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Anesthetic management during minimally invasive cardiac surgery with the Port-Access system for closure of atrial septal defect

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Introduction

Recently, the concept of minimally invasive surgery has been expanding in cardiothoracic surgery. Minimally invasive cardiac surgery is characterized by the avoidance of full sternotomy and minimizing of surgical incision. The advantages of this approach include less postoperative discomfort and earlier mobilization and discharge [1,2]. The Port-Access system (Heartport, Redwood City, CA, USA) is a newly developed cannulae/catheter-based system that permits closed-chest cardiopulmonary bypass (CPB) and enables cardiac surgical procedures to be conducted through smaller thoracic ports or limited incisions. Monitoring techniques have been considered to complement this system [3]. In June 1998, we introduced the Port-Access minimally invasive cardiac surgery in our institution for the first time in Japan, and during the last 12 months, such surgery has been performed in 25 patients. We report 15 patients undergoing Port-Access surgery for atrial septal defect (ASD) closure, and describe the anesthetic management of this new surgical approach.

Case report

Fifteen patients (7 men and 8 women) with ASD were scheduled to undergo defect closure with the Port-Access system. Their mean age was 44 years, with a range of 27 to 66 years. Cardiac catheterization revealed a ratio of pulmonary to systemic blood flow (Qp/Qs) of 2.7 ± 0.9 and a pulmonary artery mean pressure of 15 ± 3 mmHg (mean ± standard deviation) (Table 1). All patients underwent preoperative assessment of the aorta, iliac arteries, and femoral arteries by angiography.

The patients were premedicated with oral diazepam (5 mg) and intramuscular pethidine (35 mg) and atropine (0.5 mg). Anesthesia was induced by intravenous administration of midazolam (2 to 4 mg), fentanyl ($5\,\mu g \cdot kg^{-1}$), and vecuronium ($0.15\,mg \cdot kg^{-1}$), followed by endotracheal intubation with a standard single-lumen tube. Anesthesia was maintained with sevoflurane and nitrous oxide in oxygen in combination with fentanyl (15 to $20\,\mu g \cdot kg^{-1}$ in total), propofol, and vecuronium. Nitrous oxide was used only before CPB, and propofol was infused continuously during CPB at $4\,mg \cdot kg^{-1} \cdot h^{-1}$. Intraoperative monitoring included five-lead electrocardiography, pulse oximetry, capnography, urinary output measurement, and nasopharyngeal and bladder temperature. After the induction of anesthesia, the bilateral brachial arteries were cannulated to measure the pressure difference, and a central venous catheter was inserted through the right internal jugular vein. In our institution, we usually use the brachial artery for intravascular blood pressure measurement, since the brachial artery can provide more accurate estimation of aortic pressure than the radial artery [4,5]. Simultaneously, a 5 Fr sheath was placed in the right internal jugular vein by the anesthesiologist. A transesophageal echocardiography (TEE) probe was placed. TEE examination was performed to determine the diameter of the ascending aorta and to exclude severe atherosclerosis of the ascending and descending aorta as well as major aortic valve insufficiency. Defibrillator pads were placed over the right lateral and left posterior chest wall.

The Port-Access cannulae/catheter-based system (Endovascular CPB system: Heartport) consists of a set

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Table 1. Demographic and perioperative data

Patient no.	Age (yr)	Sex	Qp/Qs	PAM	Aortic occlusion time (min)	Duration of CPB (min)	Operation time (min)	Anesthetic time (min)	Postoperative discharge day
1	51	F	2.3	12	20	70	330	473	5
2	54	F	1.8	21	23	69	255	385	4
3	29	M	1.7	17	25	75	247	371	4
4	53	M	2.6	16	64	147	394	531	3
5	44	F	2.8	17	23	67	350	450	4
6	43	F	3.1	13	32	89	363	514	3
7	31	M	2.9	11	25	68	280	395	3
8	66	M	1.7	16	57	105	290	440	4
9	61	F	1.8	11	21	50	270	355	4
10	54	M	3.7	17	41	74	294	420	4
11	38	M	2.8	15	33	114	380	530	3
12	47	F	2.1	13	25	55	279	315	4
13	27	F	4.0	22	28	79	270	390	3
14	32	F	2.6	14	25	59	335	435	4
15	34	M	4.6	16	66	113	340	450	3

