks. The authors reported no recurrence of IE at 1-year follow-up [48].

Discussion

Coinciding with the increased use of intra-cardiac devices, there has been an increase in the incidence of IE, in particular *Staphylococcus aureus* IE, the most virulent biofilm-forming and invasive organism. The standard approach includes aggressive debridement of all infected tissues and foreign materials, followed by aortic valve replacement and reconstruction of the aortic root when needed. Surgery for IE is often complex; however, it provides the best chance of cure. Outcomes of the standard surgical approach for IE have improved over time, suggesting evolution in the surgical techniques and perioperative management.

Given the anticipated complexity of standard surgery for iAVE, there has been recent growing interest in exploring alternative approaches such as sutureless and transcatheter valves. Perceval sutureless valve does not require sutures for implantation (only 3 guiding sutures), which can shorten the cardiopulmonary bypass (CPB) time. Perceval valve relies on the radial force of the nitinol stent and requires a decalcified annulus, so eccentric masses must be debrided. In cases of PVE, after aggressive debridement, careful evaluation of tissue integrity (to support a sutureless valve) is mandatory before proceeding with that approach. The Perceval valve could potentially be used in selected cases of native aortic valve IE limited to the leaflets or focal annular invasion, but not for iAVE. Available data have not demonstrated convincing benefits, although surviving patients have no recurrent infection and only mild valve dysfunction. The presented studies about the use of Perceval valvesin patients with IE showed that it could be a reasonable option for patients with non-invasive disease, having the great advantage ofshortening CPB time. Similarly, few groups have reported their experience with the utilization of the Intuity sutureless valve in patients with aortic valve endocarditis.

The largest Intuity study we included in our review suggested that it could be a good option in patients with friable annulus, as it does not need as many sutures as the classical prostheses do [45]. We have observed higher early mortality rates (~14–23%) after implantation of sutureless valves in aortic valve IE, compared to the standard surgical approach (8–10% in national samples), as well as an increased incidence of peri-valvular aortic regurgitation. Additionally, very limited data are currently available about the long-term outcomes of sutureless valve implantation in IE. Thus, caution is needed regarding the use of sutureless valves in active endocarditis cases, especially with significant invasive pathology that compromises the integrity of the aortic annulus.

According to basic principles for infection control, TAVI is contraindicated in IE. However, its use is proposed in patients with a prohibitive risk for surgery who are presenting with acute heart failure, as compassionate use for hemodynamic instability rather than to eradicate the infection. The most important difference between standard aortic valve replacement and TAVI is that the latter does not include debridement of infected material. Without any debridement, TAVI carries the risk of embolization of vegetation material, colonization of the new valve, and persistent sepsis. Off-label use of TAVI to treat IE as a bridge-to-decision or palliative treatment for patients with prohibitive risk for surgery should be restricted. Few case reports showed an increased risk of stroke in patients with vegetations on the aortic valve. Also, treating TAVI IE with another TAVI (Valve-in-Valve) has been described as a lifesaving procedure in patients at high surgical risk with acute heart failure; however, according to the authors, this option should be discussed on a case-by-case basis through a multidisciplinary endocarditis team, due to the high risk of severe complications [54].

Every case of aortic valve IE, especially iAVE, needs to be evaluated by a dedicated multidisciplinary team or an "Endocarditis team" which is composed of a cardiac surgeon, cardiologist, and infectious disease specialist, to reach a thorough assessment which is appropriate for each patient. When possible, patients with invasive disease should be transferred to specialized endocarditis centers.

The present review is limited by the few available case reports and case series published about the use of sutureless and trans-catheter valves in the context of aortic valve IE. Future larger studies with a long-term follow-up are warranted to evaluate the safety and durability of these approaches in such particular cases.

Conclusions

The incidence of aortic IE is rising. Surgery for iAVE is often complex but would provide the best chance to treat endocarditis. Aggressive debridement is the key to curing the infection. Improved outcomes over time suggest advancements in surgical techniques and peri-operative management. Sutureless valves may be a reasonable option for patients with a non-invasive disease. TAVI should be restricted to lifesaving procedures in patients with prohibitive surgical risk. Every case of IE should be discussed by a dedicated multidisciplinary team, to tailor the appropriate therapy for each patient. Complex IE cases with an invasive disease should be transferred to specialized endocarditis centers.

Abbreviations

AR, aortic regurgitation; CPB, cardiopulmonary bypass; CT, computed tomography; iAVE, invasive aortic valve endocarditis; IE, infective endocarditis; PVE, prosthetic aortic valve endocarditis; STS, The Society of Thoracic Surgeons; TAVI, trans-catheter aortic valve implantation; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography.

Author Contributions

SP and HS contributed to the design of this work. HS and HE contributed to the interpretation of data. HS, SP, and HE analyzed the data. SP and HS drafted the work. HE, TF, BX, GP revised critically for important intellectual content and substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

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Conflict of Interest

Haytham Elgharably, MD has financial relationship with Edwards Lifesciences, Artivion, and LifeNet Health. Rest of authors declare that there are no conflicts of interest. Haytham Elgharably, MD has full access to all data in this study and take full responsibility for the integrity of the data and the accuracy of the data analysis.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.59958/hsf.8613.

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