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Totally Endoscopic Robotic Atrial Septal Defect Repair on the Beating Heart

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ABSTRACT

Background: Atrial septal defect (ASD) repairs have successfully been performed on the arrested heart with the da Vinci S Surgical System (Intuitive Surgical). This study assessed the feasibility, safety, and efficacy of the use of the da Vinci S Surgical System for on-pump ASD repairs on the beating heart without cross-clamping the aorta.

Methods: This prospective study included 24 consecutive patients who underwent ASD repair surgery between June 2008 and June 2009. All of the procedures were completed with the da Vinci S robot via 3 port incisions in the right chest and a 1.5-cm working port. The operations were carried out on the beating heart with mild hypothermic cardiopulmonary bypass (CPB) without cross-clamping the aorta. Venting the heart from the working port provided adequate visualization of the operative field.

Results: All patients underwent complete repairs. Fourteen patients underwent ASD closure with a fresh autogenous pericardial patch, and 10 patients underwent direct ASD closure. Concomitant surgery was required in 4 patients. The mean (±SEM) CPB time was 65.6 ± 17.7 minutes, and the mean operative time was 98.5 ± 19.3 minutes. No patient required transfusion of red blood cells. The length of patient stay in the intensive care unit was 0.5 to 1.0 days. The length of hospital stay was 4 to 5 days. Follow-up transthoracic echocardiography evaluations showed no residual atrial septal leakage. There were no operative deaths, strokes, or other complications. All of the patients were discharged.

Conclusions: We have shown that use of the da Vinci S Surgical System to perform on-pump ASD repairs on the beating heart without cross-clamping the aorta is feasible, safe, and effective.

INTRODUCTION

Computerized surgical robotic systems have developed very rapidly over the last few years. The da Vinci surgical robot (Intuitive Surgical, Sunnyvale, CA, USA) has assisted the surgeon's work by enabling telemanipulation through a master-controller activation principle with a 3D intracardiac camera.

Large atrial septal defect (ASD) repairs that are not suitable for cardiologic intervention have been successfully performed on the arrested heart with the da Vinci S Surgical System and cardiopulmonary bypass (CPB) [Gao 2008b].

To our knowledge, no reports have described use of the da Vinci S Surgical System for totally endoscopic robotic ASD repair on the beating heart. Since 2007, our group has performed different robotic cardiac operations in more than 200 cases, including ASD repairs on the arrested heart [Gao 2007a, 2007b, 2007c, 2008a, 2008b, 2009]. In the present study, we assessed the feasibility, safety, and efficacy of using the da Vinci S surgical system and CPB for performing ASD repairs on the beating heart without cross-clamping the aorta.

PATIENTS AND METHODS

Between June 2008 and June 2009, 24 patients underwent ASD repairs with the da Vinci S Surgical System after Institutional Review Board approval and informed consent were obtained. Four of the 24 patients underwent concomitant tricuspid repair. All patients had an echocardiographically confirmed ASD with mild to moderate pulmonary hypertension. The mean (±SEM) age was 39.63 ± 11.53 years (range, 18-53 years), and the mean ASD size was 2.88 ± 5.96 cm (range, 1.7-3.6 cm). All patients underwent an evaluation of

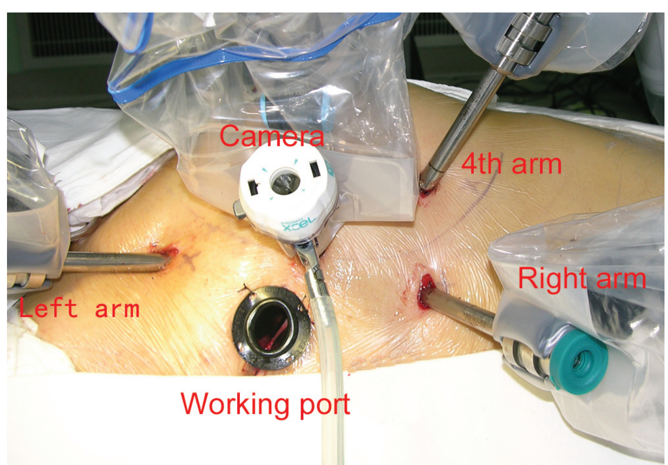

Figure 1. da Vinci S setup for atrial septal defect repairs.

