Percutaneous Placement of an Intra-Aortic Balloon Pump in the Left Axillary/Subclavian Position Provides Safe, Ambulatory Long-Term Support as Bridge to Heart Transplantation

Jerry D. Estep, MD,* Andrea M. Cordero-Reyes, MD,* Arvind Bhimaraj, MD,* Barry Trachtenberg, MD,* Nashwa Khalil, BS,* Matthias Loebe, MD, PhD,† Brian Bruckner, MD,† Carlos M. Orrego, MD,* Jean Bismuth, MD,‡ Neal S. Kleiman, MD,* Guillermo Torre-Amione, MD, PhD*‡

Houston, Texas; and Monterrey, Mexico

Objectives
This study evaluated the feasibility, tolerability, and efficacy of a strategy for percutaneous intra-aortic balloon pump (IABP) placement through the left axillary-subclavian artery to provide mechanical circulatory support in patients with end-stage heart failure as a bridge to heart transplantation.

Background
The transfemoral approach to IABP placement is associated with major disadvantages, including the risk for infection and limitation of patient mobility in those requiring extended support.

Methods
We developed a percutaneous technique for placing IABPs in the left axillary artery that permits upright sitting and ambulation. We performed a retrospective review of data from patients who had undergone left axillary IABP implantation between 2007 and 2012.

Results
Fifty patients who received a left axillary IABP as a bridge to transplantation were identified, of whom 42 (84%) underwent heart or heart–multiorgan transplantation. Cumulative survival on IABP support was 92%, and post-transplant 90-day survival was 90%. Median duration of support was 18 days. Four of 50 patients (8%) died while on IABP support, and 3 (6%) received greater mechanical circulatory support. Four patients (8%) had clinically significant thromboembolic or bleeding events without long-term sequelae. The most common minor adverse event was IABP malposition, in 22 patients (44%). Prolonged IABP support in the heart-transplantation cohort was associated with significant improvements in mean pulmonary artery pressure and in creatinine and total bilirubin concentrations.

Conclusions
Percutaneous insertion of an IABP through the left axillary artery is a feasible and relatively well-tolerated strategy to bridge patients with end-stage heart failure to heart transplantation. This form of mechanical-device treatment permits upright sitting and ambulation in those requiring extended support.

© 2013 by the American College of Cardiology Foundation

Intra-aortic balloon pumps (IABPs) are commonly used for temporary mechanical support in patients with complicated, advanced heart failure (HF) (1). The most common approach to percutaneous placement of an IABP is through the transfemoral artery, limiting patient mobility and promoting deconditioning in situations of prolonged support. Alternative sites (transsthoracic) have been utilized with a surgical approach through either the ascending aorta or the right/left axillary or subclavian artery, predominantly with the use of a conduit (either a Dacron [Invista, Wichita, Kansas] graft or vein cuff) to facilitate placement of the IABP in the descending thoracic aorta (2–9). These surgical approaches often require general anesthesia, and the reported experience is limited by case series size (4,6,8,9).

In most patients with end-stage HF needing mechanical or inotropic support, the median wait time to transplantation is 55 days (10). The use of left ventricular assist devices (LVADs) as a bridge to transplantation (BTT) has become

From “The Methodist DeBakey Heart & Vascular Center, Department of Cardiology, Houston, Texas; †The Methodist DeBakey Heart & Vascular Center, Department of Surgery, Houston, Texas; and the ‡Catedra de Cardiología y Medicina Vascular, Escuela de Medicina, Tecnológico de Monterrey, Monterrey, Mexico. The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

Manuscript received May 14, 2013; revised manuscript received June 3, 2013, accepted June 5, 2013.
a standard therapeutic strategy associated with progressively fewer complications and higher rates of survival to transplantation (11). However, many patients who are candidates for orthotopic heart transplantation (OHT) and who require long-term mechanical support are also at a relatively higher risk for LVADs on the basis of underlying etiology of HF (restrictive or infiltrating biventricular cardiomyopathy), history of a previous sternotomy, recurring ventricular dysrhythmias, dual end-organ disease requiring multigraft transplantation, and underlying elevated panel reactive antibodies. Also a patient’s refusal of an LVAD but acceptance of an OHT has been the case for a few patients at our institution. Historically, few of these patients with relative and absolute contraindications for LVADs receive an IABP as a choice of mechanical support due to prolonged immobility with the femoral route of placement.

