A Novel Approach to Percutaneous Removal of Large Tricuspid Valve Vegetations Using Suction Filtration and Veno-Venous Bypass: A Single Center Experience

Bennet George, Anthony Voelkel, John Kotter, Andrew Leventhal, and John Gurley

Background: Tricuspid valve surgery has been the de facto standard treatment for tricuspid valve endocarditis (TVE) refractory to medical therapy. It is now possible to remove right-sided vegetations percutaneously using a venous drainage cannula with an extracorporeal bypass circuit. Objectives: The purpose of our study is to describe our single-center experience of percutaneous tricuspid valve vegetation removal. Methods: We reviewed the perioperative course of 33 consecutive patients with large tricuspid valve vegetations who carried high surgical risk. Results: The cohort included 12 males and 21 females over a 40-month period with an average age of 37 years. A preponderance of patients carried an admitted or confirmed diagnosis of injection drug use (72.7%). Average vegetation size was 2.1 ± 0.7 cm prior to the procedure with a 61% reduction in size after the procedure. All patients survived the procedure and 90.9% survived the index hospitalization. Three patients proceeded to elective tricuspid valve replacement due to worsening severity of tricuspid regurgitation. Conclusion: Percutaneous removal of large tricuspid valve vegetations is a safe and effective alternative for patients with TVE who carry high-surgical risk.

INTRODUCTION

Infective endocarditis presents a major public health concern with a high economic burden on society and health care organizations. Hospitalizations related to endocarditis are steadily increasing, mirroring the rise of prescription opioid, heroin, and overdose epidemics nationally [1,2]. Tookes et al reported a single-center experience with $11.4 million spent annually in treatment costs for injection drug-related infections with an adjusted mean cost of over $180,000 for endocarditis-related hospitalizations [3]. Tricuspid valve endocarditis (TVE), specifically, accounts for 10-25% of all cases of endocarditis [4–7]. Regional prevalence trends are also worrisome with both the incidence tricuspid valve involvement and intravenous drug use (IVDU) rising [8].

The management of TVE requires highly individualized care without definite evidence-based guidelines.

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for effective treatment. While medical therapy remains the cornerstone of treatment, it may be inadequate in managing patients with large vegetations (>1 cm), persistent bacteremia despite antimicrobial therapy, fungal lesions, or recurrent septic embolization [9,10]. Surgical treatment, if offered, carries its own drawbacks given the 6–10% operative mortality along with high post-operative morbidity and mortality associated with unique patient characteristics which may cause reinfection of surgically implanted materials [11–13]. Specifically, valvulectomy may result in high morbidity related to right ventricular failure while valve replacement increases the risk of valve-related complications and the risk of recurrent endocarditis, especially with IVDU [14–17].

Recent advances in percutaneous techniques make it possible to remove large tricuspid valve vegetations, promoting infectious source control while avoiding the major disadvantages of surgery. Previous case reports have described percutaneous vacuum-assisted removal/debulking of right-sided intracardiac masses [18–22]. We retrospectively reviewed our single-center experience of nonsurgical debridement of tricuspid valve vegetations utilizing the AngioVac (AngioDynamics, Latham, NY) system to better understand this novel approach to TVE care. The AngioVac Circuit and Cannula are indicated for the removal of soft, fresh thrombi, or emboli, during extracorporeal bypass for up to 6 hr.

MATERIALS AND METHODS

Study Population

We reviewed 33 patients (12 male and 21 female) over a 40 month period. The decision to offer a percutaneous vegetation filtration (PVF) procedure was a consensus opinion amongst a team of physicians (consisting of a general cardiologist, interventional cardiologist, infectious disease specialist, and cardiothoracic surgeon) who felt that the patients would not do well with medical therapy alone. These patients were typically declined traditional surgical management due to various comorbidities felt to increase the risk of surgery including septic shock, respiratory failure, renal insufficiency, and bleeding tendency. Written informed consent prior to the procedure was obtained from the patient or a surrogate.

