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Surgical Outcomes of Congenital Atrial Septal Defect Using da VinciTM Surgical Robot System

Ji Eon Kim, M.D., Sung-Ho Jung, M.D., Gwan Sic Kim, M.D., Joon Bum Kim, M.D., Suk Jung Choo, M.D., Cheol Hyun Chung, M.D., Jae Won Lee, M.D.

Background: Minimally invasive cardiac surgery has emerged as an alternative to conventional open surgery. This report reviews our experience with atrial septal defect using the da VinciTM surgical robot system. ***Materials and Methods:*** This retrospective study included 50 consecutive patients who underwent atrial septal defect repair using the da VinciTM surgical robot system between October 2007 and May 2011. Among these, 13 patients (26%) were approached through a totally endoscopic approach and the others by mini-thoracotomy. Nineteen patients had concomitant procedures including tricuspid annuloplasty (n=10), mitral valvuloplasty (n=9), and maze procedure (n=4). The mean follow-up duration was 16.9±10.4 months. ***Results:*** No remnant interatrial shunt was detected by intraoperative or postoperative echocardiography. The atrial septal defects were mainly repaired by Gore-Tex patch closure (80%). There was no operative mortality or serious surgical complications. The aortic cross clamping time and cardiopulmonary bypass time were 74.1±32.2 and 157.6±49.7 minutes, respectively. The postoperative hospital stay was 5.5±3.3 days. ***Conclusion:*** The atrial septal defect repair with concomitant procedures like mitral valve repair or tricuspid valve repair using the da VinciTM system is a feasible method. In addition, in selected patients, complete port access can be helpful for better cosmetic results and less musculoskeletal injury.

Key words: 1. Heart septal defects
2. Minimally invasive cardiac surgery
3. da VinciTM surgical robot system
4. Totally endoscopic approach

INTRODUCTION

Broadly, if the ratio of pulmonary to systemic flow is 1.5 or more, an atrial septal defect closure is recommended. Percutaneous transcatheter device closure is now widely accepted as the first choice of treatment because it is less invasive than surgery. However, it is not always available and depends on the number, size, location of defects and comorbid diseases [1].

Recently, as in other surgical fields, minimally invasive robotic surgery is becoming more common in cardiac surgery. With the development of surgical instruments and peripheral access to cardiopulmonary bypass, robotic cardiac surgery is a good alternative for conventional open surgery. It has been reported to be a safe and feasible method and shows rapid recovery and improved quality of life. We have performed robotic cardiac surgery using the da VinciTM surgical system since August 2007, and reported early outcomes [2,3]. In this

Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, University of Ulsan College of Medicine
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Corresponding author: Jae Won Lee, Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, University of Ulsan College of Medicine, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 138-736, Korea
(Tel) 82-2-3010-3580 (Fax) 82-2-3010-6966 (E-mail) jwlee@amc.seoul.kr

study, we reviewed our experience with an atrial septal defect and cormobid disease repairs using the da VinciTM surgical system.

MATERIALS AND METHODS

1) Patients

Fifty consecutive patients who underwent atrial septal defect repair using the da VinciTM surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA) from October 2007 to May 2011 were included in this study. The mean age was 36.9±12.1 years (range, 16 to 65 years; median age, 35 years), and 41 (82%) patients were female.

2) Preoperative diagnosis

Preoperative echocardiographic data were obtained from all patients. The types of atrial septal defects included secundum in 44 patients (88%), primum in 3, and sinus venosus in 2. The remaining one patient had a remnant atrial septal defect and had undergone atrial septal defect closure with a bovine pericardial patch and mitral cleft repair via conventional sternotomy 8 years earlier in another hospital. The mean size of the defects was 23.3±7.2 mm (range, 11 to 42 mm) and three patients had multiple defects. Nineteen patients had comorbid diseases including tricuspid regurgitation >grade 2 in 7, mitral regurgitation >grade 2 in 5, mitral cleft in 4, atrial fibrillation in 4, and partial anomalous pulmonary venous return in 2 (Table 1).

3) Surgical methods

(1) Patient preparation: Under general anesthesia, patients were intubated with double-lumen endotracheal tubes or single-lumen tubes with bronchial blockers to allow left-sided single-lung ventilation. Adhesive external defibrillator patches (Quik-Combo; Physio-Control Co., Redmond, WA, USA) were applied for defibrillation. A transesophageal echocardiography (TEE) probe inserted for pre- and post-operative evaluation. A 17–21Fr venous cannula was inserted percutaneously into the right internal jugular vein after systemic heparinization (30 IU/kg) to prevent thrombus formation. Patients were placed in a left semi-lateral decubitus position with the right arm fixed on the table. After sterile preparation and draping, the right femoral vessels were accessed through a 2 cm oblique incision along the inguinal crease. After systemic heparinization (300 IU/kg), a 22–28Fr venous cannula was inserted through the right femoral vein into the inferior vena cava and the right common femoral artery was cannulated (14–17Fr).