In an attempt to identify a new, nonsurgical strategy of ambulatory mechanical support for patients as a BTT, we developed a percutaneous technique for placing IABPs in the left axillary-subclavian artery. The primary purpose of this report was to describe the feasibility, tolerability, and efficacy of this technique in patients with end-stage HF awaiting OHT.

Methods

Study population. This study was performed with a protocol approved by the institutional review board at The Methodist Hospital DeBakey Heart & Vascular Center, Houston, Texas. We retrospectively reviewed data from all patients who were referred to our advanced HF service for OHT and/or LVAD evaluation to identify those who received a left axillary IABP between January 2007 and December 2012. Standard demographic, clinical, and laboratory data (before and after extended IABP support) were retrieved by chart review.

Percutaneous placement technique. After standard sterile preparation (Online Fig. 1A), arterial access was obtained from the left brachial artery, and a 4-F arterial sheath (Avanti 11 cm × 0.035 in [Cordis Corporation, Bridgewater, New Jersey]) was placed with the patient under local anesthesia. A standard J-tip guidewire (using fluoroscopy) was then inserted to “roadmap,” or identify, the left axillary artery, hence facilitating direct axillary arterial puncture (Online Fig. 1B). In cases of a difficult brachial arterial cannulation and in those patients with a pre-existing femoral artery sheath, the femoral artery was accessed and a similar roadmap of the axillary artery was established. Direct left axillary arterial access was obtained using a micro puncture (Vaxcel Mini Stick kit, Boston Scientific, Natick, Massachusetts) or standard percutaneous needle (AMC/4 18 gauge × 2-3/4 in, Argon Medical Devices, Inc., Plano, Texas) introduced outside of the thoracic cage and directly toward the axillary artery guidewire. Depth and direction of the needle puncture were guided by cranial angulation of the x-ray gantry.

Following left axillary arterial access, a 4-F arterial sheath was placed and angiography was obtained to screen for arterial injury (Online Fig. 1C). The IABP J-tip guidewire was introduced through the axillary sheath and placed in the descending thoracic aorta, followed by an exchange for the IABP sheath. The IABP was then introduced over the wire, and the distal tip of the balloon was positioned a few centimeters beneath the level of the aortic arch, with the carina serving as a fluoroscopic landmark. Maquet IABP balloon catheters (Maquet AG, Rastatt, Germany) andDatascope IABP consoles (Datascope Corporation, Fairfield, New Jersey) were used.

IABP management. Appropriate timing of balloon inflation was confirmed similar to conventional IABPs. Intra-venous unfractionated heparin was started 4 h after IABP placement, with a goal anti–factor Xa range of 0.25–0.5 U/mL per our institutional protocol. CXRs (Online Fig. 2) and daily physical examinations were used to confirm adequate IABP position and to monitor extremity perfusion. Patients were hospitalized in either the cardiac care unit or the step-down HF unit, and they were allowed to sit upright and ambulate (Online Fig. 3). Inotrope support was weaned as tolerated after IABP placement.

Axillary IABP exchange or removal technique. In cases that required IABP exchange or in which a percutaneous closure device was placed to facilitate IABP removal, the following technique was used: a guidewire (Platinum Plus 0.018 in × 260 cm, Boston Scientific) was placed in the arterial lumen of the IABP and positioned infrarenally, followed by removal of the IABP along with the sheath. For IABP exchange, a new 7.5- or 8-F sheath was placed over the guidewire, with replacement of the IABP as previously described. For percutaneous closure, an 8-F sheath was placed and limited left axillary artery angiography was performed to screen for arterial injury, thrombus, and arterial occlusion. An 8-F closure device (Angio-Seal, St. Jude Medical, Inc., St. Paul, Minnesota, or Perclose Proglide, Abbott Vascular, Abbott Laboratories, Abbott Park, Illinois) was used at the discretion of the implanting physician on the basis of the user’s experience or preference, in accord with recommended closure standards (12,13).

