Original article

**Transesophageal echocardiography guided cannulation for peripheral cardiopulmonary bypass during robotic cardiac surgery**

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**Keywords**: transesophageal echocardiography; cardiopulmonary bypass; robotic cardiac surgery

**Background**

Minimally invasive cardiac surgery and closed chest cardiopulmonary bypass (CPB) techniques continue to evolve. Previous reports have demonstrated the benefits of fluoroscopy guided cannulation for endovascular CPB during port access cardiac surgery. However, few data are available on the role of transesophageal echocardiography (TEE) guided cannulation for peripheral CPB during robotic cardiac surgery. The purpose of this study was to evaluate TEE guided cannulation for peripheral CPB during robotic cardiac surgery.

**Methods**

We performed a retrospective analysis of intraoperative data of 129 consecutive patients underwent robotic cardiac surgical procedures requiring peripheral CPB from September 2007 to August 2011, which was established using femoral arterial inflow and kinetic venous drainage by way of the femoral vein and right internal jugular vein and a transthoracic aortic cross clamp. TEE was used to guide cannulation of the inferior vena cava (IVC), superior vena cava (SVC), and ascending aorta (AAO). The success rate and the complication rate of TEE guided cannulation for peripheral CPB were evaluated and compared with the results of fluoroscopy guided cannulation in a historical control group.

**Results**

One hundred and twenty-nine consecutive patients underwent robotic cardiac surgical procedures requiring peripheral CPB. There were 67 female (51.9%) and 62 male (48.1%) patients, ranging in age from 13 to 70 years (mean (43.94 ± 13.82) years) and body surface area 1.32 to 2.39 m² (mean (1.71 ± 0.20) m²). Some 61 (47.3%) patients underwent mitral valve repair, 27 (20.9%) mitral valve replacement, 27 (20.9%) left atrial myxoma removal, and 14 (10.9%) ventricular septal defect repair. Of the 129 patients, TEE guided cannulation of the IVC or SVC was successful in all patients (100%), and no puncture related complications occurred in all patients. Of the 129 patients, successful cannulation of the AAO was achieved in all patients (100%), and aortic perforation occurred in 1 patient (0.78%) under TEE guidance. Of the 42 patients in the historical control group, successful cannulation occurred in 39 patients (92.86%), and major complications occurred in 3 patients (7.14%) under fluoroscopy guidance. TEE guided cannulation of the AAO significantly improved success rate (100% vs. 92.86%, P=0.014) and decreased complication rate (0.78% vs. 7.14%, P=0.046).

**Conclusion**

TEE may be useful in guiding successful placement of the cannulae in the IVC, SVC, and AAO in the establishment of peripheral CPB during robotic cardiac surgery.

Conventional cardiac surgery has been performed via median sternotomy, which provides optimal access to all cardiac structures and the great vessels and allows central cannulation for cardiopulmonary bypass (CPB) under direct vision. Minimally invasive cardiac surgery and closed chest CPB techniques continue to evolve. Initially, efforts involved a limited parasternal incision with standard CPB.1,2 Subsequently, port access was used combined with endovascular CPB system, which used femoral arterial and venous access for CPB and a transfemoral endoaortic occlusion catheter.3 Currently, with the development of the Da Vinci robotic system, minimally invasive cardiac surgery can be performed through small port sites with peripheral CPB, which is established using femoral arterial inflow, kinetic venous drainage by way of the femoral vein and right internal jugular vein and a transthoracic aortic cross clamp.1 Previous reports have demonstrated the benefits of fluoroscopy cannulation for endovascular CPB,5-8 but few data are available on the utility of transesophageal echocardiography (TEE) guided cannulation for peripheral CPB. Therefore, the aim of this study was to evaluate TEE guided cannulation for peripheral CPB during robotic cardiac surgery, and compared the results with that of fluoroscopy guided cannulation in a historical control group.

