

Transesophageal Echocardiography or Fluoroscopy During Port-Access Surgery?

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Abstract

Introduction: In Port-Access cardio-surgical procedures, both intraoperative transesophageal echocardiography (TEE) and fluoroscopy can be used for placement of the catheters and cannulae needed for cardiopulmonary bypass. Our study sought to clarify whether it is possible to rely exclusively on TEE for catheter placement without increasing the risk for the patient. **Materials and Methods:** Forty patients underwent cardiac surgery with the Port-Access system. Fluoroscopy as well as TEE were used for placement of the transjugular and transfemoral catheters required for cardiopulmonary bypass. The time required for fluoroscopy was recorded, as were any complications during cannulation and cardiopulmonary bypass. **Results:** The average fluoroscopy time was 10.7 ± 12.1 min. Fluoroscopy time required for placement of the coronary sinus and pulmonary vent catheters could be reduced to zero early in the course of the study. Once we had gained enough experience with TEE, fluoroscopy for placement of the transfemoral catheters was also no longer necessary. During cannulation, 3 patients suffered complications requiring immediate surgical intervention. These complications were all diagnosed by TEE. **Conclusion:** Our data suggest that positioning of the coronary sinus and the pulmonary vent catheters is safe and practicable with TEE alone. Nonetheless, if TEE imaging is poor or fails, fluoroscopy has still a place in Port-Access surgery and should always be available intraoperatively.

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Introduction

Minimally invasive techniques are increasingly being used in cardiac surgery. In particular, coronary artery bypass grafting (CABG) and mitral valve surgery are now often done using a limited approach to the heart. The Port-Access technique is widely used in such procedures to establish cardiopulmonary bypass (CPB) by cannulating the aorta and the right atrium by way of the femoral vessels. The two other catheters that are required for the technique, a coronary sinus catheter (CSC) and a pulmonary vent (PV), are introduced via the internal jugular vein by the anaesthesiologist.^{1,2} Correct positioning of the catheters is imperative for a successful and safe procedure and can be controlled by either intraoperative X-ray or by transesophageal echocardiography (TEE).

The aims of this study were to evaluate and compare the use of fluoroscopy and TEE for confirmation of catheter position in Port-Access procedures. In particular, we tried to determine whether catheter placement can be done

safely by TEE alone to avoid intraoperative fluoroscopy and hence exposure to radiation for both patient and operating room personnel.

Materials and Methods

After having given informed consent, 40 consecutive patients [American Society of Anesthesiologists (ASA) physical status II-IV] underwent cardiac surgery with the Port-Access system (Heartport, Redwood City, CA) by a submammary minithoracotomy performed either on the left or on the right. Thirty-three patients had 2-vessel coronary artery disease and 6 had severe mitral valve insufficiency. One patient was admitted for atrial septal defect (ASD) closure. On the day before surgery, all patients had transthoracic echocardiography to evaluate the ascending aorta, aortic valve and left ventricular function. Occlusive disease of the femoral vessels was ruled out by Doppler sonography. Patients were not selected for Port-Access technique if certain contraindications applied (Table I).

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TABLE 1: EXCLUSION CRITERIA FOR PORT ACCESS CARDIAC SURGERY

- body weight <40 kg
- severe atherosclerosis of femoral or iliac arteries
- history of stroke
- history of or present neurological disease
- diameter of the ascending aorta <22 mm
- aortic aneurysm type Stanford A or B
- aortic valve insufficiency or combined failure III° or IV°

Catheter Placement

After induction of anaesthesia, the anaesthesiologist introduced a CSC and a PV through the internal jugular vein using 2 introducer sheaths. The CSC is necessary for retrograde application of cardioplegia when antegrade cardioplegia is unlikely to result in sufficient myocardial protection (e.g. in patients with diffuse coronary sclerosis, mainstem stenosis, or aortic valve insufficiency). During CPB, the PV returns blood not drained by the femoral venous cannula, which is introduced by the surgeon in Seldinger's technique into the right atrium through the femoral vein. The blood drawn by this cannula is loaded with oxygen by passing the oxygenator and then returned into the circulation by a femoral arterial return cannula. The application of antegrade cardioplegia is done with a special 3-lumen catheter with an inflatable balloon at its tip that functions as an aortic cross-clamp. This catheter is also placed through the femoral artery and is advanced through the ascending aorta slightly distally up to the ostia of the coronary arteries.