Manual pressure as a strategy for achieving hemostasis after IABP removal was reserved for those patients who had either a significant thrombus burden or arterial intimal injury that precluded percutaneous closure device placement as determined by the operator, or if device closure placement was unsuccessful (either due to loss of arterial access resulting from difficulty with the guidewire exchange technique or incomplete closure after device placement as evidenced by bleeding at the puncture site). If the catheterization laboratory was not readily available

### Abbreviations and Acronyms

- **CXR** = chest x-ray
- **HF** = heart failure
- **IABP** = intra-aortic balloon pump
- **LVAD** = left ventricular assist device
- **OHT** = orthotopic heart transplantation
postoperatively, or if the IABP sheath size was 8-F and the patient did not need early post-transplantation IABP hemodynamic support, surgical closure was performed at the time of transplantation to avoid thromboembolic events related to the IABP off anticoagulation.

**Definitions of adverse events.** Significant bleeding was defined as bleeding that required a surgical intervention and/or transfusion of blood products. Ischemic events related to thrombosis or thromboembolic phenomenon were classified as left upper extremity paresthesia, perfusion compromise on the basis of loss of radial artery pulse, transient ischemic attack, or cerebrovascular accident on the basis of standard criteria. IABP malfunction was attributed to balloon rupture or catheter fracture due to kinking that manifested as frequent console alarms or cessation of balloon inflation. IABP malposition was detected by surveillance CXR and was screened for by determining which patients required more than 1 CXR per day, with documentation of repositioning of the IABP. Repositioning was easily accomplished by placing the IABP in the standby mode and advancing it a few centimeters, with confirmation of goal position by subsequent CXR (Online Figs. 2B and 2C).

**Major adverse events** were defined as IABP-related events (pre- and post-transplantation) associated with significant bleeding or clinically defined ischemia that required surgical intervention. **Minor events** were defined as those IABP-related events not related to significant bleeding or ischemia but that required an additional intervention.

**Clinical outcome measures.** **Successful implantation** was defined as placement of the IABP without the need for aborting the procedure. **Total duration of support** (in days) and, in those patients who received physical therapy–guided ambulation, distance walked (in feet) were monitored. **Successful IABP removal** using placement of a percutaneous closure device was defined as a device closure without peri-procedural complications. Ninety-day post-transplantation mortality was calculated. Data from available hemodynamic assessments and selected laboratory tests were compared between baseline (pre-IABP) and after extended IABP support.

**Statistical analysis.** Mean values \( \pm \) SD are reported for continuous variables, and numbers (%) of patients are reported for categorical variables. Kaplan-Meier curves were constructed to capture major event–free, cumulative, and post-transplantation survival. Analysis of parameters before and after IABP support was performed using

---

**Figure 1**  **Patient Outcomes**

Values are median (range) days of support. *All 4 deaths occurred while patients were on a waiting list(s) due to multiorgan failure (13 [10–40] days), with 1 patient listed for repeat transplantation (40 days). | Three patients had progressive heart failure (HF): 1 with ventricular tachycardia/fibrillation (VT/VF), 1 with concomitant acute renal failure both requiring high-risk left ventricular assist device (LVAD) (50 [37–63] days), and 1 with progressive biventricular HF requiring high-risk total artificial heart implantation after remote orthotopic heart transplantation (OHT) (37 days). | One patient underwent intra-aortic balloon pump (IABP) removal due to bleeding after 60 days of support and received an OHT as status 1B by exemption. | Median (range) days of support: 15 (4–61) days. | Median (range) days of support: 23 (12–133) days. ↪Median (range) days of support: 98 (44–152) days. BTT = bridge to transplantation. Heartmate II is a trademark of Thoratec Corporation (Pleasanton, California).
a 2-sided paired \(t\) test. A significance level of \(p < 0.05\) was used.

Results

Study population and indications. We identified 50 patients who received a percutaneously placed left axillary IABP as BTT (Fig. 1). Table 1 outlines the baseline demographic and clinical characteristics of the study population. Patients were predominantly male (78%), mean age was 56 ± 11 years, and mean LVEF was 25 ± 15%. All patients had significantly reduced functional capacity, and the majority were refractory to inotropic therapy. Those not on inotropic therapy had pre-existing contraindications such as recurring ventricular tachycardia or fibrillation, severe transplant vasculopathy, symptoms consistent with unstable angina, or infiltrative/restrictive cardiomyopathy with non-sustained ventricular tachycardia.

