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Tricuspid Valve Endocarditis: A Review of Current Treatment Modalities

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Abbreviations

CT: Computed tomography; CVCs: Central venous catheters; ICDs: Implantable cardioverter defibrillators; HIV: Human immunodeficiency virus; IE: Infective endocarditis; IV: Intravenous; NVE: Native valve endocarditis; MRSA: Methicillin resistant Staphylococcus aureus; MSSA: Methicillin sensitive Staphylococcus aureus; PET: Positron emission; PVE: Prosthetic valve endocarditis; OR: Operating room; STS: Society of Thoracic Surgeons; TV: Tricuspid valve; US: United States

Keywords

Infective endocarditis, Tricuspid valve, Pulmonic valve, Percutaneous intervention

Introduction

Infective endocarditis (IE) is an infection of the native or prosthetic valves of the heart, intra-cardiac device and rarely, embryonic remnants which are typically present in the right atrium [1,2]. Overall, the incidence of IE has grown to 11-15 cases per 100,000 individuals per year [3]. Historically, men have a higher proportion of IE cases then women, but the incidence is increasing in women [4,5]. Over recent decades, the proportion of patients whom develop endocarditis with a history of underlying rheumatic heart disease is decreasing whereas the number of patients with prosthetic valves and implanted cardiac devices (i.e. pacemakers) has increased [6].

Right-sided infective endocarditis makes up 5-10% of all IE cases [1]. The substantial difference in incidence between right-sided and left-sided endocarditis may be explained by a low prevalence of pathologic conditions affecting the right-sided valves, such as congenital malformations, properties and vascularity of the endothelium, and lower pressure and jet velocity associated with right-sided valves in comparison to the left [7,8].

In comparison to left-sided endocarditis, endocarditis involving the right side is more commonly associated with intravenous (IV) drug use, intracardiac devices and central venous catheters, all of which have become increasingly prevalent over the last 2-3 decades [1] (Figure 1). Of note, IV drug use is the most common risk factor for right-sided endocarditis and is rising in incidence in developed countries [1]. In conjunction with the rise of IV heroin use in the United States (US), the proportion of IE admissions doubled from 6% in 2000 to 12% in 2013 [9]. This further increased from 2010-2015 from 15% to 29% [10]. Currently, up to 86% of cases of IE with a history of IV drug use affect the right heart with the tricuspid valve (TV) most commonly involved [11]. In addition, patients with a history of IV drug use who are co-infected with human immunodeficiency virus (HIV) have more than double the risk of developing IE compared to HIV negative patients [12].

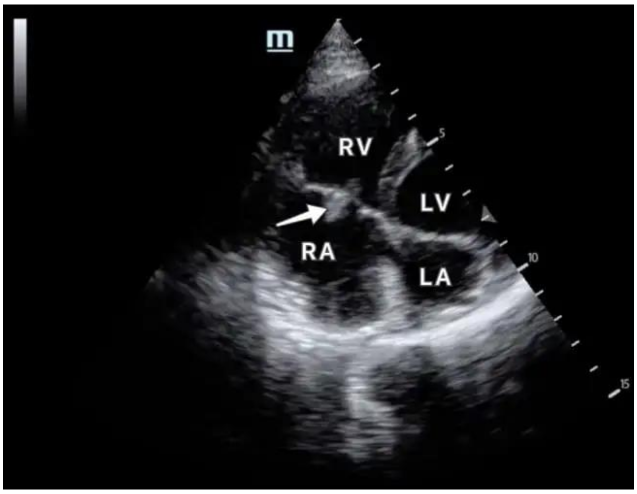

Figure 1: Infective Endocarditis identified on the tricuspid valve on transthoracic echocardiography in the apical 4 chamber view (Identified by the white arrow). RA (right atrium), RV (right ventricle), LA (left atrium) and LV (left ventricle) [67].

Intracardiac device-associated endocarditis typically will involve the tricuspid valve or the contiguous endocardium in the right ventricle [1]. The source of infection can be percutaneous from an infected pocket (i.e. pacemakers or defibrillators) of the implanted device or through hematogenous bacterial seeding [1]. A prior study evaluating pacemakers and defibrillator implantations between 1993 and 2008 had found that the incidence of device-associated IE had risen 210% with an increase in device implantation of 96% during that time [13,14]. Of note, the historical risk for developing endocarditis following permanent pacemaker implantation is 0.5-1% in the first year and rises with increasing device complexity, such as implantable cardioverter defibrillators (ICDs) which demonstrate a 1.7% risk within the first year [1,15].