TEE and Preoperative Period

After induction of anaesthesia, the TEE probe was introduced by the anaesthesiologist. Initially, the ascending aorta and the aortic valve were examined in two transesophageal planes (0°, 90°-120°). Subsequently, the descending aorta was visualised in 2 planes as were the distal aortic arch and the renal arteries. Moreover, a cursory evaluation of global left and right ventricular function was done. For placement of the CSC, the transesophageal bicaval view was used (110°-130°) and a second anaesthesiologist advanced the catheter under echocardiographic control into the ostium of the coronary sinus. Unless the catheter tip was clearly identified within the atrium and pointed towards the opening of the sinus, the catheter was not advanced. Once the catheter tip was localised within the ostium, it was advanced farther into the sinus to avoid it being pushed back into the atrium during inflation of the balloon. Control of the catheter position was done by bicaval and cross views as well as by a modified 4-chamber view.

Once the CSC was correctly placed, the PV was advanced into the pulmonary artery trunk by monitoring the characteristic pressure signals. When problems in crossing the tricuspid valve were encountered, TEE was used to determine the position of the catheter tip, and the catheter was advanced under echocardiographic control.

TEE and Intraoperative Period

For placement of the venous cannula by the surgeon, a bicaval echocardiographic view of the right atrium and vena cava was used in order to monitor correct advancement of the guide wire and subsequent positioning of the venous cannula with its tip at the junction of right atrium and superior vena cava. As accidental perforation of the right auricle is a potential danger, as well as deviation through the septum or through the fossa ovalis, we carefully identified position of the catheter tip in the right atrium. After correct placement was confirmed, flow through the cannula was assessed by colour-flow Doppler.

To observe the passage of the intra-aortic balloon catheter, we began with a longitudinal echocardiographic view of the descending aorta to monitor advancement of the guide wire introduced through the femoral artery. Subsequently, a longitudinal view of the left ventricle and ascending aorta was used to monitor correct position of the guide wire within the ascending aorta distally to the aortic valve. Once the balloon catheter was in place and the guide wire was removed, TEE was used again to check the catheter's position and integrity of the aortic valve, the ascending and the descending aorta.

While the endoaortic balloon was inflated, we used TEE to rule out dislocation of the catheter towards the aortic valve or the brachiocephalic trunk. In case of migration of the balloon, the perfusionist and the surgeon were notified immediately. Eventual migration of the inflated balloon during antegrade administration of cardioplegia was also monitored with TEE. If the balloon could not be stabilised, or if antegrade cardioplegia could not be applied adequately, the balloon was repositioned, or retrograde cardioplegia was used in addition.

During aortic clamping, balloon position was continuously monitored with TEE to detect endoclamp migration and accidental occlusion of the brachiocephalic vessels immediately.

In mitral valve surgery, eventual air bubbles in the ventricle were thoroughly looked for before aortic declamping. After separation from CPB, global and segmental left ventricular wall motions were assessed in all patients.

Fluoroscopy was used whenever positioning of the catheters could not be certainly monitored with TEE, and during CPB to confirm correct position of the aortic balloon if this could not be achieved certainly enough with TEE.

Statistical Analysis

All data are presented as mean $\pm$ standard deviation and range. Calculation and data analyses were performed using the statistical package—GraphPad InStat 3.0 (GraphPad Software, San Diego, CA). Statistical significance was determined by using the Wilcoxon-Mann-Whitney U test. Differences were considered to be statistically significant if P was less than 0.05.

Results

A total of 40 patients (16 women, 24 men) underwent cardiac surgery with CPB using the Port-Access system. Thirty-three of these patients underwent CABG, 6 had mitral valve repair and 1 patient presented for atrial septal defect closure. The mean age was 61.7 ± 12.4 years. Minor aortic valve insufficiency was detected on preoperative TEE in 2 patients; however, this did not represent a contraindication for Port-Access surgery. Likewise, no patient scheduled for Port-Access surgery was excluded because of contraindications.

Fluoroscopy Times

In 32 patients, catheter advancement and positioning was checked by continuous fluoroscopy in addition to echocardiography. The average time required for fluoroscopy was 10.7 minutes. Patients receiving coronary artery bypass grafts required significantly more fluoroscopy time than patients undergoing mitral valve repair. The mean fluoroscopy times required for placement of transfemoral and transjugular catheters are listed in Table II.

Twenty patients required continuous fluoroscopy of less than 10 minutes, 5 patients required between 10 and 20 minutes and 7 patients were exposed for more than 20 minutes.