Clinical efficacy outcomes. Left axillary IABP placement in the catheter laboratory was successful in all 50 patients, without implant-related complications. Forty-two patients (84%) supported with an axillary IABP successfully underwent OHT. The median (range) durations of support were 15 (4 to 61), 23 (12 to 133), and 98 (44 to 152) days in the heart, heart–kidney, and heart–lung BTT cohorts, respectively. Cumulative survival in the entire cohort while on extended IABP support was 92% (Fig. 2A), and 90-day post-transplantation survival was 90% (Fig. 2B).

All 50 patients were candidates for sitting upright or ambulating during support. The first 16 patients received dedicated physical therapist-assisted ambulation sessions, with a median (range) of 2 (2 to 9) sessions to minimize deconditioning (Online Fig. 4). In the remaining 34 patients, nursing-guided ambulation was implemented, with a median (range) of 3 (2 to 15) sessions tolerated per patient. In the successful BTT cohort (n = 42), we observed a significant decrease in pulmonary hypertension and noted improvement in both renal and liver end-organ function (Table 2).

Adverse events. Adverse events are shown in Table 3. No significant bleeding or arterial ischemic issues were seen at the time of IABP placement. One patient (2%) developed significant access site–related bleeding after 60 days of support; this bleeding necessitated removal of the IABP and surgical repair of an acquired pseudoaneurysm. Overall, 2 patients (4%) required surgical evaluation for acquired left-hand ischemia and received left brachial artery embolectomy after 22 days (pre-transplant) and after 25 days (third day post-transplant) of IABP support. Of the 42 heart or heart–multiorgan transplant recipients, 3 (7%) underwent removal of the IABP prior to OHT secondary to axillary IABP–related complications (including 1 patient who underwent brachial artery embolectomy at day 22 and 2 patients due to IABP rupture and unsuccessful IABP exchange at days 15 and 30). These 3 patients were subsequently supported by either a femoral IABP or by inotrope treatment and invasive hemodynamic monitoring to maintain clinical stability prior to OHT.

The median number of CXRs obtained for monitoring prolonged IABP support was 16. IABP malposition requiring repositioning at the bedside was seen in 22 patients (44%). Ten patients (20%) required IABP exchange in the catheter laboratory, predominantly due to IABP kinking or malposition (7 patients) and balloon rupture (3 patients). Four patients had major events (2 ischemic and 2 bleeding), with a major event–free survival rate of ~92% (Fig. 2C).

Results of left axillary IABP removal. The IABP-removal strategies and associated angiographic findings are listed in Online Table 1. Percutaneous device closure was performed in 29 of the 50 patients (58%), predominantly using the 8-F Angio-Seal closure device. Device closure was successful in 27 of 29 attempts (93%). In one patient, late post-procedure access-site bleeding developed 3 days after 8-F Angio-Seal closure device placement, secondary to incomplete closure, necessitating surgical evacuation of the hematoma. Another patient had incomplete closure that required manual pressure to attain hemostasis. Application of manual pressure as a strategy for attaining hemostasis was successful in 7 patients, performed due to relative contraindications for closure device placement, including left axillary artery thrombus and/or intimal tear irregularities (Online Fig. 5).

Discussion

IABPs placed via femoral access have been used to treat patients with cardiogenic shock and advanced HF as a bridge to clinical stability, OHT, or permanent LVAD placement (1,14,15). To our knowledge, the current report is the first and largest series to demonstrate the feasibility and tolerability of percutaneously placed IABPs through the left axillary artery for extended support. The major advantages of our approach in patients awaiting OHT are that it avoids a surgical cut-down and general anesthesia. Moreover, extended transthoracic IABP use provides hemodynamic and end-organ (renal and liver) support while allowing early ambulation and physical reconditioning.