Device Description

The AngioVac venous drainage cannula and the extracorporeal bypass circuit provide suction-assisted removal of endovascular masses (e.g., thrombus, tumor, or vegetation) from the vena cava, right atrium, right ventricle, and pulmonary trunk (Fig. 1). The distal tip of the large bore inflow cannula has a balloon-actuated, expandable, and funnel-shaped tip (Fig. 2). An inline filter traps intravascular debris while returning blood to the patient and maintaining hemodynamic stability with a veno-venous extracorporeal bypass circuit. No arterial access is required for this circuit.

Procedure Description

All PVF procedures were performed in the cardiac catheterization laboratory under conscious sedation (intravenous midazolam, fentanyl, and ketamine) and local anesthesia (lidocaine infiltration) along with technical support from a perfusionist and intrafacility surgical back-up. Anticoagulation was achieved with unfractionated heparin titrated by point of care activated clotting time targeted to a goal of >250 sec as measured on a Hemochron® machine. A 17 or 19-French sheath was inserted into the femoral vein followed by insertion of a 26-French GORE® DrySeal (W.L Gore & Associates, Flagstaff, AZ) sheath in the right internal jugular vein. The 22-French AngioVac inflow cannula and its dilator were inserted into the right internal jugular venous sheath over a wire and advanced to the right atrium under direct fluoroscopic guidance. Once the dilator and guidewire were removed, the AngioVac cannula was temporarily clamped and connected to the cardiopulmonary bypass circuit and filter, and the 17-French return cannula was inserted into the femoral venous sheath. Finally, the AngioVac circuit was primed and de-aired. Venovenous extracorporeal bypass was started with 3–4 liters per minute flow (3000–4000 RPM). Under direct transesophageal or intracardiac echocardiographic monitoring, multiple passes across the tricuspid valve were made to remove the valvular vegetation (Fig. 3).

After satisfactory debulking was achieved (as defined as removal of >1 cm of particulate and/or the inability to remove any additional particulate), the inflow cannula was removed from the internal jugular sheath and the blood from the extracorporeal circuit was purged and returned to the patient via the return cannula. The particulate was collected in a filter and sent for microbiologic analysis. The vascular sheaths were removed and vascular closure was achieved with a “purse-string” suture. The patients were monitored in the catheterization recovery area and subsequently for at least one night in an intensive care unit. Further care was dictated by the patients’ inpatient care team.

Statistical Analysis

For descriptive purposes, quantitative variables are presented as mean ± standard deviation and categorical variables are summarized as percentages.
RESULTS

Preprocedural Patient Characteristics

A total of 33 patients were reviewed whose baseline clinical characteristics are summarized in Table I. Mean age was $37 \pm 12$ years and 33% of the patients were men. Overall, 6.1% had hypertension, 12.1% had diabetes mellitus, 18.2% had left ventricular dysfunction (estimated ejection fraction $<50\%$ by echocardiogram), 69.7% were tobacco users, 57.6% had hepatitis C, and 72.7% had a confirmed or admitted history of substance abuse. Indwelling catheters were present in 6.1% of patients. Pacemaker/defibrillator leads were also present in 6.1% of patients. All patients had native TVE aside from one patient who had a prior bioprosthetic valve.

Most patients (75.8%) grew *Staphylococcus* organisms with 14 patients growing methicillin-resistant *Staphylococcus aureus* (MRSA) and 11 patients growing methicillin-sensitive *S. aureus* (MSSA). Five patients had polymicrobial infections with an average of 3 organisms per patient. Five patients had fungemia, all growing various *Candida* species. Roughly half (54.5%) of the patients had active bacteremia with a positive blood culture within 48 hours of the procedure. The average size of the vegetations as measured by echo was $2.12 \pm 0.7$ cm in the longest dimension. Severe tricuspid regurgitation was appreciated by echocardiogram in 18.1% of patients. The average time from diagnosis to procedure was $10 \pm 9$ days.

Postprocedure Outcomes

A summary of clinical outcomes is displayed in Table II. All patients survived the PVF procedure and

![Diagram of catheterization and cardiovascular interventions](image-url)
30 (90.9%) patients survived the index hospitalization. The only periprocedural complication noted was the development of cardiac tamponade requiring emergency pericardiocentesis in one patient.

