Techniques

Direct Cannulation of the Infrahepatic Vena Cava for Emergent Cardiopulmonary Bypass Support

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Cannulation for cardiopulmonary bypass, although seemingly routine, can pose technical challenges. In patients undergoing repeat sternotomy, for example, peripherally established cardiopulmonary bypass may be necessary to ensure safe entry into the chest; however, establishing bypass in this way can sometimes be complicated by patients' body habitus. We describe a technique for direct cannulation of the infrahepatic abdominal vena cava that was required for emergent cardiopulmonary bypass. The patient was a 62-year-old woman who had presented with severely symptomatic left main coronary stenosis 3 months after elective aortic valve replacement. She had gone into cardiogenic shock as general anesthesia was being induced for repeat sternotomy and myocardial revascularization. Emergent establishment of femorofemoral cardiopulmonary bypass was precluded by difficulties in advancing the femoral venous cannula beyond the pelvic brim. Hence, an emergent celiotomy was performed, and the abdominal vena cava was directly cannulated to establish venous drainage for cardiopulmonary bypass. The rest of the operation was uneventful. Our technique for direct cannulation of the infrahepatic abdominal vena cava may be used in exceptional circumstances. Necessary precautions and potential pitfalls are also presented. ***(Tex Heart Inst J 2009;36(4):316-20)***

Key words: *Cardiopulmonary bypass/instrumentation/methods; shock, cardiogenic; vena cava, inferior*

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Cannulation for cardiopulmonary bypass (CPB), although seemingly routine, can at times pose technical challenges. Many new cannulation methods have been developed during the past decade, such as axillary artery cannulation, direct brachiocephalic artery cannulation, aortic arch cannulation, and descending aortic cannulation.[1,2] Venous drainage is typically accomplished through dual-stage right atrial cannulation, bicaval cannulation, femoral venous cannulation, or, for minimally invasive approaches, a combination of femoral and internal jugular cannulation.[3] Single percutaneous dual-stage venous cannulation has recently emerged as an excellent technique for peripheral CPB.[4] Axillary vein cannulation, in certain circumstances, has also been reported.[5] We describe a technique of direct cannulation of the infrahepatic abdominal vena cava that was necessary to emergently establish CPB.

Case Report

In February 2008, a 62-year-old woman presented at our institution with recurrent episodes of unstable angina 3 months after undergoing uneventful, elective, subaortic myocardial resection and aortic valve replacement with a 21-mm Toronto valve (St. Jude Medical, Inc.; St. Paul, Minn) for symptomatic aortic valve stenosis. Coronary angiography performed 3 months before the aortic valve replacement had revealed only mild left main stenosis. Concurrent medical problems included hypertension and hyperlipidemia, which were well controlled medically. The patient was of small stature, being 5'2" (157 cm) tall and weighing 66.2 kg (body mass index, 27.5 kg/m^2).

A few weeks after the initial aortic valve replacement, the patient had recurrent episodes of worsening unstable angina pectoris, which significantly hampered her daily activities. A repeat coronary angiogram at this time revealed severe stenosis of the left main coronary artery. The rapid progression of the left main stenosis seemed unlikely to be related to the aortic valve replacement, because myocardial protection had predominantly involved retrograde cardioplegia, and direct coronary perfusion catheters had not been used during the procedure. A review of the patient's previous coronary angiograms revealed that the tip of the coronary catheter had impinged on the side-

wall of the left main coronary artery, which could have contributed to intimal injury and the consequent progression of stenosis. The patient was immediately scheduled for myocardial revascularization.