**METHODS**

**Patients**

We retrospectively reviewed all records of 129 patients. We excluded patients who underwent median sternotomy for cardiac surgery, patients with previous sternotomy, and patients with previous sternotomy for non-cardiac surgery. We also excluded patients who underwent concomitant procedures such as coronary artery bypass grafting, valve replacement, and aortic surgery. The demographic characteristics of the patients are presented in Table 1. There were 67 female (51.9%) and 62 male (48.1%) patients, ranging in age from 13 to 70 years (mean (43.94 ± 13.82) years) and body surface area 1.32 to 2.39 m² (mean (1.71 ± 0.20) m²). Some 61 (47.3%) patients underwent mitral valve repair, 27 (20.9%) mitral valve replacement, 27 (20.9%) left atrial myxoma removal, and 14 (10.9%) ventricular septal defect repair. Of the 129 patients, TEE guided cannulation of the IVC or SVC was successful in all patients (100%), and no puncture related complications occurred in all patients. Of the 129 patients, successful cannulation of the AAO was achieved in all patients (100%), and aortic perforation occurred in 1 patient (0.78%) under TEE guidance. Of the 42 patients in the historical control group, successful cannulation occurred in 39 patients (92.86%), and major complications occurred in 3 patients (7.14%) under fluoroscopy guidance. TEE guided cannulation of the AAO significantly improved success rate (100% vs. 92.86%, P=0.014) and decreased complication rate (0.78% vs. 7.14%, P=0.046).
consecutive patients who underwent robotic cardiac surgical procedures requiring peripheral CPB at our institute from September 2007 to August 2011. The study conforms to local institute ethics guidelines and the principles outlined in the Declaration of Helsinki. Informed consent from all the patients was obtained for the surgery.

Surgical procedure
All procedures were performed with peripheral CPB, transthoracic aortic crossclamp, and antegrade cardioplegia utilizing the da Vinci S Surgical System (Intuitive Surgical, Inc., Sunnyvale, Calif, USA).

TEE guided cannulation for peripheral CPB
All the cannulae in the inferior vena cava (IVC), superior vena cava (SVC), and ascending aorta (AAO) were placed under TEE guidance. The TEE was performed using a Vivid 7 ultrasound system (GE Medical Systems, Horten, Norway), which equipped with a 2.9 to 6.7 MHz 6T multiplane transesophageal phased array probe. After induction of anaesthesia, a left sided double lumen endotracheal intubation and cannulation of the right internal jugular vein, the TEE probe was inserted into the mid esophagus.

TEE guided cannulation of the IVC
The intrahepatic IVC view (70 to 90 degrees) and the mid esophageal bivacal view (80 to 110 degrees) were obtained in turn. A guidewire was inserted through a cutdown into the right femoral vein. The guidewire was guided by TEE into the IVC, and then guided into the right atrium (RA). Pass a femoral venous cannula (Fr23, Medtronic, Inc, Minneapolis, MN, USA) over the guidewire with its distal end parallel to the IVC wall and its distal tip positioned at or above the IVC/RA junction (Figure 1), and then removed the guidewire.

TEE guided cannulation of the SVC
The mid esophageal bivacal view (80 to 110 degrees) was obtained. Under TEE guidance, a guidewire was advanced into the RA via the cannula in the right internal jugular vein and then the cannula was removed, and an arterial cannula (Fr20, Medtronic, Inc, Minneapolis, MN, USA) was inserted over the guidewire with the distal end of the cannula parallel to the SVC wall and its distal tip positioned at or above the SVC/RA junction (Figure 2). The guidewire was then removed.

TEE guided cannulation of the AAO
The mid esophageal aortic valve long-axis view (120 to 160 degrees) was obtained. After cross clamping of the AAO, an angiocath (a cannula adapted for antegrade administration of cardioplegic solution) (Becton Dickinson Infusion Therapy Systems Inc., Sandy Utah) was inserted into the AAO via the fourth intercostal space, with its distal tip located in the aortic root under TEE guidance. Color flow imaging was used to indicate whether the angiocath was following the appropriate course, and rapid flush of the cardioplegic solution was used to identify the tip of the angiocath (Figure 3).

The sizes of the cannulae were determined by the patient’s body surface area and circulatory requirements. We defined TEE guided cannulation as successful if the cannula in the IVC or SVC was verified at the desired position by the surgeon during the operation and without puncture-related complications occurred, and if the angiocath in the AAO was verified in place and without aortic regurgitation and puncture related complications.
occurred during administering of the cardioplegic solution.

**Statistical analysis**

Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were presented by frequency or percentage. Continuous variables were compared using Student’s t test for unpaired samples. Categorical variables were compared using chi-square or Fisher’s exact test as appropriate. A P value <0.05 was considered significant. Statistical analyses were performed using SPSS 16.0 for Windows (SPSS Institute Inc., Chicago, USA).

