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Alternative non-femoral accesses for intra-aortic balloon pumping

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Abstract

Access from the femoral arteries to the thoracic aorta for intra-aortic balloon pump (IABP) insertion may not be feasible in a substantial number of patients with severe peripheral vascular disease. Since using an alternative access is inevitable in a certain number of patients requiring IABP support, all alternative accesses should be added to the surgical armamentarium. Herein, we present our 27-year experience with different alternative accesses for IABP insertion following failed contraindication to femoral artery cannulation. The alternative techniques described below were: transthoracic insertion with a tube graft, transthoracic insertion – direct, transaxillary/subclavian insertion and transbrachial insertion.

Keywords

intra-aortic balloon pump; IABP; alternative access for IABP; transfemoral IABP; transthoracic IABP

Introduction

Intra-aortic balloon pumping (IABP) uses the principle of diastolic counterpulsation, increasing diastolic coronary perfusion pressure, reducing systolic afterload, affecting the myocardial oxygen supply/demand ratio favorably and increasing the cardiac output. Since Kantrowitz et al.[1] reported the first successful clinical use of a device inserted through the femoral artery in 1968, it has become the standard for the introduction of the IABP.[2] Although recent improvements have been made in guide-wire technology and smaller catheters ease the use of the femoral arteries, access to the thoracic aorta from the femoral arteries is not possible in a substantial number of patients with small or atheromatous femoral arteries, advanced obstructive aortailiac disease and contaminated or previously cannulated groins.

In this patient population, the balloon catheter may be passed into the descending thoracic aorta through alternative routes, such as the ascending aorta,[3] the axillary arteries,[4] the subclavian arteries[5] or the brachial arteries.[6] In this article, we present our experience with different alternative accesses for IABP insertion following the failure of or contraindication to femoral artery cannulation.

Materials and Method

Between January 1985 and December 2012, medical data of the patients undergoing the insertion of IABPs were retrospectively analyzed. Data were collected in accordance with the local regulations and approved by the Institutional Review Board.

During the 27-year study period, a total of 3010 IABPs were inserted at our clinic. In 2972 patients, the balloon was inserted through the femoral artery. Among them, 567 received the IABP in the intensive care unit (ICU) without surgery. Thirty-eight patients received IABPs which were inserted through an alternative route,

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Table 1. Brief summary of the results.

Intra-aortic Balloon Pump use between 1985 and 2012	Total number of patients, n 3010 Transfemoral insertion, n, (%) 2972 (98.7) Alternative access, n, (%) 38 (1.3)			
Alternative Access	Transthoracic, n (%) 28 (73.7)		Transaxillary, n, (%) 10 (26.3)	
Surgical Technique	Direct, n, (%) 9 (32.1)	Graft, n, (%) 19 (67.9)	Direct, n, (%) 6 (60)	Graft, n, (%) 4 (40)
OR insertion, n, (%)	9 (100)	19 (100)	2 (20)	4 (40)
ICU insertion, n, (%)	–	–	4 (40)	–
IABP duration, mean (range)	58.6 (26–132)		46.2 (18–112)	

OR: operating room; ICU: intensive care unit; IABP: intra-aortic balloon pump.

Table 2. The Demographic Data and Characteristics of the Patients.

	Transfemoral	%	Alternative access	%	P
Age	59.6 ± 10.2		63.2 ± 11.4		<0.001
Male	2727	92	29	76	0.00067
Female	245		9		
DM	560	19	11	29	0.11
COPD	242	8	4	11	0.59
PAD	168	6	38	100	<0.001
Valvular disease	295	10	4	11	0.9
CAD	2148	72	34	89	0.018
Medical Follow	529	18	0	0	0.0042

COPD: chronic obstructive pulmonary disease; DM: diabetes mellitus; PAD: peripheral arterial disease; CAD: coronary artery disease.

following the failure of femoral artery cannulation (Table 1). The mean age of the patients for alternative access was 63.2 ± 11.4 years (range, 39-86 years) and there were 29 men and nine women. The demographic data and characteristics of the patients undergoing transfemoral and transaxillary/subclavian IABP are shown in Table 2.

Techniques and timing of the implementation of IABP usage by alternative routes

In the operating room, we used the grafted axillary/subclavian approach to prevent arm ischemia in patients who were unable to be weaned from the pump, if the transfemoral route was not suitable. We performed the subclavian approach in patients with hemodynamic problems, despite inotropic support, and in patients in whom timing was important.

We performed the direct subclavian approach for patients who were able to be weaned from the pump, but suffering from hemodynamic problems despite inotropic support. Timing was also critical. We preferred the transthoracic route in cases of hemodynamic problems, greater emergency to introduce the balloon and all the other alternative approaches were exhausted.