TABLE II: MEAN TIMES OF FLUOROSCOPY (MINUTES) REQUIRED FOR POSITIONING OF TRANSJUGULAR CATHETERS AND FEMORAL CANNULAE FOR CARDIOPULMONARY BYPASS IN PORT ACCESS CARDIAC SURGERY

	n	Total	Jugular catheters (CSC and PV)	Femoral aortic and venous cannulae
All patients	32	10.7 $\pm$ 12.1 (0.8 – 35.9)	7.8 $\pm$ 11.5 (0 – 28.0)	2.9 $\pm$ 1.8 (0.6 – 7.9)
CABG	25	11.7 $\pm$ 12.9 (1.2 – 35.9)	8.5 $\pm$ 12.4 (0 – 28.0)	3.2 $\pm$ 1.8 (0.6 – 7.9)
Mitral valve surgery	6	7.0 $\pm$ 8.6 (0.8 – 24.3)	4.8 $\pm$ 7.3 (0 – 19.4)	2.2 $\pm$ 1.8 (0.8 – 4.9)
ASD closure	1	9.4	7.2	2.2

Data are given as means $\pm$ SD and (range)

ASD: atrial septal defect; CABG: coronary artery bypass grafting;
CSC: coronary sinus catheter; PV: pulmonary vent

In the first 2 patients, placement of the CSC and PV required a total of 28 minutes of fluoroscopy, but total fluoroscopy time declined continuously with each succeeding patient. Beginning with patient 17 it was possible to dispense with the use of fluoroscopy in the placement of the transjugular catheters and rely on echocardiography alone.

Though not statistically significant, fluoroscopy times required for placement of the transfemoral arterial and venous catheters were considerably less as compared to fluoroscopy times during placement of CSC and PV. Similarly, fluoroscopy periods also declined over time, and fluoroscopy was no longer needed in the last 8 patients (Fig 1).

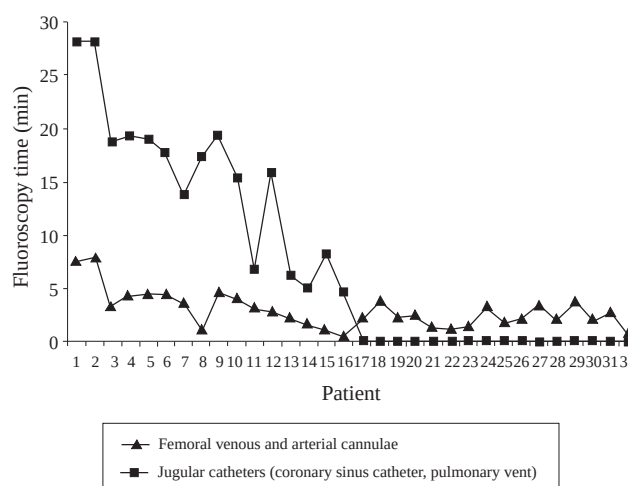


Fig. 1. Fluoroscopy times required in 32 patients for positioning of Port Access catheters and cannulae. Beginning with patient 33, fluoroscopy was forgone.

Complications

During advancement of the intra-aortic balloon catheter, a retrograde dissection of the descending and ascending aorta occurred which was recognised on TEE immediately. Emergency sternotomy with replacement of the ascending aorta and the proximal aortic arch was performed. This procedure was otherwise uneventful, and the patient was extubated on the first postoperative day without neurologic sequelae. Another emergency sternotomy became necessary as a result of accidental perforation of the right atrial appendage with the guide wire of the femoral venous cannula and subsequent intrathoracic bleeding. The third major complication was noted when the patient suffered a rupture of the coronary sinus during the placement of the CSC, also requiring immediate surgical intervention. All of the above complications resulted in a switch to conventional open surgical technique which was performed without problems in all of these 3 patients.

In 5 patients, we observed a dislocation of the initially

correctly placed coronary sinus catheter during routine intraoperative TEE. Repositioning of the catheter was not possible in all the patients. Nonetheless, Port-Access technique could be employed because cardioplegia could be administered efficiently by the antegrade mode. In the patient with atrial septal defect, the venous return cannula was accidentally advanced through the defect into the left atrium. The malposition was immediately detected on TEE and corrected manually by the surgeon.

Finally, routine TEE after separation from CPB showed an unchanged left ventricular function. In 38 patients, the aortic valve was competent. In 2 patients with pre-existing aortic valve insufficiency, no increase in the degree of insufficiency was observed. Three of the 6 patients who underwent mitral valve reconstruction showed minimal, insignificant insufficiency of the mitral valve at the end of the procedure. The atrial septal defect was closed completely with no left-to-right shunt remaining.

Discussion

Perioperative TEE is of established value in the diagnosis and quality control of modern cardiac surgery.³⁻⁵ In particular, TEE is essential in minimally invasive surgery such as Port-Access procedures, because the catheters required for CPB are not readily accessible. An alternative to TEE in these procedures is fluoroscopy.⁶

TEE does not require many personnel and can be done readily and safely, and does not interfere with the surgical procedure.^{7,8} In addition, the extent of atherosclerotic alterations of the aorta can be accurately assessed.⁹ Retrograde dissection of the aorta during cannulation is also rapidly diagnosed.^{10,11} Specifically in minimally invasive procedures, TEE allows rapid assessment of right and left ventricular function, volume status and detection of free air within the ventricle.¹² However, efficient use of TEE in Port-Access procedures requires a high level of experience and expertise on the part of the physician employing TEE, since the relevant events are often of rapid onset and dramatic nature.^{13,14} In contrast, fluoroscopy can usually be operated by qualified operating room personnel. However, the fluoroscopy apparatus is unwieldy and the surgical procedure must be interrupted. In addition, the application of a radiolucent dye is at times necessary, and there is the danger of exposure of operating room personnel and patient to radiation.