Transthoracic IABP support as a BTT while permitting ambulation has been reported in a small number of patients (total of 52) using a surgically placed and tunneled prosthetic or vein graft (3,7–9). In our group of patients with end-stage HF, we were able to successfully support 84% of the patients using this technique as a bridge to heart or heart–multiorgan transplantation compared with ~79% reported in studies of transthoracic IABP placement using surgical grafts (3,7–9). Our observation that renal and hepatic function, as reflected by decreases in serum creatinine and total bilirubin concentrations, improved after axillary IABP support is consistent with findings from a previous report in which extended femoral artery IABP placement was used (16,17). In addition, in those who underwent OHT, the presence of the IABP offered the advantage of facilitating weaning from...
We consider the left axillary artery to be the preferred side for prolonged support, as opposed to the right, to avoid the cerebral vascular accident using our approach, a finding similar to that reported by others who used surgical grafts (8,9). Although many of our patients had automated, implantable cardioverter-defibrillator pockets, the pockets were medial to the IABP entry site, and this did not add to the technical challenges of IABP implantation. Importantly, during prolonged IABP support, we did not observe a clinically significant decrease in platelet count, an up-front concern given the possible extended mechanical damage to platelets. We did find a higher ischemic complication rate compared with benchmark femoral artery IABP safety data (18). In contrast to these benchmark data, prolonged femoral IABP support of 20 days or more is associated with more frequent complications (19). In our cohort, the median (range) time to complications after IABP insertion was 20 (5 to 152) days. Compared with data from a case series ($n = 43$) with prolonged femoral IABP in the context of bridge-to-OHT, our IABP-related infection rate was significantly lower (0% vs. 30%) and similar to the 0% infection rate reported by others who used a surgical approach for transthoracic IABP placement (7–9). In contrast to surgically placed IABPs with the use of prosthetic grafts, which pose a potential risk for future infection (especially important after prolonged immunosuppression, as anecdotally experienced in 1 patient at our center), we did not see any cases of post-transplantation-related IABP infection, including in those patients who had undergone Angio-Seal arterial closure.

Compared with use of the femoral approach, axillary IABP malposition requiring simple bedside repositioning is more common and is most likely secondary to patient mobility. Bedside repositioning performed in 44% of patients with IABP in the standby position was not associated with acute adverse clinical events. The rate of IABP device malfunction necessitating IABP exchange in the catheter laboratory (20% of our patients) was not greater than that reported with surgically placed axillary or subclavian IABPs (20%–50%), and our rate of successful IABP exchange was 92% (3,7–9).

We currently favor using the 8-F Angio-Seal closure technique to facilitate IABP removal due to its ease of device deployment on the basis of our operators’ experience. However, we feel that the use of percutaneous closure devices that utilize endovascular suture placement is an acceptable alternative. The left axillary artery is largely free of significant arterial branches, so closure device–related ischemia was not seen. IABP removal facilitated by closure device placement was uncomplicated in 92% of attempts. In patients who do not require IABP support early after transplantation, our current strategy is to remove the IABP either at the time of surgery or within 24 hours after OHT, in the catheter laboratory, using a percutaneous device to avoid unnecessary risk related to acquired brachial thrombus formation, which occurred in 1 of our patients.

Our utilization of IABP was reserved for those patients with end-stage HF based on severely limited functional

---

### Table 1: Baseline Patient Demographic Characteristics (N = 50)

| Age (yrs) | 56 ± 11 |
| Sex | Male 39 (78), Female 11 (22) |
| Etiology | Ischemic 24 (48), Dilated (nonischemic) 8 (16), Valvular 2 (4), Other* 16 (32) |
| Indication for IABP as BTT strategy | Underlying etiology Infiltrating CM 7 (14), Restrictive CM 5 (10), Repeat OHT 3 (6), Valvular heart disease with a mechanical valve prosthesis 2 (4), History of previous sternotomy 16 (32), Recurrent ventricular tachycardia/fibrillation 12 (24), Dual end-organ disease requiring multigorgan transplantation 8 (16), Preferred BTT strategy† 5 (10) |
| Functional capacity | NYHA class IIIb or IV 50 (100), MVO$_2$ 11 ± 4 |
| Physical examination | Weight (lb) 194 ± 35, BMI (kg/cm$^2$) 29 ± 4, Systolic blood pressure (mm Hg) 103 ± 10, Diastolic blood pressure (mm Hg) 65 ± 9, Heart rate (beats/min) 88 ± 16 |
| Selected laboratory values | BUN (mg/dl) 38 ± 25, Creatinine (mg/dl) 1.7 ± 0.9 |
| Echocardiography | LVEF (%) 25 ± 15, LVEDd (cm) 6.1 ± 1 |
| Invasive hemodynamics | Right atrial pressure (mm Hg) 13 ± 6, Pulmonary artery pressure (mm Hg) 34 ± 11, Pulmonary capillary wedge pressure (mm Hg) 24 ± 9, Cardiac output (l/min) 4.3 ± 1, Cardiac index (l/min/m$^2$) 2.1 ± 1, Pulmonary vascular resistance (Wood units) 3.1 ± 2 |