① Mini-thoracotomy: An anterior mini-thoracotomy was made in the fourth intercostal space via a 4 cm skin incision. Two additional port incisions were made in the third intercostal space, just anterior to the anterior axillary line and in the sixth intercostal space, posterior to the anterior axillary line for the left and right robotic arms, respectively. The endoscopic camera was placed through the mini-thoracotomy. The Chitwood aortic clamp was inserted in the third intercostal space as posteriorly as possible to the mid-axillary line to prevent interference between the instruments. The atrial retractor that was equipped with the third arm of the robot was inserted through the anterior margin of the mini-thoracotomy.

② Complete port access: The port for left and right robotic arms and Chitwood aortic clamp were inserted into the same site of the mini-thoracotomy case. The endoscopic port incision was made in the fourth intercostal space, anterior to

Table 1. Baseline characteristics

Variable	Value
No. of patients	50
Age (yr)	36.9±12.1
Female gender (%)	41 (82.0)
Body weight (kg)	58.4±8.5
ASD type (%)	
Secundum	44 (88.0)
Primum	3 (6.0)
Sinus venosus	2 (4.0)
Remnant ASD	1 (2.0)
ASD size (mm)	23.3±7.2
Comorbid diseases (%)	
Tricupid regulgitation	7 (14.0)
Mitral regulgitation	5 (10.0)
Mitral cleft	4 (8.0)
PAPVR	2 (2.0)
Atrial fibrillation	4 (8.0)

Values are presented as mean±standard deviation or number (%).
ASD, atrial septal defect; PAPVR, partial anomalous pulmonary venous return.

the anterior axillary line and the assistant entrance in the fourth intercostal space, at the anterior axillary line (near the center of the triangle composed of the three ports for the left and right robotic arms and endoscope). The fifth port for the atrial retractor was made in the fourth or fifth intercostal space, at the midclavicular line.

(2) Intrathoracic procedure: A pericardiotomy was made and pericardial stay sutures placed. Caval snares were placed and cardiopulmonary bypass initiated with moderate hypothermia. A root cannula was inserted after purse string suture. Perfusion pressure was reduced and aortic cross clamping was performed. Cardioplegic solution (Custodiol histidine-tryptophan-ketoglutarate [HTK] solution, 2,000 mL; Odyssey Pharmaceuticals, East Hanover, NJ, USA) was administered. In complete port access cases, the root cannula was removed after cardioplegia. An atrial incision was made near the interatrial septum for better surgical exposure. All surgical procedures (including atrial septal defect closure, tricuspid annuloplasty [TAP] and mitral valvuloplasty [MVP]) were performed without any limitation.

4) Follow-up

The mean follow-up duration was 16.9±10.4 months. Follow-up was done by reviews of the records from admission and the outpatient visits. We routinely took postoperative chest radiographs, electrocardiograms, and echocardiograms.

RESULTS

A total of 50 atrial septal defect repairs were performed with concomitant tricuspid annuloplasty in 10, mitral valvuloplasty in 9, and a maze procedure in 4. Thirteen patients (26%) were approached by a totally endoscopic approach, while all tricuspid ring annuloplasty, mitral valvuloplasty, and maze procedures were approached by mini-thoracotomy. The atrial septal defects were mainly repaired by Gore-Tex patch closure (80%). In the two cases of sinus venosus type atrial septal defects, partial anomalous pulmonary venous returns were accompanied by right superior pulmonary veins draining into the superior vena cava and right atrium. Those were repaired by interatrial baffling. All maze procedures were performed using cryoablation. Two patients underwent right-sided and the others biatrial maze procedures. The surgical procedures are described in detail in Table 2.

The mean cardiopulmonary bypass (CPB) times were 157.6±49.7 minutes: 153.2±50.1 minutes for mini thoracotomy cases and 170.3±48.1 minutes for totally endoscopic cases. The aortic cross-clamp (ACC) times were 74.1±32.2 minutes: 72.3±33.6 and 79.0±28.2 minutes, respectively. There were no significant differences in CPB and ACC time (p=0.290, p=0.525).

Postoperatively, the mean hospital stay and intensive care unit stay were 5.5±3.3 days (range, 2 to 17 days) and 26.8±19.0 hours (range, 5 to 119 hours). During the same period, compared to sternotomy patients (n=30), there was significant difference (9.6±5.3 days, $p<0.001$; 71.3±110.9 hours, p=0.004). Automated endoscope system for optimal positioning (AESOP) patients (n=44) tended to stay longer, but the difference was not statistically significant (6.7±2.9 days, 36.5±16.7 hours).

There was no early or late mortality. Nor did any early surgical complications occur including reoperation for surgical failure (remnant atrial septal defect, mitral regurgitation, and tricuspid regurgitation), postoperative bleeding, or conversion to thoracotomy or sternotomy. There was no remnant interatrial shunt on intraoperative or postoperative echocardiography. All the patients who underwent maze procedures maintained sinus rhythm without medication for the duration of follow-up (mean duration 13 months).