In the ICU, we performed direct axillary/subclavian IABP without any delay for patients who had postoperative low cardiac output.

Techniques of IABP insertion

Once the percutaneous Seldinger or open transfemoral techniques failed, one of the alternative techniques described below was used:

a) *Transthoracic Insertion with a Tube Graft*: The insertion of the transthoracic IABP is carried out in the operating room (OR). A partial occlusive clamp is placed on the distal ascending aorta where an aortotomy is made. A polytetrafluoroethylene (PTFE) or Dacron prosthesis is sutured to the side with a polypropylene running suture. The partial occlusive clamp is removed and, then, a clamp is placed on the prosthesis. Before being inserted, a gradual downward bend is made in the distal end of the somewhat stiff catheter. After it is passed through the prosthetic

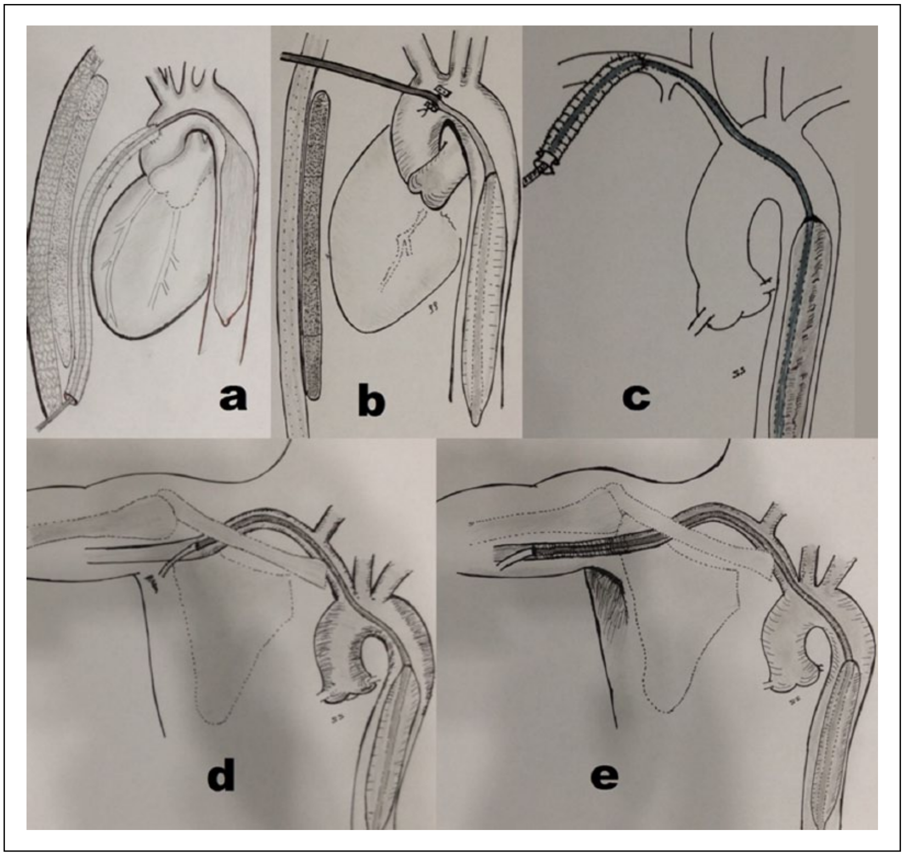

Figure 1. Alternative accesses for intra-aortic balloon pump.
Schematic drawing of intra-aortic balloon catheter inside the descending aorta through different accesses. (a) transthoracic insertion with a graft, (b) transthoracic direct insertion, (c) transaxillary insertion with a graft, (d) transaxillary direct insertion, (e) brachial artery insertion.

conduit, the catheter can be guided directly over the aortic arch and avoid the arch vessel cannulation. The positioning of the balloon distal to the left subclavian artery is approximated, relating the total length of the balloon catheter to the length inserted (Figure 1a). Transesophageal ultrasound check is beneficial. At closure, the graft lies over the heart, with the distal portion exiting inferiorly to the closed sternum. The end of the graft is enclosed in the subcutaneous portion of the incision. The balloon catheter alone exits at the skin level. A heavy tie around the distal end of the graft over the sleeve of the balloon catheter provides hemostatic fixation of the balloon within the graft. The removal of the transthoracic IABP is done in the ICU under local anesthesia. The lower portion of the sternotomy incision is opened, the securing tie is cut and the balloon is removed. A vascular clamp is applied to the graft. The distal end of the graft is excised and the remaining portion is over-sewn. It is ligated and the subcutaneous tissue and skin are closed. We performed this technique in 19 of 38 patients.