Surgical Technique

During the induction of general anesthesia, the patient went into cardiogenic shock, and cardiopulmonary resuscitation was begun immediately. An intra-aortic balloon pump (IABP) was inserted via the right femoral artery, while a simultaneous cutdown was performed on the contralateral femoral vessels to establish femorofemoral CPB. After heparin was administered, the femoral artery was cannulated with a 19F Bio-Medicus® arterial cannula (Medtronic, Inc.; Minneapolis, Minn) with no technical problems. However, when we attempted to insert the venous catheter via the left femoral vein, we could not advance the dual-stage 24/29F percutaneous venous cannula (Medtronic) over the guidewire past the pelvic brim, which precluded femorofemoral CPB. We then attempted to cannulate the right femoral vein and encountered similar difficulties. Subsequently, we advanced a single-stage 24F venous cannula (Edwards Lifesciences, LLC; Irvine, Calif) up to the level of the pelvic brim; however, upon initiation of CPB, we discovered that drainage was inadequate. At that point, despite spontaneous resumption of myocardial electromechanical activity, the patient needed high doses of inotropic medications to maintain cardiac output.

Given the urgency of the situation, an emergent midline celiotomy was performed, followed by a limited Cattell-Braasch maneuver (Fig. 1). The aortic bifurcation and the abdominal vena cava were exposed transperitoneally just above the confluence of the common iliac veins (Fig. 2).[6] A purse-string suture of 5-0 Prolene was placed directly on the vena cava (Fig. 3). A 16-gauge

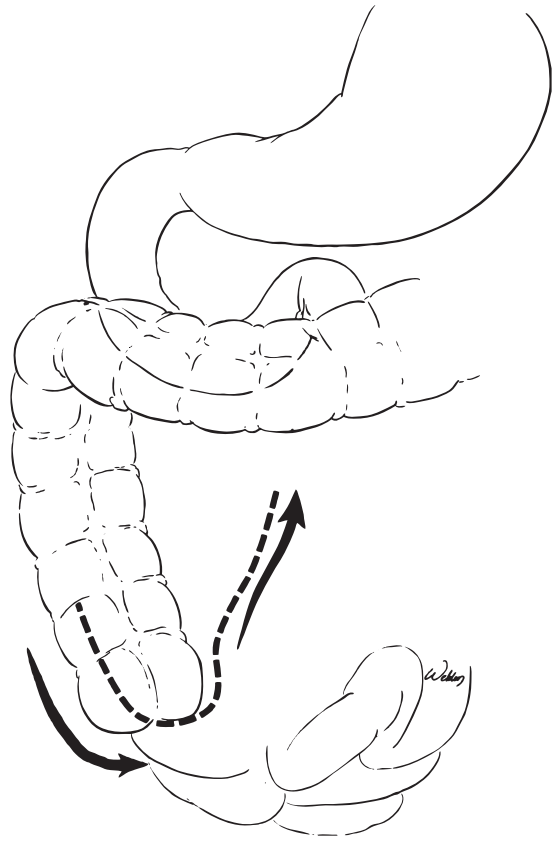

Fig. 1 *Incision for limited Cattell-Braasch maneuver used to expose the inferior vena cava at the confluence of the common iliac veins. The peritoneal reflection of the cecum and proximal ascending colon is incised at the retroperitoneal attachments and along the white line of Toldt (dotted line). Modified by Raja R. Gopaldas, MD, from illustrations originally published in Hirshberg A, Mattox KL.* Top Knife: The Art and Craft of Trauma Surgery. *Shrewsbury (UK): Castle Hill Barns; 2004. Permission to reprint granted by editors and artist.*