Qp/Qs, ratio of systemic blood flow to pulmonary blood flow; PAM, pulmonary artery mean pressure; CPB, cardiopulmonary bypass

of two cannulae and three catheters: a femoral venous cannula (Endovenous Drainage cannula), a femoral arterial cannula (Endoarterial Return cannula), an aortic balloon occlusion clamp (Endoaortic Clamp catheter), a pulmonary artery vent catheter (Endopulmonary Vent catheter), and a coronary sinus catheter (Endocoronary Sinus catheter). The Endovenous Drainage cannula is inserted via the femoral vein and is used for draining venous blood from the right side of the heart. Arterial inflow from CPB is connected to the Endoarterial Return cannula to deliver oxygenated blood to the patient. The Endoaortic Clamp catheter is used to occlude the ascending aorta, to deliver cardioplegia to the coronary arteries, to vent the aortic root, and to monitor aortic root pressure as well as balloon pressure. The Endopulmonary Vent catheter is introduced into the pulmonary artery to decompress the heart during CPB. The Endocoronary Sinus catheter is placed in the coronary sinus through the right internal jugular vein to deliver cardioplegia in a retrograde manner. Figure 1 shows the schema of catheter placement used in our patients undergoing Port-Access surgery for ASD closure. Since the femoral veins and arteries of our patients were too small to allow introduction of the original cannulae, we substituted a 20 Fr femoral venous cannula (FEM II 020V: Research Medical, West Midvale, UT, USA) for a 28 Fr Endovenous Drainage cannula and a 16 or 18 Fr arterial cannula (FEM II 016A or FEM II 018A: Research Medical) for a 21 or 23 Fr Endoarterial Return cannula. The venous blood from the superior vena cava was drained by a 16 or 18 Fr venous cannula (FEM II 016V or FEM II 018V: Research Medical). Passage of this cannula was facilitated by passing a guide wire through the 5 Fr sheath placed in the right internal jugular vein. The surgeon manipulated and inserted the arterial cannula and the two venous cannulae under TEE guidance provided by the anesthesiologist. The Endoaortic Clamp catheter was introduced into the ascending aorta through the left femoral artery, and it was properly positioned with the aid of TEE and fluoroscopy. We did not use an Endopulmonary Vent catheter or an Endocoronary Sinus catheter, since cardiac decompression was facilitated by the Endoaortic Clamp catheter during CPB, and retrograde cardioplegic administration was not needed because of the short aortic occlusion time.

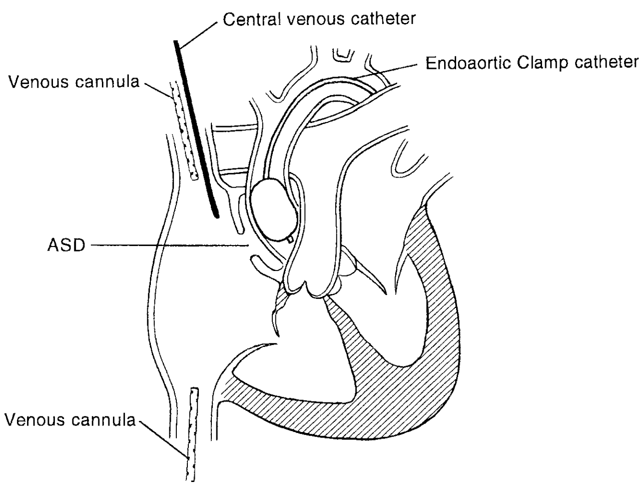

Fig. 1. Diagram of the endovascular cardiopulmonary bypass system for Port-Access minimally invasive cardiac surgery used in our patients with atrial septal defect (ASD)

CPB was conducted at normothermia using a centrifugal pump, a membrane oxygenator, and arterial filtration. After decompression of the heart, the balloon of the Endoaortic Clamp catheter was inflated and the ascending aorta was occluded, and cold potassium–blood cardioplegia was delivered into the aortic root, i.e., in an antegrade manner. During CPB, the balloon pressure was monitored to verify static inflation, and proper positioning of the Endoaortic Clamp catheter in the ascending aorta was verified by TEE and simultaneous comparison of bilateral brachial arterial pressures and aortic root pressure. Changes in cerebral perfusion were monitored by near-infrared spectroscopy (NIRS) (NIRO-300, Hamamatsu Photonics, K.K., Hamamatsu, Japan). In two patients, immediately after antegrade administration of cardioplegia, the right brachial arterial pressure decreased, and there was a significant difference between the two brachial arterial pressures. Simultaneously, NIRS showed a significant reduction in intracranial oxyhemoglobin and a reciprocal increase in deoxyhemoglobin. Fluoroscopy and TEE confirmed a migration of the Endoaortic Clamp catheter with partial obstruction of the innominate artery. Cardioplegic flow was temporally decreased, and the occlusion balloon was deflated, then repositioned and reinflated.