b) *Transthoracic Insertion – Direct*: Direct transthoracic balloon insertion is also carried out in the OR. The IABP is placed through the ascending aorta in a non-calcified portion. Two Prolene concentric purse string sutures are placed, through which the balloon is inserted into the aorta with the aid of a needle and a flexible guide-wire (Seldinger technique). The IABP is positioned as described above. The balloon catheter is secured by the purse-string sutures after checking the correct position by transesophageal ultrasound. The balloon exits the superior portion of the sternotomy incision where it was secured to the skin (Figure 1b). To remove the balloon, we re-transfer the patient to the operating room where the sternotomy is reopened. The intra-aortic balloon is deflated and removed. The arteriotomy is closed using Prolene sutures. The sternotomy is then closed in the usual fashion. Nine IABPs were inserted using this technique.
c) *Transaxillary/subclavian Insertion (Direct or with a tube graft)*: This procedure can be performed in the OR, ICU or cardiac catheterization laboratory

Table 3. Indications for alternative access intra-aortic balloon pumping.

Indication for IABP	Transthoracic n (%)	Transaxillary n (%)	Total
Total occlusion of abdominal aorta	4 (66.7%)	2 (33.3%)	6
Abdominal aortic aneursym	3 (60%)	2 (40%)	5
Bilateral iliac aneursym	2 (66.7%)	1 (33.3%)	3
Aorta-iliac aneursym	4 (66.7%)	2 (33.3%)	6
Bilateral iliac artery occlusion	8 (72.7%)	3 (27.3%)	11
Bilateral femoral artery occlusion	4 (80%)	1 (20%)	5
History of bilateral femoro-popliteal bypass	1 (50%)	1 (50%)	2
	28 (73.7%)	10 (26.3%)	38

IABP: Intra-aortic balloon pump.

under local anesthesia. The axillary-subclavian artery junction is exposed through an incision at the deltoid pectoralis groove. Following major and minor pectoralis muscle incision, the subclavian or axillary artery is identified and mobilized. The IABP can be inserted using one of the techniques described below (Figures 1c and 1d). 1) Two 5/0 polypropylene purse-string sutures are made on the surface of the artery. Under reliable transesophageal echocardiogram (TEE) monitoring, an IABP catheter can be easily inserted using the Seldinger technique. 2) A PTFE or Dacron graft is sewn onto an appropriately sized arteriotomy in the artery with a polypropylene suture, using a side clamp. The balloon wire is passed through the graft and positioned in the descending aorta and the balloon is inserted and appropriately positioned under the guidance of TEE. The balloon catheter is tied around the graft. The wound over the graft is closed in layers. As a result, the only foreign material which traverses the skin is the balloon catheter. IABP surgical removal is carried out in the ICU for both techniques. It consists of simply re-opening the wound and tightening the purse strings for the first and ligating the graft at its base close to the anastomosis and excising the rest of the graft for the second technique, after the balloon is deflated and removed. This technique was used in 10 of 38 patients.

d) *Transbrachial Insertion*: The technique was briefly described by Noel et al.[7] The insertion is performed under local anesthesia, using the Seldinger technique through the brachial artery, a few centimeters above the elbow (Figure 1d). The balloon catheter is positioned under the guidance of fluoroscopy or TEE. Upon removal, minimal bleeding occurring at the insertion site is controlled by gentle manual compression. This technique was not used in our study.

Results

While IABP was indicated for low cardiac output syndrome, the use of an alternative access was indicated for peripheral vascular disease. The most common indication for an alternative route to IABP was bilateral aortoiliac arterial occlusion. Other indications are shown in Table 3. Preoperative cases and cases in which IABP inserted during medical follow-up were excluded.

A synthetic graft was used in 19 patients and four patients with a transthoracic route and transaxillary/subclavian route, respectively (Table 1).

Transthoracic insertion (28 patients) was preferred for patients who required IABP support due to failed weaning from CPB. Both direct (9 patients) and with a tube graft (19 patients) techniques were used (Table 1). Transthoracic patients received either 34 ml or 40 ml 9F (7 patients), 8F (9 patients) or 7.5F (12 patients) catheters, according to body surface area (BSA). The transaxillary insertion method (10 patients) was reserved for those whose required IABP support postoperatively. Either 34 ml or 40 ml 7.5F catheters were chosen according to the BSA in all transaxillary patients. Both direct (6 patients) and through a graft (4 patients) techniques were used. Four patients had the transaxillary procedure performed in the ICU and the rest in the OR (Table 1).