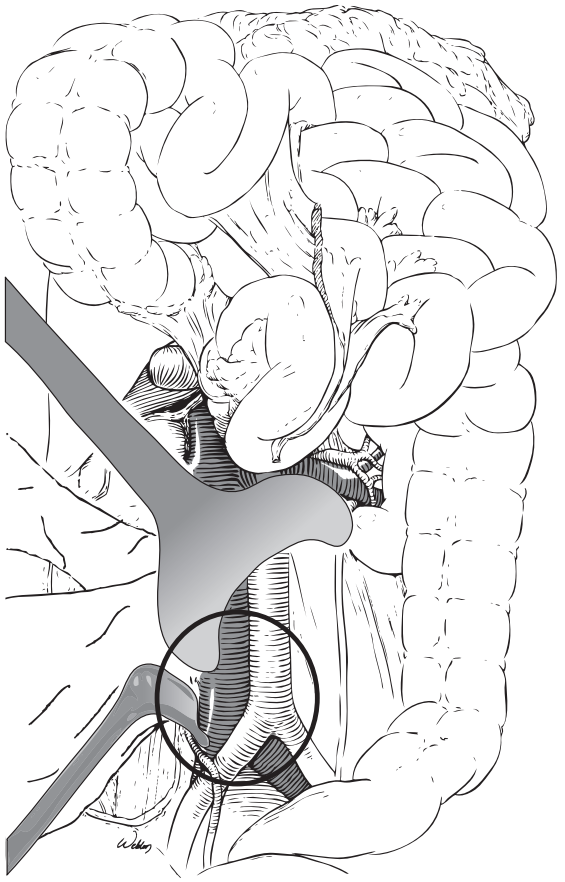

Fig. 2 *Transperitoneal limited exposure of the inferior vena cava (IVC) above the aortic bifurcation (circle). Extensive exposure of the IVC is not required as long as there is enough room to safely place a cannula or, if necessary, a side-biting clamp. Modified by Raja R. Gopaldas, MD, from illustrations originally published in Hirshberg A, Mattox KL.* Top Knife: The Art and Craft of Trauma Surgery. *Shrewsbury (UK): Castle Hill Barns; 2004. Permission to reprint granted by editors and artist.*

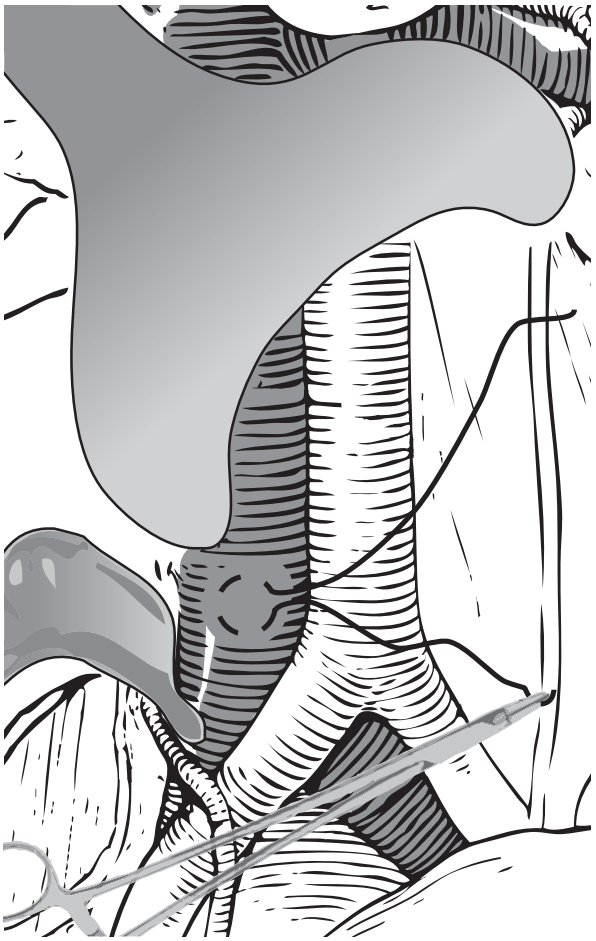

Fig. 3 *Placement of purse-string suture for cannulation; 5-0 Prolene is used. The diameter of the purse-string should be large enough to admit the cannula but not so large as to compromise luminal diameter. Modified by Raja R. Gopaldas, MD, from illustrations originally published in Hirshberg A, Mattox KL.* Top Knife: The Art and Craft of Trauma Surgery. *Shrewsbury (UK): Castle Hill Barns; 2004. Permission to reprint granted by editors and artist.*