In right-sided IE, Staphylococcus aureus is the most common causative organism, seen in approximately 60-90% of cases, with the proportion of methicillin-resistant Staphylococcus aureus (MRSA) also rising [16]. Streptococci and coagulase negative staphylococci are additional frequent causes of right-sided IE, with Streptococcus pneumoniae more frequently occurring in patients with chronic alcohol use [11].

It should be noted, that streptococcus pneumoniae is still more frequently associated with left-sided IE compared to right-sided IE [1,11]. Fungal endocarditis is associated with a very high mortality and comprises approximately 3% of all IE cases but rarely involves the right heart [11,17]. In contrast, patients with intracardiac device-associated IE demonstrate distinctly different patterns of pathologic microbes with coagulase-negative staphylococcal infections responsible for 25% of intra-cardiac device associated IE cases.18 In prosthetic valve endocarditis (PVE) cases, Staphylococcus aureus is the predominant microbe [18]. One prior study had reported that up to two thirds of IE cases associated with central venous catheters (CVCs) were associated with Staphylococcus aureus and coagulase negative staphylococci [19].

Clinically, patient's with right-sided IE will present with persistent fever associated with pulmonary complaints as well as anemia and microscopic hematuria; the latter of which develop as a result of immune complex deposition rather than systemic emboli [11,20]. Symptoms may include chest pain, dyspnea, cough and even hemoptysis from septic pulmonary emboli [11,20]. The most common complications of right-sided endocarditis are valvular regurgitation, abscess formation and septic pulmonary embolism (Figure 2) [21].

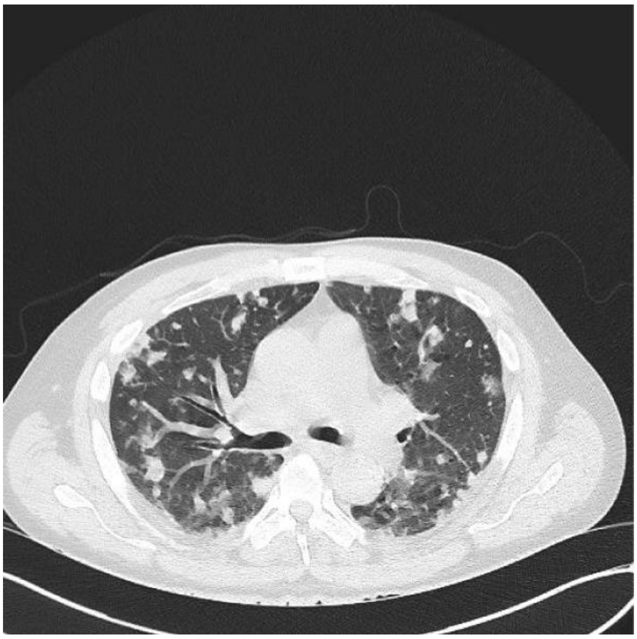

Figure 2: Septic pulmonary emboli visualized on CTA chest in the sagittal view [68].

Overall, pulmonary involvement occurs in 80% of cases with heterogenous pathology ranging from minor atelectasis to large infiltrates to pleural exudates and even cavitation which most typically involve the lower lobes [22]. Further complications can be identified as valvular/local or peripheral. Valvular and local complications include valvular regurgitation (tricuspid more common than pulmonic), valvular stenosis, valvular destruction, valve leaflet perforation and valve annulus abscess formation [1,21,22]. The peripheral complications include pulmonary emboli, systemic embolism and infarcts (typically paradoxical embolism via a patent foramen ovale or other intracardiac shunt), high-degree atrioventricular block, septic shock, or multi-system organ failure [1,21,22].

The diagnosis of infective endocarditis is based on a combination of clinical exam, imaging data and laboratory data [16]. The Duke criteria is the mainstay of diagnosis of IE with the major criteria consisting of positive blood cultures from typical micro-organisms (i.e. staphylococci and streptococci) and the presence of valvular vegetations [16]. The minor clinical criteria used include fever, predisposing risk factor (i.e. IV drug use), vascular phenomena (arterial emboli, pulmonary infarcts, mycotic aneurysm, intracranial hemorrhage, conjunctival hemorrhage and Janeway lesions), immunologic phenomena (glomerulonephritis, Osler's nodes, Roth's spots and positive rheumatoid factor) or microbiologic evidence which does not fit the major criteria [16,23]. In 2023, the Duke criteria for IE had undergone modification and updates with major criteria now separated to 3 major criteria: microbiologic, imaging, and surgical [23,24].