Among those patients whose IABP was inserted through the transthoracic route (28 patients), 18 were weaned from balloon support. In eight of them, removal of the balloon was carried out under local anesthesia in the ICU. All patients in the direct insertion group and three patients with tube grafts were returned to the operating room for repeat sternotomy and excision of the IABP. The mean IAPB assistance time was 58.6 hours (range, 26 to 132 hours). Three patients in the direct and seven patients in the tube graft group died, mainly due to low cardiac output and multi-organ failure. There was no balloon placement- or removal-related mortality. The mean time to discharge was 26 days postoperatively (range, 12 to 52 days). Three patients suffered from complications related to intra-aortic balloon pump use,

Table 4. The complications and mortality rates of transfemoral and alternative access.

	Transfemoral (n)	%	Alternative access (n)	%	P
Ischemia of extremity	333	11	0	0	0.029
Bleeding	38	1	1	3	0.46
Infection	18	1	1	3	0.117
Paraplegia	5	0	0	0	0.8
Aortic dissection	7	0	0	0	0.76
Balloon rupture	75	3	2	5	0.288
Mortality	796	27	12	32	0.507

including balloon rupture, graft infection and bleeding. A ruptured balloon, marked by the sudden appearance of blood in the balloon tubing, was observed in two patients and required immediate removal of the balloon. The balloon was removed quickly through the graft under local anesthesia without complication. Graft infection developed in one patient, as documented by positive culture results. He was returned to the operating room and mediastinal debridement and excision of the graft were performed. The patient died due to acute renal failure on day 21 postoperatively. One patient had postoperative mediastinal bleeding requiring re-exploration. The origin of the bleeding was the aortic insertion site of the direct IAPB catheter. Bleeding was managed by another purse string and the patient was discharged uneventfully.

Among the patients in whom the IABP was inserted through the transaxillary route (10 patients), eight were weaned from the balloon support. In all of them, the balloon was removed in the ICU under local anesthesia. The mean IAPB assistance time was 46.2 hours (range, 18 to 112 hours). One patient in the direct and one patient in the tube graft group died due to low cardiac output and multi-organ failure. There were no death events directly related to the balloon placement or removal. The mean time to discharge was 16 days postoperatively (range, 9 to 32 days). One patient suffered intra-aortic balloon pumping-induced complications, including balloon rupture. A ruptured balloon was detected during the insertion and another balloon was re-inserted uneventfully. The complication and mortality rates of transfemoral and alternative access are shown in Table 4.

Discussion

There has been an ongoing debate regarding the use of IABP counter-pulsation to support the failing myocardium. Although there has been a lack of convincing evidence which improves outcomes, IABP support continues to be routinely used to support hemodynamic instability due to postcardiotomy myocardial depression, myocardial infarction, cardiogenic shock or very high-risk patients undergoing angioplasty or coronary artery bypass grafting.[2,8,9] The insertion of an IABP is accomplished percutaneously and the approach is either right or left common femoral artery in 90%-99% of cases.[2,8,9] Balloon insertion can be unsuccessful in 2.6%-10% of cases due to a balloon leak, poor inflation of a balloon, poor augmentation or difficulties associated with balloon insertion.[2,10] Different alternative approaches are described to circumvent the difficulty of insertion. An alternate approach was needed for IABP insertion in 1.1% of cases in the Benchmark registry, which included worldwide, prospectively collected data from 203 hospitals on 16909 patients.[2] Similarly, an alternative approach was required in 38 patients in our study.

In more than two-thirds of our patients, transthoracic insertion was preferred as a second choice. All transthoracic balloon pumps were placed intraoperatively, after the cardiac procedure was performed. The patients, however, failed to demonstrate good cardiac hemodynamics, despite maximal efforts at optimal fluid status and the use of pharmacological agents. Our mortality was 10/28 in patients who received transthoracic IABP, consistent with the reported mortality in the literature (27% to 71.4%).[3,11–13]

Until now, a variety of techniques have been reported for inserting the transthoracic IABP in the ascending aorta.[10–13] They can be divided into two: techniques using a prosthetic graft from the aorta to the subcutaneous tissues (19/28 patients) and techniques using purse string sutures to secure the balloon catheter in place (9/28 patients). In the transthoracic approach, the cases in which we used grafts, were the first cases of our cohort. Between 1985 and 2000, our transthoracic approach was grafted IABP. After 2000, a direct approach has been widely adopted and the need for using grafts has been reduced with the development of surgical techniques and improvements in IABP technology.