Values are mean ± SD or n (%). *Includes amyloidosis (n = 6), repeat transplantation (n = 3), restrictive cardiomyopathy (n = 3), hypertrophic cardiomyopathy (n = 2), predominant ventricular tachycardia (n = 2), hemochromatosis (n = 1), and postpartum cardiomyopathy (n = 1). †Patients may have had more than 1 relative contraindication for left ventricular assist device (LVAD) support. ‡Incorporation of patient preference or refusal of up-front BTT strategy. §Available data from 25/50 patients.

BMI = body mass index; BTT = bridge to transplantation; BUN = blood urea nitrogen; CM = cardiomyopathy; LVEF = left ventricular ejection fraction; MVO$_2$ = peak myocardial oxygen consumption; NYHA = New York Heart Association; OHT = orthotopic heart transplantation.

cardiopulmonary bypass and offered additional early postoperative support similar to those in a report from others (3).
capacity, compromised end-organ function, and an adverse hemodynamic profile (high pulmonary capillary wedge pressure and low cardiac index), with the majority of patients refractory to inotropic support. Although we were successful in supporting many of our patients, a limitation intrinsic to the degree of hemodynamic support provided by IABPs accounts in part for our observed inability to successfully bridge 8 of 50 (16%) patients to OHT. More robust circulatory support (i.e., total artificial heart or biventricular assist devices) should be considered if IABP function alone is insufficient in improving the hemodynamic profile in patients deemed high risk for LVAD support.

**Study limitations.** The retrospective nature of this study, in addition to being a single-center experience, constitutes the major limitation. Complete hemodynamic information was not compiled, patients had variable degrees of extended support, and our data were derived over a span of several years. It may be difficult to extrapolate our tolerability and transplant success rate experience to patients with more overt hemodynamic compromise, to transplant centers with longer wait times, or to patients with long wait times related to large body habitus and/or ABO blood type. In addition, we used varied IABP removal strategies (from percutaneous

---

**Table 2**

**Comparison of Pertinent Hemodynamic and Laboratory Values Before and After Extended Axillary IABP Support (N = 42)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before Implantation*</th>
<th>After Implantation†</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP (mm Hg)</td>
<td>13 ± 5.8</td>
<td>10 ± 6</td>
<td>0.09</td>
</tr>
<tr>
<td>mPAP (mm Hg)</td>
<td>34 ± 10.9</td>
<td>27 ± 9</td>
<td>0.006</td>
</tr>
<tr>
<td>WBCs (k/μl)</td>
<td>8.0 ± 3.1</td>
<td>8.2 ± 2.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Creatinine (mg/dl)</td>
<td>1.7 ± 1.0</td>
<td>1.5 ± 0.8</td>
<td>0.01</td>
</tr>
<tr>
<td>BUN (mg/dl)</td>
<td>36.1 ± 24</td>
<td>28.9 ± 17</td>
<td>0.01</td>
</tr>
<tr>
<td>Hemoglobin (g/dl)</td>
<td>11.6 ± 2.1</td>
<td>10.8 ± 1.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Platelets (k/μl)</td>
<td>189 ± 75</td>
<td>162 ± 53</td>
<td>0.01</td>
</tr>
<tr>
<td>AST (U/l)</td>
<td>62.7 ± 117</td>
<td>46.8 ± 52</td>
<td>0.2</td>
</tr>
<tr>
<td>ALT (U/l)</td>
<td>50 ± 78.9</td>
<td>36.7 ± 20.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Total bilirubin (mg/dl)</td>
<td>1.1 ± 0.6</td>
<td>0.8 ± 0.5</td>
<td>0.003</td>
</tr>
<tr>
<td>PT (s)</td>
<td>17.7 ± 5.4</td>
<td>16.4 ± 4.3</td>
<td>0.6</td>
</tr>
<tr>
<td>INR</td>
<td>1.5 ± 0.6</td>
<td>1.4 ± 0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Values are mean ± SD. *Day 0. †Median days of intra-aortic balloon pump (IABP) support: 18; range: 4 to 152. ‡Hemodynamic (pulmonary capillary wedge pressure and cardiac output not available) and laboratory values obtained on day of OHT. ALT = alanine aminotransferase; AST = aspartate aminotransferase; INR = International normalized ratio; mPAP = mean pulmonary arterial pressure; PT = prothrombin time; RAP = right atrial pressure; WBCs = white blood cells; other abbreviations as in Table 1.