In our study, if fluoroscopy was used, fluoroscopy times of at least 20 minutes were needed in 22.6% of the patients, exposing personnel and patients to considerable radiation hazard. In the first 5 patients in our study, fluoroscopy for placement and confirmation of catheter position required the most time when fluoroscopy was used as the primary monitoring method for cannulation. Over time, we were

able to significantly reduce these times as experience and expertise with TEE for Port-Access surgery increased and the surgeon and the anaesthesiologist became more and more confident. On the average, more fluoroscopy time was necessary to place the CSC and PV as compared to the venous and arterial cannulae. However, starting with patient 17 of our series, we were able to place the CSC and PV with TEE alone without resorting to fluoroscopy. Nonetheless, the transfemoral catheters were still placed with the adjuvant help of fluoroscopy until patient 32, but total time required for fluoroscopy decreased constantly. In mitral valve procedures, time required for fluoroscopy decreased the most. It bears emphasis, however, that mitral valve procedures were not done until patient 8. As a consequence, experience with Port-Access procedures already existed. Also, in patients with coronary artery disease, a high degree of generalised atherosclerosis often made placement of venous or arterial cannulae very difficult.

Although one study recommends routine fluoroscopic confirmation of the position of the CSC,¹⁵ we ceased fluoroscopic control after patient 16 in our series and relied on TEE alone. We found that, in contrast to fluoroscopy, TEE also allowed the real-time diagnosis of complications related to the placement of catheters required for CPB. For instance, clockwise rotation of the TEE probe gives a cross-sectional view of the coronary sinus. Rotation of the probe in the opposite direction provides an excellent longitudinal view of the adjacent inferior vena cava. A longitudinal view of the coronary sinus can be achieved using the four-chamber view. It is imperative for the placement of the sinus catheter not to change the echocardiographic view, especially while the catheter is being advanced. A rupture of the coronary sinus can be detected by the observation of the consecutive development of a pericardial effusion.¹⁶ Although a catheter which has migrated during the procedure can also be repositioned under echocardiographic control, we failed in this attempt in all of 5 patients in that migration of the CSC was observed.

Nonetheless, it is important to remember that problems such as a perforation or dissection of femoral vessels or the aortic arch during advancement of the guide wire cannot be diagnosed with TEE alone. This is both due to the large distance of these vessels from the probe as well as poor echogenicity of the tissues.¹⁷ Consequently, we used fluoroscopy whenever there was reason to believe that such a complication had occurred.

During CABG, TEE reliably identifies the position of the intra-aortic balloon catheter relative to the aortic valve. This also holds true for visualisation of the antegrade application of cardioplegic solution. At times, this is quite difficult in mitral valve procedures because the left atrium and the

ascending aorta are often dislocated by the surgeon for better exposure of the mitral valve itself.¹⁵ However, in our series, we did not note a case of secondary migration of the balloon catheter after successful initial placement and occlusion of the aorta. As a result, we believe it is safe to rely on intermittent echocardiographic checks alone and to forgo fluoroscopy altogether. Again, it is imperative that initial placement of the balloon catheter was free of complications, and also that continuous invasive blood pressure monitoring in both radial arteries is present. In individual patients, TEE may not, for a variety of reasons, adequately visualise the relevant anatomy and, hence, it may not be possible to safely place the various catheters. If reliable visualisation of the catheters and cannulae is also impossible with fluoroscopy, we feel that the Port-Access approach should be abandoned and a conventional surgical approach be chosen.

If an atrial septal defect is of large size, the venous cannula is sometimes accidentally advanced through the defect into the left atrium. If the echocardiographer notes this problem, he must inform the surgeon immediately so that the cannula can be repositioned manually under echocardiographic control.

When biplanar TEE probes are used, it is sometimes extremely difficult to adequately visualise the relevant anatomy. Therefore, we believe that for Port-Access procedures multi-planar TEE probes with their wide range of viewing options are the better choice. If TEE is carried out by the anaesthesiologist as in our hospital, a second anaesthesiologist should be available for simultaneous patient monitoring and anaesthetic delivery, while the first concentrates on TEE alone during placement of the cannulae and catheters or checking ventricular function and volume status.¹³

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