The microbiologic major criteria include positive blood cultures demonstrating microorganisms that commonly cause IE isolated from 2 or more separate blood cultures; micro-organisms that are rarely associated with IE isolated from 3 or more blood culture sets; or positive nucleic acid based technique for identifying Coxiella burnetii, Bartonella species or Tropheryma whipplei; or indirect immunofluorescence assays for detection IgM and IgG antibodies for Bartonella henselae or Bartonella quintana with immunoglobulin G (IgG titer less than 1:800 [23].

The imaging major criteria is broken down into either echocardiographic and cardiac computed tomography (CT) imaging or positron emission CT (PET/CT) with 18F-fluorodeoxyglucose. Regarding the echocardiography and CT, the major criteria are met when there is an identified vegetation, valvular or leaflet perforation, valvular or leaflet aneurysm, abscess, pseudoaneurysm or intracardiac fistula, or new/worsening significant valvular regurgitation on echocardiogram, or new partial dehiscence of prosthetic valve [23]. It is important to note that on echocardiographic evaluation, patients with a history of IV drug use may have structural abnormalities independent of infective endocarditis including focal thickening, valve prolapse, and regurgitation which are likely the result of particles contaminating the illicit substances being injected [25]. Additionally, the imaging major criteria may be with PET/CT demonstrating abnormal metabolic activity involving the native or prosthetic valve, ascending aortic graft (with additional evidence of valvular involvement), intracardiac device leads or other prosthetic material [23]. Lastly, the major surgical criteria are met when there is evidence of documented IE by direct inspection during cardiac surgery for which neither the major imaging criteria nor subsequent histologic or microbiologic criteria confirm the diagnosis [23].

The treatment of right-sided endocarditis is divided into antibiotics, percutaneous interventions, and surgical interventions.

Antibiotic Therapy

Antibiotic treatment of IE, including the tricuspid valve, is a staple of management. Typically, the treatment duration of tricuspid valve endocarditis is 6 weeks from the date of the first negative blood culture [26,27]. On occasion, individuals with tricuspid valve IE are candidates for the shorter duration of antibiotic regimen of 2 weeks. The shortened course is recommended when patients have no evidence of renal failure, simultaneous left-sided infection, or extrapulmonary metastatic infections. Additional exclusions for the 2-week antibiotic regimen include MRSA infection or patients with PVE [26]. More complicated infections that preclude 2 week-courses of antibiotics include native mitral or aortic valve endocarditis, PVE, patients with renal failure, or other extracardiac sites of infection.

Oral antibiotic courses have also been evaluated in the Partial Oral versus Intravenous antibiotic Treatment of endocarditis, or POET trial. This study demonstrated that after an initial phase of IV treatment, up to 20% of patients with uncomplicated right-sided IE were able to complete their antibiotic treatment with oral medications [28]. This study had delineated the treatment of IE into 2 treatment phases: an initial phase and a continuation phase [28,29]. In the initial phase, up to 2 weeks of hospital-based treatments are used with rapidly bactericidal antibiotics as well as cardiac surgery or cardiac percutaneous interventions [28,29].

In general, the initial antibiotics used in treatment of tricuspid valve IE should be based on the most common pathogens, which are Staphylococcus and Streptococcus species [27]. As a result, Vancomycin is the antibiotic of choice in most cases due to the high likelihood of MRSA as the causative organism. For patients with methicillin sensitive Staphylococcus aureus (MSSA), the antibiotic regimen may be de-escalated due to the potential toxicities associated with vancomycin and transitioning to more less potentially toxic antibiotics [26,27]. Appropriate regimens for the MSSA infections include nafcillin, oxacillin, or cefazolin [27]. Antibiotic regimens for other causative organisms are based local susceptibilities and other factors. Of note, the HACEK organisms, Haemophilus, Aggregatibacter, Cardiobacterium, Eikenella and Kingella, are gram-negative bacilli which are significant causes of initial blood culture negative IE. Treatment of IE caused by the HACEK organisms typically involves ceftriaxone or other 3rd generation cephalosporins and fluoroquinolones [30]. Furthermore, the use of rifampin should be considered for patients with PVE with Staphylococcus aureus, as the strain is susceptible [31,32]. In all cases, once final susceptibilities are obtained, the empiric treatment should be changed to targeted therapy for the organism within 24-48 hours of its identification [33].