The operations were performed through a partial median sternotomy with a small incision (5 to 6cm in length) and guided by video-assisted endoscopic techniques. After completion of the intracardiac procedures, the intracardiac air was evacuated by active suction through the Endoaortic Clamp catheter, and no obvious air bubble was noted by TEE examination. All patients were easily weaned from CPB with infusion of low-dose dopamine or dobutamine. The duration of CPB was 82 ± 27min, with an aortic endovascular occlusion time of 33 ± 16min. After weaning from CPB, TEE examination of the ascending aorta showed no change in internal diameter or apparent intimal damage. The operation time was 312 ± 47min with an anesthetic time of 430 ± 64min. In 9 of the 15 patients, the endotracheal tube was removed in the operating room, and the remaining 6 patients were extubated within 2h after arrival in the intensive care unit. Postoperatively, the overall pain levels were relatively low, and the patients experienced mild discomfort that was well controlled with intermittent intramuscular administration of pethidine. Intraoperative awareness was not manifested, which may be related to the use of a balanced anesthetic technique involving the administration of volatile (sevoflurane) or intravenous (propofol) anesthetic agents during surgery. The postoperative course was uneventful, without apparent neurologic deficit, and the patients were discharged from the hospital on postoperative day 3.7 ± 0.6 (Table 1).

Discussion

The Port-Access CPB system is a catheter-based endovascular CPB system that uses femoral arterial and venous access for CPB with a transfemoral aortic balloon occlusion clamp, and enables the heart to be arrested and protected with cardioplegic solution in a manner equivalent to that used in conventional cardiac surgery. It should be noted that the endovascular CPB system has a relative risk compared with conventional external aortic cross-clamping. Such risks include possible trauma to the aortic valve or aorta by the occlusion balloon, and embolization of aortic plaque dislodged during balloon placement, inflation, and deflation. In addition, patients with manifest peripheral vascular disease are contraindicated for femoral-femoral CPB because of potential retrograde aortic dissection [6,7]. We selected patients with ASD for Port-Access cardiac surgery because they were relatively young and had no history of hypertension or diabetes mellitus. Preoperative examination revealed no obvious atherosclerotic changes in the ascending or descending aorta. Although the Port-Access system has been used in several types of cardiac surgery, including coronary artery bypass grafting and mitral valve replacement and repair procedures [8–10], young patients with ASD are suitable candidates for this surgical approach because of the lower probability of underlying vascular involvement. The intraoperative course was uneventful, except in two patients who had partial occlusion of the innominate artery during CPB without any neurological deficit at discharge from hospital. Furthermore, no significant postoperative complications were observed. Historic control data from our institution showed extubation times of 4 to 8h and postoperative discharge times of 10 to 14 days in patients undergoing traditional ASD closure. The patients' recovery was favorable, with earlier extubation, less incision pain, and a reduced period of hospitalization. Moreover, the cosmetic results were satisfactory to all the patients.

During CPB, pump flow tended to cause the balloon to migrate toward the aortic valve, and administration of antegrade cardioplegia pressurized the balloon toward the aortic arch. TEE and bilateral brachial pressure monitoring were used successfully to monitor the proper positioning of the endoaortic occlusion balloon in the ascending aorta. TEE is essential to evaluate cardiac function as well as the proper placement and positioning of the various catheters [11,12]. Simultaneous comparison of right and left brachial arterial pressures is useful to detect innominate artery obstruction, although there is a possibility of blood pressure discrepancies between the two sites, particularly in patients with atherosclerosis. Transcranial Doppler (TCD) is also reported to be useful to detect cerebral hypoperfusion during Port-Access endovascular CPB [13]. However, TCD is sometimes unreliable because of the difficulty of obtaining a good-quality TCD signal throughout CPB. In our cases, changes in cerebral perfusion were monitored by NIRS. NIRS can be used as a noninvasive and simple modality for continuous monitoring of regional cerebral oxygenation and hemodynamics. By decreasing cardioplegia delivery, the CPB pump flow pushed the balloon out of the aortic arch toward the aortic valve, and the occlusion balloon was repositioned and reinflated. The monitoring set-up is important for Port-Access cardiac surgery; nonetheless, good communication among all members is crucial [14]. Insertion and proper placement of various cannulae and catheters for safe endovascular CPB must be performed with the cooperation of surgeons, anesthesiologists, and perfusionists. All members should understand the effectiveness and limits of monitoring methods and their role during Port-Access cardiac surgery.

In summary, we have used the Port-Access system for minimally invasive cardiac surgery in 15 patients with ASD. This approach provided early extubation and postoperative discharge. The combination of monitoring modalities, including TEE, pressure measurements, and NIRS, was useful for monitoring changes in tissue perfusion due to catheter malposition. Good communication among surgical personnel during Port-Access procedures is essential.

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