**RESULTS**

From September 2007 to August 2011, 129 consecutive patients underwent robotic cardiac surgical procedures requiring peripheral CPB at our institute. There were 67 female (51.9%) and 62 male (48.1%) patients, ranging in age from 13 to 70 years (mean (43.94 ± 13.82) years) and body surface area 1.32 to 2.39 m² (mean (1.71 ± 0.20) m²). Sixty-one (47.3%) patients underwent mitral valve repair, 27 (20.9%) mitral valve replacement, 27 (20.9%) left atrial myxoma removal, and 14 (10.9%) ventricular septal defect repair.

Of the 129 patients, TEE guided cannulation of the IVC or SVC was successful in all patients (100%), and no puncture related complications occurred in all patients. Of the 129 patients, successful cannulation of the AAO was achieved in all patients (100%), and aortic perforation occurred in 1 patient (0.78%) under TEE guidance. Of the 42 patients in the historical control group, successful cannulation occurred in 39 patients (92.6%), and major complications occurred in 3 patients (7.14%) under fluoroscopy guidance. TEE guided cannulation of the AAO significantly improved success rate (100% vs. 92.86%, P=0.014) and decreased complication rate (0.78% vs. 7.14%, P=0.046).

**DISCUSSION**

Traditional cardiac surgery has been performed by median sternotomy. Robotic assisted minimally invasive cardiac operations are being performed through smaller incisions with advances in cardiopulmonary perfusion and robotic instrumentation. Robotic-assisted techniques can be used for a variety of cardiac procedures. To date, we have completed 129 procedures with the da Vinci S system, including mitral valve repair (47.3%), mitral valve replacement (20.9%), left atrial myxoma removal (20.9%) , and ventricular septal defect repair (10.9%).

Our results indicate that TEE can be used to guide successful placement of the cannulae in the IVC and SVC in all patients during establishment of peripheral CPB, and there were no puncture related complications occurred. TEE may provide direct visualization of the guidewire and cannula in the IVC and SVC. Under TEE guidance, the guidewire and cannula are always seen clearly entering the RA from IVC or SVC because they are positioned perpendicular to the ultrasound beam in the RA. In addition, the higher resolution of TEE and proximity to the guidewire and cannula make their imaging easier and their relation to the surrounding anatomic structures clearer.

The study shows that TEE can be used to guide successful placement of the angiocath in the AAO, and aortic perforation occurred in one patient under TEE guidance. TEE may also provide clear visualization of the AAO along the puncture tract during the period of the angiocath is placed. This enables the operator to avoid damaging the AAO which is not the case in angiographic fluoroscopic guidance. However, the angiocath in the AAO is often difficult to visualize because the angiocath is always in the oblique position to the ultrasound beam and its surface is smooth and reflect the ultrasound away from the transducer. We found that color flow imaging was helpful for following its course and rapid flush of the cardioplegic solution into the angiocath for locating its tip.

Every CPB procedure requires high-flow cannulae in the IVC and SVC for withdrawing blood from the RA of the patient. An improperly positioned venous cannula will obstruct the flow of blood into the extracorporeal circuit. This may elevate central venous pressure and encourage extravasation of blood volume from the vascular compartment into the extracellular compartment. Most robotic cardiac procedures include additional cannulation of the angiocath in the AAO for administering cardioplegia solution to the heart. During the period when the AAO is cross-clamped, if the blood is not removed, the blood volume will distend the left side of the heart and the pulmonary vasculature.

To perform robotic cardiac procedures through small port sites, surgeons need to operate in a restricted space, and peripheral vessel cannulation for CPB has been used. Successful placement of the cannula in the IVC or SVC is essential to maintain adequate venous drainage and ensure good visualization in the operative field. Successful placement of the angiocath in the AAO is essential to prevent aortic regurgitation and left ventricular distention, or an inability to adequately arrest the heart. The surgeon is blind to the appropriate positioning of the cannulae because of the limited surgical access. Reliable surface landmarks are lacked for surgeons to position the cannulae accurately without diagnostic testing, and the landmark-guided technique is associated with potential problems at the cannulation sites, including perforation or rupture of the vessels and intimal tear with retrograde dissection. Routine use of fluoroscopy would lengthen operative time and expose the patients and staff to extra irradiation. TEE may
provide direct visualization of the target vessels and cannulae. The present study shows that, successful placement of the cannulae in the IVC, SVC and AAO can be easily achievable by means of TEE guidance. The ability to guide their successful placement by TEE during insertion could help to eliminate the potential complications during robotic cardiac surgery.

In conclusion, TEE may be useful in guiding successful placement of the cannulae in the IVC, SVC, and AAO in the establishment of peripheral CPB during robotic cardiac surgery.

REFERENCES


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