Surgical Treatment

The primary purpose of surgery for tricuspid valve IE is the safe removal of all infectious material present on the tricuspid valve and eliminate further septic pulmonary emboli [34]. The indications for surgery are (1) right ventricular dysfunction due to new-onset severe tricuspid valve regurgitation non-responsive to diuretics, (2) respiratory insufficiency requiring mechanical ventilatory support after recurrent pulmonary emboli, (3) large tricuspid valve vegetation larger than 2.0 cm after recurrent septic pulmonary emboli, (4) simultaneous involvement of left-sided structures (Figure 3) and (5) persistent bacteremia with at least 1 week of positive blood cultures after initiation of appropriate antibiotic therapy [33]. A variety of surgical interventions have been developed for tricuspid valve IE and range from tricuspid valvectomy, repair, and replacement [35]. The optimal surgical treatment of tricuspid valve IE is controversial, especially in patients with a history of IV drug use given the high rates of recidivism as well as social issues including lack of social support and resources [36].

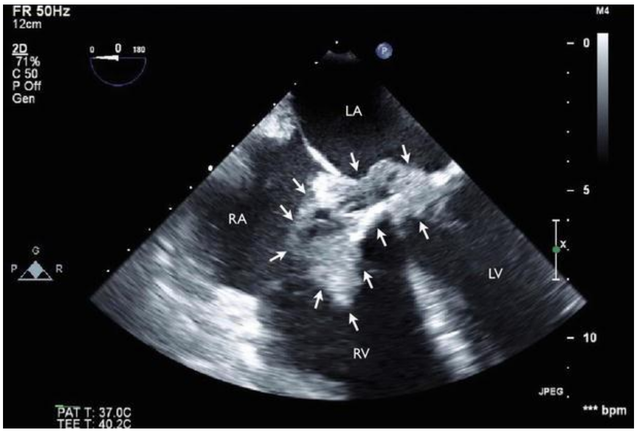

Figure 3: Mitral and tricuspid endocarditis seen in the mid-esophageal 4 chamber view [69].

Many centers prioritize tricuspid valve repair over replacement or valvectomy as resection is frequently reported to have higher complication rates [37-43]. Reconstruction of the tricuspid valve is favored over replacement due to high risk of reinfection, poor outcomes with valve replacement, and patient compliance [37]. Unfortunately, the complete debridement of diffuse multifocal vegetations and extensive valve destruction infrequently leave sufficient tissue necessary for repair [37]. Commonly utilized tricuspid valve repair techniques include pericardium leaflet patch repair/augmentation, bicuspidization, use of artificial chordae, and prosthetic annuloplasty [42]. There are several notable differences in techniques currently available. Leaflet patch augmentation and chordal replacement are technically complex procedures and should be utilized with caution by surgeons not accustomed to TV repair [36,43]. In cases of tricuspid IE due to IV drug use, avoidance of any prosthetic material during repair is generally preferred to limit the risk of recurrent endocarditis from recidivism [36,43]. Notably, ring annuloplasty has more prosthetic material than the De Vega procedure, but the latter has been associated with TV regurgitation recurrence [36,43]. The Kay annuloplasty or bicuspidization can be considered when the vegetation is limited to the posterior leaflet, whereas vegetectomy alone may be associated with recurrent IE [36,43]. Implantation of an annuloplasty ring in patients undergoing TV repair reduces future tricuspid annulus dilatation and the occurrence of TV regurgitation [36,43]. It is necessary to stabilize the valve geometry to achieve long-term competence. This becomes especially crucial in patients with massive destruction of one or two leaflets, which mandates extensive repair with leaflet resection or a commissuroplasty [43]. A nationwide study evaluating patients whom had undergone tricuspid valve intervention due to IE between 2000 and 2013 compared tricuspid valve repair and replacement and had demonstrated similar in-hospital mortality rates [44]. Tricuspid valve repair was associated with lower rates of perioperative complications including massive blood product transfusion, need of dialysis, deep wound infection, as well as shorter intensive care unit stays and lower hospital costs in comparison to tricuspid valve replacement [44]. Furthermore, patients undergoing tricuspid valve repair had lower risks for all-cause readmission, re-admission for adverse liver outcomes, need for new permanent pacemakers and all-cause mortality compared to patients who underwent tricuspid valve replacement [36,37,44]. Finally, a separate study comparing long-term mortality rates in surgical treatment in tricuspid valve IE at 10-, 20-, and 25-years were 66%, 60%, and 44%, respectively without significant differences in tricuspid repair versus replacement [45].