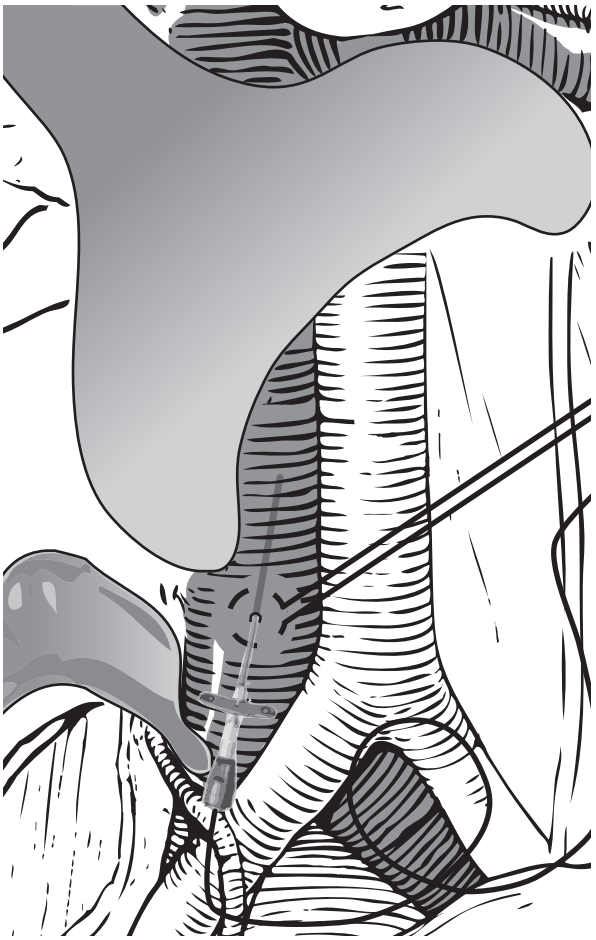

Fig. 4 *Insertion of a 16-gauge needle and guidewire into the vena cava at the center of the purse-string. This enables controlled dilation for gaining entry into the vena cava and prevents unnecessary manipulation during insertion of the large-bore venous cannula. Modified by Raja R. Gopaldas, MD, from illustrations originally published in Hirshberg A, Mattox KL.* Top Knife: The Art and Craft of Trauma Surgery. *Shrewsbury (UK): Castle Hill Barns; 2004. Permission to reprint granted by editors and artist.*

introducer needle was inserted at the center of the purse-string suture, and the dual-stage 24/29F percutaneous venous cannula was advanced into the vena cava with use of the Seldinger technique (Fig. 4). The dilator and guidewire were removed while the cannula was secured with a Rummel tourniquet on the purse-string suture and connected to the CPB circuit (Fig. 5). The position of the cannula in the right atrium was confirmed by transesophageal echocardiography. We achieved excellent venous drainage and established total CPB with high flows of 50 mL/kg throughout the operation. The patient was cooled to 30 °C while re-entry into the chest and myocardial dissection were accomplished. After the ascending aorta was cross-clamped, diastolic cardioplegic arrest was achieved with a combination of antegrade and retrograde blood cardioplegia. Because of the emergent nature of the operation, a saphenous vein graft was used to create an aortocoronary bypass to the left anterior descending coronary artery and the largest obtuse marginal branch of the circumflex artery. The anastomoses were completed expeditiously to facilitate myocardial reperfusion and recovery during the rewarming phase. Once spontaneous sinus rhythm had resumed, the patient was successfully weaned from CPB, although she still needed physiologic support by epinephrine and an IABP.

Decannulation was accomplished without difficulty. A 2nd suture with felt buttresses was used to reinforce the cavotomy and to ensure thorough hemostasis. All arteriotomies and venotomies were appropriately repaired, and the incisions were closed in the standard manner.