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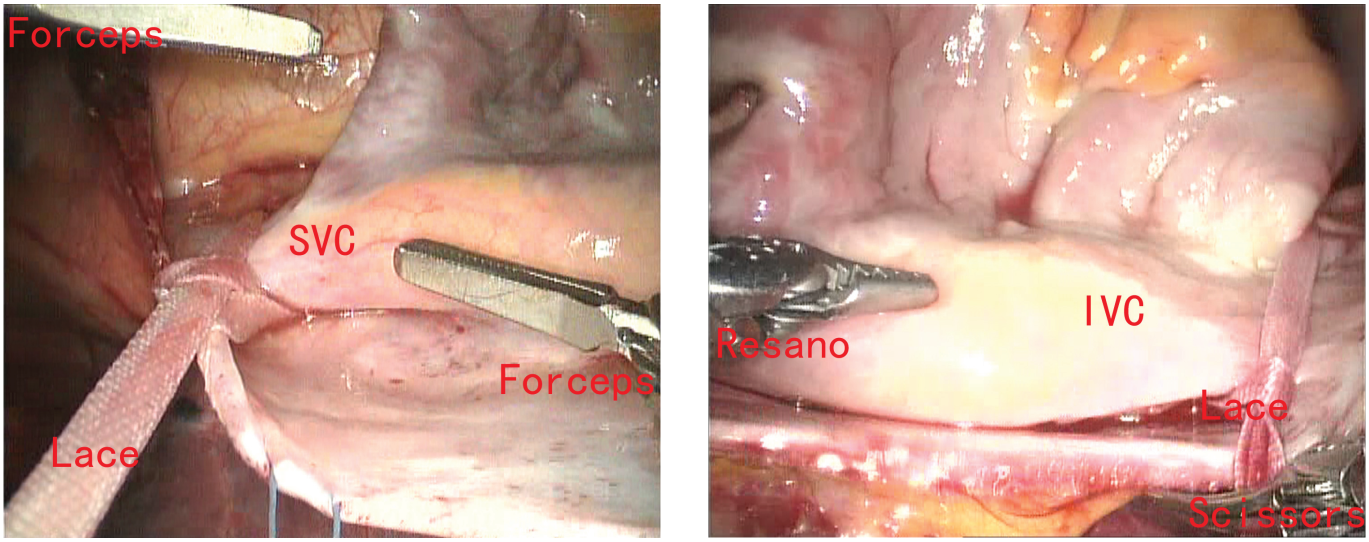

Figure 2. The superior vena cava (SVC) snared robotically with a thin lace (left) and the inferior vena cava (IVC) snared robotically with a thin lace (right).

their medical history, a physical examination, and chest radiography and transthoracic echocardiography evaluations.

Surgical Procedure

All patients were intubated for single-lung ventilation. Both a central venous catheter and a 15F venous drainage cannula were placed percutaneously into the right internal jugular vein. A transesophageal echocardiography (TEE) probe was positioned after intubation. External defibrillator patches were placed to subtend the maximum cardiac mass. Each patient was positioned with the right chest elevated approximately 30° and with the right arm tucked at the side. Femoral arterial (18F or 20F) and venous (21F or 23F) cannulation was performed through a 2-cm transverse right groin incision by means of the Seldinger guidewire method and TEE guidance. Bicaval venous drainage was instituted through the jugular and femoral/inferior vena cava cannulas.