---

**Figure 2**

(A) Cumulative survival in the intent-to-BTT cohort. (B) Ninety-day survival post-OHT in patients bridged with axillary IABP. (C) Major event-free survival in the IABP BTT cohort. Major events in 2 cases were ischemic and required brachial artery embolectomy, and 2 cases were bleeding related. (See Table 3 for details.) Abbreviations as in Fig. 1.

---

**Table 3**

**Percutaneous Axillary IABP Characteristics and Events at the Time of Implantation or During Extended Support (N = 50)**

<table>
<thead>
<tr>
<th>Event</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial IABP sheath size</td>
<td>3 (6)</td>
</tr>
<tr>
<td>7-F</td>
<td>46 (92)</td>
</tr>
<tr>
<td>8-F</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Duration of support (days)</td>
<td>18 (4–152)</td>
</tr>
<tr>
<td>IABP-related mortality*</td>
<td>0</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>0</td>
</tr>
<tr>
<td>Major limb ischemia</td>
<td>2 (3.8)</td>
</tr>
<tr>
<td>Neurologic events</td>
<td>5 (9.6)</td>
</tr>
<tr>
<td>Paresthesia</td>
<td>0</td>
</tr>
<tr>
<td>TIA or CVA</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Severe access site bleeding (arterial or venous)</td>
<td>22 (44)</td>
</tr>
<tr>
<td>At time of implantation</td>
<td>0</td>
</tr>
<tr>
<td>During IABP support</td>
<td>0</td>
</tr>
<tr>
<td>IABP-related infection</td>
<td>0</td>
</tr>
<tr>
<td>IABP malposition requiring position adjustment‡</td>
<td>22 (44)</td>
</tr>
<tr>
<td>IABP malfunction requiring exchange.#</td>
<td>10 (20)</td>
</tr>
</tbody>
</table>

Values are n (%) or median (range). *Death as a direct consequence of IABP therapy. ‡Pneumothorax as direct consequence of IABP implantation, assessed by chest radiography. †Loss of pulse or sensation, abnormal limb temperature or pallor, and requiring surgical intervention. §Without limb ischemia, 1 patient developed brachialplexus injury that resolved after several sessions of physical therapy. ¶Bleeding requiring surgical intervention and/or blood transfusions. *Malposition, suggested by either console alarm or position changes noted in surveillance chest radiography, with subsequent bedside repositioning. #Exchange guided by fluoroscopy in the catheter laboratory secondary to rupture, overt malposition, or catheter fracture caused by kinking. CVA = cerebrovascular accident; IABP = intra-aortic balloon pump; TIA = transient ischemic attack.
device-assisted closure to surgical closure); therefore, it is difficult to define the true safety profile of percutaneous closure given the small sample size for each approach. Finally, procedural experience and variation can contribute to further enhancement of risk. We had a limited number of users (3) who were proficient in the IABP placement technique.

**Conclusions**

Percutaneous insertion of an IABP through the left axillary artery is feasible, with an acceptable safety profile for support for several days to weeks. This form of mechanical device support allows for sitting upright and ambulation, and can be used to bridge end-stage HF patients to heart or heart–multigraft transplantation. The ideal patient is one with end-stage cardiomyopathy, with progressive HF refractory to aggressive medical therapy, and with relative contraindications for an up-front LVAD BTT strategy. The left axillary artery may be the site of choice for future percutaneous devices in supporting patients with complicated, advanced HF.

**Reprint requests and correspondence:** Dr. Jerry D. Estep, The Methodist DeBakey Heart and Vascular Center, Department of Cardiology, Smith Tower, 6550 Fannin Street, Suite 1901, Houston, Texas 77030. E-mail: jestep@houstonmethodist.org.

**REFERENCES**


**Key Words:** heart failure ● heart transplant ● intra-aortic balloon pump ● subclavian artery.

**APPENDIX**

For a supplemental table and figures, please see the online version of this article.