The patient's subsequent course in the intensive care unit was uneventful. She was weaned from the inotropic medications shortly after the operation, and the

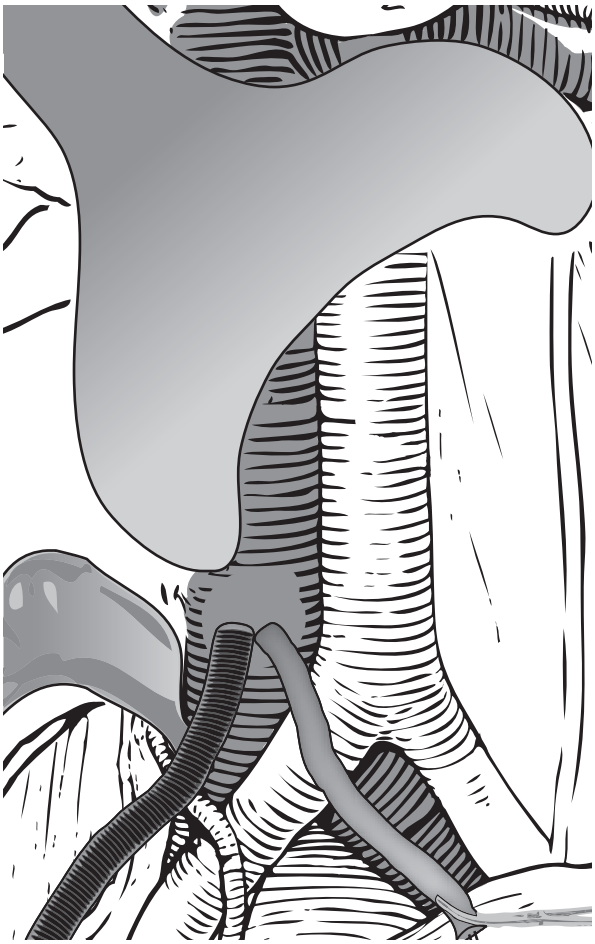

Fig. 5 *Final position of the dual-stage venous cannula after it is inserted via the Seldinger technique and secured with a Rummel tourniquet. To prevent back-bleeding or air-entrainment, care must be taken to ensure that the hole in the inferior vena cava does not extend beyond the confines of the purse-string. The position of the tip of the cannula in the right atrium may be confirmed with transesophageal echocardiography. Modified by Raja R. Gopaldas, MD, from illustrations originally published in Hirshberg A, Mattox KL.* Top Knife: The Art and Craft of Trauma Surgery. *Shrewsbury (UK): Castle Hill Barns; 2004. Permission to reprint granted by editors and artist.*

IABP was discontinued within 48 hours. The patient was discharged from the hospital on the 16th postoperative day. She was doing well at follow-up 1 month after surgery. Four months postoperatively, symptomatic narrowing developed in the vein conduit to the left anterior descending coronary artery. This narrowing was successfully treated by percutaneous coronary intervention. The patient was doing well at her most recent follow-up visit, 1 year after the operation.

Discussion

The ability of surgeons to perform increasingly complex procedures over time has fostered the adaptation of existing CPB techniques to particular circumstances. Establishing venous drainage is often the most difficult part of an emergent cannulation. The most commonly used venous cannulation technique involves introducing a dual-stage cannula into the right atrium.[3] For procedures that may require access to the right side of the heart, bicaval cannulation techniques are used to completely isolate the venous return to the heart without risking airlock during CPB. Irrespective of the technique used, the tip of the venous cannula must lie directly parallel to the walls of the vena cava or within the right atrium.[7] The farther the venous cannula tip is from the right atrium, the more important it becomes to ensure that the tip is positioned properly to maintain adequate drainage. In particular, patients with small stature (as in our patient) or low body mass index (such as pediatric patients) are more difficult to cannulate, especially with bicaval techniques.