With regard to the three deaths, one involved a 24-year-old male with previous bioprosthetic tricuspid valve infected with MRSA, Enterococcus faecium, Acinetobacter baumannii, and Candida glabrata, who injected drugs intravenously during the index hospitalization, and ultimately passed away 22 days after PVF from severe sepsis. The second death occurred in a 48-year-old female with MRSA infection who was later diagnosed with an extensive epidural abscess extending from C1 to T1 with spinal cord compression and extensive spinal cord edema in whom the family decided to withdraw care 18 days after the PVF. The last death involved a 69-year-old male who had been bedbound for several years prior to becoming septic. He developed an aortic valve perforation and spinal osteomyelitis, was not an acceptable surgical candidate, and subsequently died.

Echocardiograms were performed in 23 of the patients after the procedure was complete. Patients typically had an echocardiogram 4 ± 3 days before PVF but 13 ± 15 days would elapse before a subsequent echo was performed. While 43.5% of patients with a post-PVF echocardiogram demonstrated a worsening severity of tricuspid regurgitation, only three (9.1%) proceeded to elective tricuspid valve replacement after medical stabilization and clearance of blood cultures. Figure 4 illustrates the changes in the degree of tricuspid regurgitation before and after the procedure. As expected, 82.6% of patients with a postprocedure echocardiogram demonstrated a visible persistent vegetation. The average vegetation size on follow-up echocardiogram was 0.82 ± 0.5 cm in longest dimension, representing an average vegetation size reduction of 1.3 cm (61%). Five patients had follow-up blood cultures demonstrating persistent bloodstream infection, three of which were actively infected at the time of the PVF procedure. No patients required surgery because of progression of infection or persistent/recurrent bacteremia.

The average hemoglobin in the patients at the time of the procedure was 8.52 g/dL. On post-PVF day one, the average reduction in hemoglobin was 0.4 ± 1 and
0.11 ± 1.8 g/dL after one week. One-third of the patients (33%) required a blood transfusion within the first week after PVF. On average, 2.7 units of packed red blood cells were needed for a patient requiring a transfusion. Only one patient requiring transfusion, had access-site related bleeding.

**DISCUSSION**

Right-sided endocarditis accounts for 10–25% of all endocarditis cases [4–7]. The optimal management of

![Table I](image1.png)

**TABLE I. Baseline Clinical Characteristics of Patients**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>37 ± 12</td>
</tr>
<tr>
<td>Male (%)</td>
<td>36.3%</td>
</tr>
<tr>
<td>Hypertension</td>
<td>6.1%</td>
</tr>
<tr>
<td>Diabetes mellitus, type 2</td>
<td>12.1%</td>
</tr>
<tr>
<td>Left ventricular dysfunction</td>
<td>18.2%</td>
</tr>
<tr>
<td>Tobacco abuse</td>
<td>69.7%</td>
</tr>
<tr>
<td>Hepatitis C</td>
<td>57.6%</td>
</tr>
<tr>
<td>Pacemaker/defibrillator present</td>
<td>6.1%</td>
</tr>
<tr>
<td>Indwelling catheter present</td>
<td>6.1%</td>
</tr>
<tr>
<td>Bioprosthetic tricuspid valve</td>
<td>3.0%</td>
</tr>
<tr>
<td>History of polysubstance abuse</td>
<td>72.7%</td>
</tr>
<tr>
<td>Average vegetation size (cm)</td>
<td>2.1 ± 0.7</td>
</tr>
<tr>
<td>Severe tricuspid regurgitation</td>
<td>18.1%</td>
</tr>
</tbody>
</table>

![Table II](image2.png)

**TABLE II. Clinical Outcomes of Patients after Debulking Procedure**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death from any cause during index hospitalization</td>
<td>9.1%</td>
</tr>
<tr>
<td>Proceeded to tricuspid valve surgery</td>
<td>9.1%</td>
</tr>
<tr>
<td>Subsequent bacteremia</td>
<td>15.2%</td>
</tr>
<tr>
<td>Persistent vegetation</td>
<td>82.6%</td>
</tr>
<tr>
<td>Average vegetation size (cm)</td>
<td>0.82 ± 0.5</td>
</tr>
<tr>
<td>Worsening degree of tricuspid regurgitation</td>
<td>43.5%</td>
</tr>
<tr>
<td>Average hemoglobin drop one-day postprocedure (g/dL)</td>
<td>0.40 ± 1.0</td>
</tr>
<tr>
<td>Average hemoglobin drop one-week postprocedure (g/dL)</td>
<td>0.11 ± 1.8</td>
</tr>
<tr>
<td>Transfusion required</td>
<td>33.0%</td>
</tr>
<tr>
<td>Average units blood per patient requiring transfusion</td>
<td>2.7</td>
</tr>
<tr>
<td>Access-site related bleeding (n)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