Despite reported outcomes in the surgical literature, tricuspid valve replacement remains the most commonly performed intervention for tricuspid valve IE. However, there is a Class 1 recommendation from the American Association of Thoracic Surgery for vegetation debridement and repair of the valve [46]. As few cardiothoracic surgeons have experience with complex tricuspid valve reconstruction and repair, many may have a low threshold for performing tricuspid valve replacement instead [36,46]. Additionally, for those patients with extensive or total destruction of the tricuspid valve leaflets, replacement may be the only therapeutic option, especially in the absence of randomized clinical trials [36]. The above factors, along with the patient population likely contribute to why tricuspid valve replacement is the most common surgical procedure for tricuspid valve IE [47]. In a study evaluating tricuspid valve surgeries from 2002 to 2009 in patients with active endocarditis, 50% had undergone replacement, 40% underwent repair and 10% underwent valvectomy [47]. There has been no difference in mortality between tricuspid valve replacement or repair, [41] with overall surgical mortality appearing low, regardless of surgical procedure (i.e. tricuspid valve repair or replacement) [48]. Of concern, valve replacement, whether biologic or mechanical, may expose the patient to valve-related complications including heart block requiring pacemaker as well as an increased risk for endocarditis, though it is more prevalent with mechanical prostheses [37,38,49]. Overall, the need for a new permanent pacemaker prior to discharge in one study was revealed to be 12.5% in the replacement and 3.1% in the repair group. This may also contribute to the long-term tricuspid valve dysfunction that permanent transvalvular pacing wire can lead to due to leaflet malcoaptation, perforation, or restriction [36]. Since bioprosthetic tricuspid valves are reported to have excellent long-term durability in the low pressure right-sided circulation system and low rates of structural valve deterioration and low need for reoperation, they are the preferred option if replacement is unavoidable. Finally, the long-term need for warfarin also factors into the recommendation against mechanical prosthetic tricuspid valves.

Tricuspid valvectomy is the excision and removal of the tricuspid valve and is a consideration for patients with tricuspid valve endocarditis in patients who use IV drugs with complex social concerns whom ultimately have a high risk of re-operation for prosthetic valve infection [36]. The advantages of this procedure include the short operating room (OR) time, limited use of foreign material, avoidance for the need of anticoagulation and a lower risk of heart block requiring a pacemaker [37]. This procedure does lead to massive tricuspid regurgitation (TR) and ventricularization of right atrial pressures which may lead to chronic right heart failure [38]. A study done in 2012 to 2016 comparing tricuspid valve valvectomy, repair and replacement demonstrated no difference in 30-day mortality although valvectomy demonstrated lower 1-year risks for unplanned hospital re-admission [39]. Additionally, the risk of bleeding requiring reoperation, major stroke, prolonged ventilator time, intensive care unit stay and overall length of stay were similar in all 3 groups [39]. This study also demonstrated 30-day mortality rates in patients with TV valvectomy, repair, and replacement was 4%, 0%, and 0%; respectively [39] The low event rates in tricuspid valve replacement were seen in a special population of patients who were available for 1-year follow up and satisfied the requirements for drug abstinence. A 2019 metanalysis of TV valvectomy compared to TV replacement reported similar rates in 30-day postoperative mortality, post-operative right heart failure, recurrent endocarditis, and similar 1-year survival rates [40]. The 1-year freedom from reoperation was numerically lower in the valvectomy group but was not statistically different. In contrast, a contemporary report from the Society of Thoracic Surgery (STS) evaluating all tricuspid valve surgeries from 2011 to 2016 had shown that tricuspid valvectomy had a significantly higher mortality rate compared to replacement and repair (16% compared to 2% and 3%, respectively) [41]. In this study the patients who underwent valvectomy had higher rates of active infection, urgent/emergent surgery, more comorbidities, and worse liver function including higher Mayo End-stage liver disease (MELD) scores and lower albumin levels [41]. Ultimately, this likely lead to the use of tricuspid valvectomy as a staged procedure for eventual tricuspid valve replacement or as palliation [36]. Finally, the argument for use of valvectomy as a bridge prior to tricuspid valve replacement allows for patients who can maintain follow up and abstinence from IV drugs to undergo a planned, elective, staged intervention. This process allows the patient the opportunity to be drug- and infection-free and reduces the risk of possible urgent re-operation for an infected prosthetic valve [39].