Three patients suffered from late complications that required readmission. Two patients were clinically diagnosed with post-pericardiotomy syndrome; one patient was treated with steroid and the other with pericardiostomy and non-steroidal anti-inflammatory drugs. The last one had a peripheral vascular access site infection with femoral artery pseudoaneurysm formation at 30 days after surgery. She underwent an emergency operation for superficial femoral artery angioplasty and was treated with antibiotics.

DISCUSSION

As an alternative to the conventional sternotomy approach, less invasive cardiac surgery has been widely performed. Particularly, the da VinciTM surgical robot system has been

Table 2. Operative data

Variable	Total	Mini-thoracotomy	Completely port access
No. of patients	50	37	13
Surgical procedures			
ASD closure only	33	24 (64.9)	9 (69.2)
ASD closure+maze	1	1 (2.7)	0
ASD closure+MVP	5	5 (13.5)	0
ASD closure+MVP+maze	1	1 (2.7)	0
ASD closure+MVP+TAP	2	2 (5.4)	0
ASD closure+MVP+TAP+maze	1	1 (2.7)	0
ASD closure+TAP	6	2 (5.4)	4 (30.8)
ASD closure+TAP+maze	1	1 (2.7)	0
Atrial septal defect repair	50	37	13
Gore-Tex patch closure	40	29	11
Direct closure	5	3	2
Autologous pericardial patch closure	3	3	0
Intraatrial baffling with Gore-tex patch	2	2	0
Mitral repair (n=9)	14	14	0
Annuloplasty			
Cosgrove band	4	4	-
Tailor ring	1	1	-
New chorda formation	3	3	-
Triangular resection	2	2	-
Cleft repair	4	4	-
Tricuspid repair	10	6	4
Suture annuloplasty			
De Vega	5	4	1
Modified de Vega	2	0	2
Kay	1	0	1
Ring annuloplasty			
MC3	1	1	-
Cosgrove	1	1	-
Maze procedure	4	4	0

Values are presented as number or number (%).
ASD, atrial septal defect; MVP, mitral valvuloplasty; TAP, tricuspid annuloplasty.

considered as the representative of less invasive techniques. The present study demonstrated that atrial septal defect closure and other comorbid disease repair using the da VinciTM surgical system is feasible and safe.

The biggest reason for performing robotic surgery is that it is less invasive, with smaller incisions, less pain, and quicker recovery. Previous reports on postoperative quality of life after robotic surgery noted the minimized degree of invasiveness, hastened postoperative recovery and return to employment-based activities, and improved quality of life, although the length of hospital stay was unchanged [4-6]. In our experience, although it is a subjective evaluation, patients who underwent robotic surgery have shown greater satisfaction with cosmetic results and less pain. In addition, the length of hospital stay was shorter than for conventional sternotomy patients.

In our experience, da VinciTM operations showed great safety, even in redo operation cases. As mentioned above, there were only three cases with late complications. Other than two post-pericardiotomy syndrome cases, there was only one complication. Also, a da VinciTM operation could be applied to any atrial septal defect regardless of type, size, and

location. We used a patch for atrial septal closures in most of the cases (45/50, 90%). Other procedures, including TAP, MVP, and the maze procedure, were performed without any limitation.

Totally endoscopic atrial septal defect closures were first reported by Torracca et al. [7] in 2001 and Argenziano et al. [8] in 2003. We also approached completely by a port access in thirteen patients with relatively simple diseases. Complete port access can reduce incisions and musculoskeletal injury and shows better cosmetic results. In these cases, we used a long metal needle for the root cannula, instead of a 14-gauge angiocatheter or endo-aortic clamp balloon [9]. After cardioplegia infusion, the root cannula was removed for better accessibility. In this situation, it was difficult to remove air from the left heart. However, by using CO_2 gas (flow 1.5 L/min), minimizing left atrial blood suction during the operation, and identifying the air by TEE, we prevented air embolism. Furthermore, unlike earlier reports, we performed patch closures in most cases. By doing so, every type of atrial septal defect could be repaired without additional operation risks, regardless of the size, number, and location.

Despite its many advantages, robotic surgery has several limitations. First, it is difficult to access the da VinciTM surgical system. It is very expensive equipment and health insurance in the Republic of Korea does not cover robotic surgery, so the cost of surgery is very high. In our hospital, the cost of surgery to the patient is 2 to 3 times more expensive than conventional sternotomy surgery (sternotomy 7–8; AESOP 10; da VinciTM 15 million KRW). Also, robotic surgery requires more operation time and few surgeons are skilled in robotic surgery. However, as time passes, it can be expected that the da VinciTM surgical system will come into widespread use. Then, because the learning curve of the operation technique is steep [10,11], more patients should have easy access to da VinciTM operation.

CONCLUSION

Atrial septal defect repair and concomitant mitral valve repair, tricuspid annuloplasty, or maze procedure using the da VinciTM surgical system can be performed safely under any conditions with reasonable surgical outcomes. Complete port access is a helpful method in selected patients.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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