Furthermore, both techniques have their own unique set of problems and complications. They both offer the advantage of rapid placement through the ascending aorta under direct vision, preventing lower extremity ischemia, which is common with femoral placement.[3]

However, both have the risk of embolisation due to dislodged intraluminal debris during the insertion and stripping of a thrombus on the catheter or the balloon during catheter removal, which may cause neurological events or distal visceral ischemia.[14,15] Hazelrigg et al.[3] reported a retrospective review of 100 cases of transthoracic pumps and found that the incidence of thromboembolism-induced neurological events was 3.7%. Other embolic events with transthoracic IABP placement included spinal cord ischemia, coronary artery occlusion, renal artery occlusion and bowel ischemia.[3,15,16] Fortunately, we experienced none of these problems. As a result, we suggest that the lack of comorbidities may be the underlying reason for the complete absence of complications in patients in whom IABP was implemented through the transthoracic route. We also believe that comorbidities (low ejection fraction, perioperative myocardial infarction, etc.), but not the location where IABP was performed, were the leading causes of death in 10 patients.

Moreover, the graft technique eliminates the need for repeated sternotomy and the balloon can be removed in the intensive care unit without general anesthesia. The need for re-sternotomy in the direct technique and foreign graft material left in the graft technique may result in increased infection risks. In a study including 39 patients who underwent transthoracic support with a graft, McGeehin et al.[11] found the incidence of mediastinal infection associated with the procedure to be 2.5%. Postoperative mediastinitis requiring graft removal and debridement developed in one of our patients (1/28). Postoperative mediastinal hemorrhage is another problem, as IABP provides another invasive site for potential postoperative mediastinal bleeding. The reported incidence of this potentially fatal complication is 3.6%.[3] In our study, there was only one episode of postoperative mediastinal hemorrhage which was directly related to the IABP (1/28). Aberrant cannulation is another risk for both techniques, which should be eliminated by using fluoroscopy or TEE.[12] A higher incidence of a ruptured transthoracic balloon has been reported, possibly related to calcified aortic plaques, balloon fatigue or damaged balloon during its placement.[3] In our experience, we observed only a single case of balloon rupture. If the transthoracic route has to be done, we recommend inserting the IABP by direct cannulation, considering the serious complications after IABP insertion reported in the literature .

The transaxillary route is another alternative technique which we preserve for our patients who need IABP after surgery. The results of this technique are not definitively known, since most studies have small sample sizes with a limited number of case reports.[4,5,17,18] There are mainly two techniques reported: one, in which a graft was sewn and the catheter was passed through it to the descending aorta, was used in relatively elective conditions (4/10 patients) to increase ambulation and upper extremity blood supply. The direct Seldinger technique was used (6/10 patients) in the emergency setting. We routinely used the right axillary artery for the insertion, as the majority of the cases were post coronary artery bypass surgery patients and using the left axillary artery, at least in theory, may interfere with the left thoracic artery blood flow. Potential complications of transaxillary insertion are ischemia of the ipsilateral extremity, balloon rupture, bleeding, neurologic or ischemic complications due to embolization and infection. In our series, the only complication we encountered was balloon rupture during the insertion.

Our results showed that the insertion of an IABP, either through the ascending aorta or the axillary artery, is not associated with significantly increased complications or mortality rates, compared to the femoral insertion. Based on our experience in the operating room, for patients who were unable to be weaned from the pump, we recommend the grafted axillary/subclavian approach if the transfemoral route is not suitable, to prevent arm ischemia. We also suggest utilizing the direct subclavian approach for patients who can be weaned from the pump, but suffering from hemodynamic problems despite the inotropic support. Timing is also of utmost importance. Furthermore, we recommend the urgent subclavian approach in patients with low cardiac output in the ICU. Similarly, we preferred the transthoracic route in the presence of hemodynamic problems and an emergency to introduce the balloon or when all the other alternative approaches were exhausted. In addition, we believe that extremity ischemia is not a prohibiting factor to the use of alternative routes.

On the other hand, the limitation of the present study lies in its retrospective design. The authors also reported that the perioperative inability to insert the device and some minor complications, like thrombocytopenia, were not recorded.

In conclusion, patients with severe peripheral atherosclerosis or distal abdominal aortic aneurysms, previously considered at high risk for complications or even absolutely contraindicated for IABP, can safely and effectively benefit from IABP assistance, using an alternative technique. We believe that all of the alternative approaches should be added to the surgical armamentarium. However, further large-scale studies are needed to validate the advantages and disadvantages of these approaches.

Declaration of Conflicting Interest

The authors declare that there is no conflict of interest.

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