The camera cannula was placed 2 to 3 cm right lateral to the nipple in the fourth intercostal space (ICS). A 1.5-cm incision in the same ICS was used as a working port for the assistant. da Vinci instrument arms were inserted through two 1-cm trocar incisions. The right instrument generally was positioned 4 to 6 cm lateral to the working port in the sixth ICS. The left instrument arm was positioned medial and cephalad to the right arm in the second or third ICS. The fourth arm trocar site was in the axillary anterior line in the fifth ICS (Figure 1). A surgeon at the patient's side facilitated instrument changes and needle/suture passing and retrieval. Under mild hypothermic conditions (rectal temperature, 34°C-35°C), CPB full flow was maintained with a mean systemic pressure of >60 mm Hg. To avoid air embolism, we insufflated carbon dioxide continuously at 6 to 8 mm Hg into the chest for air displacement. On the beating heart, a right atriotomy was performed after the superior vena cava and the inferior vena cava were snared robotically with a thin lace (Figure 2), and the ASD was exposed with the atrial retractor by the fourth arm. A small suction catheter was placed in the right atrium through the working port. Running 4-0 GORE-TEX suture (W. L. Gore & Associates, Flagstaff, AZ, USA) was used to directly close the ASD in 10 patients, autogenous pericardium patching was used in 14 patients, and concomitant tricuspid valve repair was performed with the De Vega technique in 4 patients. The right atrium was closed by 4-0 GORE-TEX in a running suture. As the interatrial septum was closed, the lung was briefly inflated, and the interatrial suture line was secured when there was no evidence of air retained in the left atrium. All of the ASD repairs and the right atrial closure were completed with the da Vinci robot. Throughout the procedure, the heart was monitored via TEE to ensure that there was no residual air in the atrial cavities. The patient was weaned off CPB, and chest tubes were inserted. A postrepair TEE evaluation was performed for each patient.

Data are presented as the mean ± SEM; *P* values <.05 were considered statistically significant.

RESULTS

All patients underwent successful ASD repairs with the da Vinci Surgical System without difficulty because the suction catheter from the working port and the atrial retractor provided adequate visualization of the operative field (Figure 3). All operations were performed by the same console surgeon and 1 surgeon at the patient's side. The mean CPB time was 65.6 ± 17.7 minutes. The mean operative time (from docking to incision closure) was 98.5 ± 19.3 minutes. No patient required transfusion of red blood cells. The postrepair intraoperative TEE evaluation showed no residual septal leakage. The length of patient stay in the intensive care unit was 0.5 to 1.0 days. The total length of the hospital stay was 4 to 5 days for all patients. One patient (4.5%) experienced postoperative atrial fibrillation before discharge. At the 6-month follow-up,

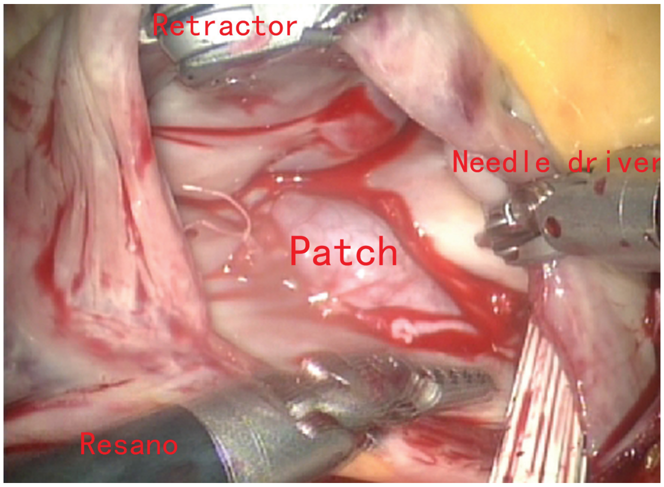

Figure 3. Atrial septal defect repair completed.

no residual atrial septal leakage was found by transthoracic echocardiography, and no other complications were found.

There were no operative deaths, strokes, or other complications. There were no intraoperative conversions to alternative surgical techniques, and there were no da Vinci system–related adverse events. All procedures that were started with the da Vinci system were completed with robotic assistance. All of the patients were discharged with an excellent cosmetic appearance (Figure 4).