Closed-chest CPB, typically accomplished by femoral vessel cannulation, was first used at the Mayo Clinic in the 1960s to establish hypothermic circulatory arrest for neurosurgical interventions.[8] Currently, closed-chest CPB is typically used as a safeguard during difficult reentries into the chest.[9] During the past decade, percutaneous approaches to venous cannulation have been in vogue, particularly for minimally invasive procedures. Establishing percutaneous venous drainage via the left femoral vein usually requires the advancement of a guidewire into the inferior vena cava (IVC) because of the more angulated course of the vein over the pelvic brim.[10] However, a guidewire may not always be necessary when the right femoral vein is cannulated.[11] Typically, the femoral venous cannula is a long, dual-stage cannula with a primary drainage site at the tip and a secondary drainage site that is designed to be positioned at the level of the renal veins. Sometimes during the operation, after the heart is adequately exposed and mobilized, it is necessary to place a 2nd cannula in either the jugular vein or the right atrium in order to establish full flows.[4] Kinetic and vacuum assistance are helpful adjuncts to venous drainage when smaller-caliber percutaneous cannulas are used.[12]

In our case, establishing venous drainage via either femoral vein was impossible because of the patient's small stature, which anatomically precluded advancement of the venous cannula into the right atrium. Nonetheless, the patient's rapid clinical deterioration necessitated the expeditious establishment of total CPB. Hence, we immediately proceeded with a celiotomy and direct cannulation of the IVC. When a dual-stage percutaneous venous cannula is placed directly in the abdominal IVC, one has to ensure that both stages of the cannula are positioned within the lumen of the vena cava. Of note, the cannula need not be advanced as far as usual during direct cannulation of the IVC as long as proper placement of the 2nd stage is ensured. We used the Seldinger technique to advance the can-

nula into the vena cava, because this technique is a very controlled method of entry and minimizes the amount of uncontrolled blood loss during cannulation. Moreover, the size of the venotomy typically conforms to the size of the cannula as it is simultaneously dilated and advanced into the lumen. The usual stab-and-cannulate method used in other vessels is not ideal for cannulating the abdominal vena cava because it increases the risk of back-bleeding and entails additional manipulation that increases the risk of caval injury. Because the infrahepatic abdominal vena cava is much more delicate than the supradiaphragmatic vena cava, we believe that the stab-and-cannulate method poses a high risk of inadvertent enlargement of the venotomy beyond the confines of the purse-string suture, which leads to uncontrollable bleeding and potential airlock. Felt pledgets on the cannulating purse-string suture function as a buttress to prevent enlargement of needle holes that could contribute to bleeding. The purse-string on the vena cava should be slightly larger than the venous cannula, in order to prevent any tears that occur during dilation of the entry site from extending beyond the confines of the suture and causing uncontrolled bleeding.

Because a significant volume of venous blood from the lower extremity constantly travels past the cannulation site in the abdominal vena cava to reach the sump holes of the venous cannula, the risk of bleeding is greatest at the cannulation site. Hence, it is important to check the abdominal cavity at appropriate intervals to ensure that there is no substantial loss of circulating blood through an improperly secured caval cannula. It is also essential that the venous cannula be firmly secured with a suture to the abdominal fascia to avoid unnecessary manipulation. Once decannulation has been accomplished, it is prudent to use pledgeted reinforcements to secure the integrity of the repair.

Conclusion

Direct cannulation of the abdominal vena cava can be accomplished to establish CPB in rare, dire circumstances in which CPB cannot be established expeditiously in the conventional manner. This technique is challenging and requires close attention to technical details. The caval cannulation site has to be kept as low as possible in the abdomen but away from the confluence of the veins. Keeping the cannulation site low also avoids any unnecessary retroperitoneal dissection. The venous cannula should be thoroughly secured to avoid avulsion, catastrophic bleeding, and failure of CPB.

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