![Fig. 3](image3.png)

**Fig. 3.** Tricuspid valve vegetation imaged with intracardiac echo (ICE). Insert A shows a 2.5 × 1.7 cm tricuspid valve vegetation on ICE before the start of the debulking procedure. Intraoperative ICE imaging shows suction removal of the tricuspid valve vegetation during the procedure (B) and immediately after (C). The gross specimen is shown after removal from the filter (D).

![Fig. 4](image4.png)

**Fig. 4.** Tricuspid regurgitation before and after procedure.

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patients presenting with tricuspid valve vegetations that persist despite appropriate medical therapy represents a significant therapeutic challenge. Current guidelines for surgical intervention in patients with endocarditis do not include right-sided lesions, and alternative therapies need study to supplement conventional surgical approaches [23]. The unique risk factors accompanying this patient population (e.g., increased risk of reinfec-
tion of prosthetic surgical materials) confer increased morbidity with cardiac surgery. While vacuum-assisted debulking of tricuspid valve vegetations has been described in case reports before [18–20,22], this is the largest published series using this novel approach.

Although TVE carries lower risk of mortality when compared with endocarditis involving other valves, mortality is still high, ranging from 15.4 to 37% [4,6,11,24,25]. Institutionally, mortality for TVE has ranged from 25 to 28% [8]. Vegetation size is a major predictor of prognosis. Vegetation sizes >2 cm carried 25% mortality compared with 3.8% in a retrospective review of 220 patients with TVE [24]. In another series of 21 patients with TVE, vegetations <1 cm in size had a cure rate of 100% while vegetations >1 cm were cured only 60% of the time [9]. Comparatively, inpatient mortality was 9.1% in our patient cohort, which, despite the small sample size, appears substantially less than what is reported in the literature.

While many patients developed a worsening severity of tricuspid regurgitation, right-sided valvular dysfunction is often well-tolerated and right-sided valvulotomy resulting in wide open regurgitation may be the operation of choice among injection drug users [14]. The long-term consequences of prolonged open regurgitation remain unknown and serial follow-up would be needed.

Blood loss appears to have been a significant complication related PVF. While the average hemoglobin difference of 0.11 ± 1.8 g/dL from the day of PVF to one week later appears minimal, 33% of the cohort required blood transfusion. The majority of blood loss, however, was not directly related to the procedure itself, as only one patient had access-site bleeding. It is important to note that the majority of the patients were septic and coinfected with hepatitis C making disseminated intravascular coagulation, thrombocytopenia, and coagulopathy related to liver dysfunction significant clinical challenges during inpatient management.

All limitations of a retrospective study design apply to this study as well. The sample size was small and the study was conducted at a single center. Furthermore, there was no control group available for comparison. As a result, our findings may not be generalizable to different populations. Another potential limitation of the study is the lack of data detailing the extent of pulmonary septic emboli caused by the procedure. Nonetheless, this current dataset represents the largest series of patients treated with vacuum-assisted suction filtration and describes the successful use of the AngioVac device as a potential alternative to tricuspid valve surgery. By debulking the infectious site, there is potential for a lower microbial burden leading to more effective antimicrobial therapy. Future randomized, controlled trials are needed to validate our assertions.

CONCLUSION

Right-sided endocarditis is an infectious disease carrying significant morbidity and mortality. Percutaneous removal using suction filtration and veno-venous bypass may provide a safe alternative to open heart surgery for removal of large tricuspid valve vegetations. Further evaluation is warranted regarding this potentially paradigm-shifting alternative to open heart surgery.

REFERENCES