DISCUSSION

ASD closure is most commonly performed with interventional methods; however, large ASD closures still need to be performed via surgical procedures under cardioplegic arrest with cross-clamping of the aorta. Several reports have described surgical procedures using beating heart techniques in which aortic cross-clamping and cardioplegic arrest were not used [Matsumoto 2002; Thompson 2003; Salerno 2007]. The advantages of this method of myocardial protection include avoidance of ischemia-reperfusion injury, performance of the surgery with the heart in a more physiological state, decreased use of inotropic medications, and a shorter hospital stay [Miyairi 1996; Matsumoto 2002]. In addition, proximal aortic arteriosclerosis is the source of macro- and microemboli that are produced at the time of placement and release of the aortic cross-clamp [Blauth 1992; Davila-Roman 1994; Murkin 1999; Mizuno 2000].

Minimally invasive techniques have been developed for heart surgery. In 2007, we initially used the da Vinci S Surgical System for ASD repair surgery under cardioplegic arrest by cross-clamping the aorta with a Chitwood clamp [Gao 2008b]. We subsequently evolved the technique to accomplish totally endoscopic robotic ASD repair on the beating heart. The technique of on-pump beating heart ASD repair without cross-clamping the aorta offers several advantages, described above. More importantly, this technique is an effective and safe alternative to techniques involving cardioplegic arrest.

Figure 4. Postoperation incisions.

Potential concerns related to this technique include performance of the surgery in a relatively blood-filled field, limited surgical precision owing to the difficult exposure, risk of air embolization, and a limited ability to perform a closure procedure on a very large ASD on the beating heart.

In fact, our operations were performed without difficulty because the atrial retractor (Intuitive Surgical) through the fourth arm and the small suction catheter from the working port were able to provide adequate visualization of the operative field (Figure 3). The concomitant tricuspid valve repairs carried out in 4 patients were easily performed. In our patients, we observed no complications, such as stroke or residual ASD due to dehiscence of the atrial suture line.

For the prevention of air embolism, each patient was positioned with the right chest elevated approximately 30°. Furthermore, the left atrium was kept full without being suctioned. Throughout the procedure, we insufflated carbon dioxide continuously at 6 to 8 mm Hg into the chest for air displacement. De-airing of the left atrium at the end of the procedure was easily done. As the interatrial septum was closed, the lung was briefly inflated, and the interatrial suture line was secured when there was no evidence of air retained in the left atrium. Any air in the left atrium would be carbon dioxide, which is easily absorbed.

On the basis of this knowledge, it seems reasonable to perform robotic ASD closure under on-pump beating heart conditions. We felt this technique to be superior to cardioplegic techniques because it avoids aortic cross-clamping and cardioplegia delivery and because it shortens the durations of CPB and the total operation. In our study, the mean CPB time in beating heart patients was 48.01 ± 18.67 minutes for direct closure and 74.80 ± 10.81 minutes for patching, whereas the mean CPB duration in arrested-heart patients was 90.33 ± 26.86 minutes for direct closure and 97.69 ± 11.15 minutes for patching ($P < .05$).

In addition, this technique does not increase the risk of central nervous system injury [Thompson 2003]. It is not possible to determine with certainty whether minor neurocognitive disorders due to microembolization occurred. We have not performed neurocognitive evaluations for these patients, but this risk is an important aspect that requires further investigation.

Possible contraindications to robotic ASD repair surgery on the beating heart include the presence of mobile vegetations in patients with infective endocarditis or large left atrial thrombi, because of the risk of embolization.

The robotic system performed safely and efficiently, with no operative deaths or conversions due to a system malfunction. Moreover, there were no incision conversions, either to a larger thoracotomy or to a median sternotomy. These patients benefited from minimal musculoskeletal trauma, an absence of transfusion, and early discharge with excellent cosmetic results.

In conclusion, we believe that the use of the da Vinci S Surgical System is feasible, safe, and effective for performing on-pump beating heart ASD repairs without cross-clamping the aorta. The surgical results are excellent.

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