Percutaneous Treatment Options

Further treatment modalities have been developed for percutaneous treatment for patients deemed to be poor surgical candidates [50,51]. Currently, the AngioVac system is the most commonly used percutaneous system. It is a vacuum-based device used for percutaneous aspiration of undesirable intravascular materials and was approved by the FDA in 2014 [52,53]. This system has a venovenous extracorporeal bypass circuit with an external filtration system and a reperfusion cannula to allow for blood return [36]. This system has also been used for mechanical thrombectomy in the setting of caval thrombosis and pulmonary emboli [54,55]. A meta-analysis in 2019 had demonstrated the safety and efficacy of the AngioVac system for right heart vegetations and intracardiac thrombi [56]. Another device used in the percutaneous treatment of tricuspid valve IE is the Flowtriever System which has been used previously for the removal of large-volume venous thrombus and pulmonary emboli [57].

Currently, the percutaneous aspiration or vegetectomy is used often in the setting of poor surgical candidacy in patients with known IV drug use and/or clinical instability [36,58,59]. A review evaluating outcomes of 33 high-risk surgical patients with large tricuspid valve vegetations who underwent percutaneous vegetectomy with the AngioVac system demonstrated a 61% reduction in the size of the vegetation and 90.9% survival during the index hospitalization [58]. Another study in 2014 using the AngioVac system in 24 patients with tricuspid valve IE demonstrated similar positive outcomes in improving surgical candidacy [59]. In this series, the 30-day mortality rate was 0% and the success rate (defined as >70% vegetation debulking) was 90% [59]. Of note, the benchmark >70% debulking was based on the Registry of AngioVac Procedure [59,60]. A subsequent meta-analysis investigated the efficacy and safety of AngioVac assisted debulking in 301 patients in 2022. This demonstrated an 89.2% procedural success rate (defined as >50% reduction in size) and a clinical success rate of 79.1% [61]. However the clinical success was defined as procedural success, in-hospital survival, the absence of recurrent bacteremia, and valve function not requiring further intervention. In this group bacterial clearance was achieved in 82.5% of patients receiving IV antibiotics with percutaneous debulking [61]. Overall, procedural complications occurred in 10.1% which included primarily worsening of incident tricuspid regurgitation with less-frequent complications including septic pulmonary emboli, arrhythmia, dislodgement of intracardiac devices, systemic embolism, perforation of cardiac tissue, pneumonia, renal failure and blood transfusion [62]. These findings argue that the use of the AngioVac system for percutaneous vegetectomy may preclude surgery or potentially improve surgical candidacy by functioning as a bridge to surgery in patients initially assessed as poor surgical candidates.

Comparison of all 3 general modalities

While randomized three-way head-to-head studies comparing all 3 treatment modalities do not exist due to multiple variables, few observational and retrospective studies do exist. The most recent known study was performed comparing outcomes for tricuspid valve endocarditis in patients who had received medical management with antibiotic therapy alone(n=100), percutaneous aspiration vegetectomy with antibiotic therapy (n=66), and surgical intervention with antibiotic therapy(n=49) [63]. The 30-day and 1-year mortalities were 6.0% and 9.0%, respectively in the medical management group; 2.0% and 4.1% in the surgical group and 6.1% and 15.2% in the percutaneous treatment group.64 Notably, the Kaplan Meier survival analysis demonstrated no significant difference in the three groups despite 97% of percutaneously treated patients had vegetations >2 cm compared to 59% of surgically treated patients [63]. There was however, a trend towards decreased 30-day mortality in the patients whom received surgery in comparison to medical therapy though there was no difference with the percutaneous vegetectomy group. As always, great care must be taken in interpretation of non-randomized studies involving medical procedures as many potential biases may be introduced including selection bias, survival bias, and even publication bias as examples.

Future, Evolution of Transcatheter Therapies and Use

As percutaneous technologies continue to advance it is highly likely that the use of transcatheter aspiration will have expanding use. It is similarly likely that increased clinical experience will lead to aspiration vegetectomy serving as a bridge to definitive surgery, bridge for further transcatheter interventions, or even as a means of palliation depending upon patient-level and system-level characteristics [62]. For additional consideration, the evolution of percutaneous approaches may lead to a stepwise approach in left-sided endocarditis or intracardiac devices [62-64]. Current studies under development are seeking to evaluate percutaneous mechanical aspiration of tricuspid valve IE with medical therapy in addition to observing long-term clinical outcomes of the procedure [65,66]. These studies hope to compare outcomes and efficacy of percutaneous technologies to sole antibiotic therapy and to compare the efficacy of percutaneous treatment to surgical procedures as they continue to evolve.

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Conflict of Interest

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