Totally endoscopic atrial septal repair in adults with computer-enhanced telemanipulation

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Objective: Standard surgical closure of an atrial septal defect via sternotomy is a safe and effective procedure with low morbidity and mortality. Considering that young female patients are frequently operated on for atrial septal defects, a minimally invasive procedure avoiding sternotomy is convincingly desirable and led to the approach through a right anterolateral minithoracotomy. The recent clinical introduction of robotically assisted surgery further reduced skin incisions and enabled totally endoscopic procedures through ports. This article reports on a first series of atrial septal defect closures of which the first case was operated on August 24, 1999, in a totally endoscopic closed chest technique using a computer-enhanced telemanipulation system.

Methods: We performed totally endoscopic atrial septal repair using the da Vinci surgical system (Intuitive Surgical, Mountain View, Calif) in 10 consecutive adult patients. Median age was 45.5 ± 10.0 years, and preoperative New York Heart Association functional class was 1.8 ± 0.1 . Left ventricular ejection fraction was normal in all patients and mean pulmonary artery pressure amounted to 35 ± 7 mm Hg. Shunt volume ranged from 24% to 70%. All patients displayed a fossa ovalis type of atrial septal defect; 2 of them multiperforated.

Results: Neither intraoperative nor postoperative complications occurred. Two patients had to be converted to minithoracotomy due to endoaortic balloon clamp failure. Length of operation was 262 ± 37 minutes, and cardiopulmonary bypass time was 161 ± 26 minutes. Intraoperative transesophageal echocardiography certified complete closure of the atrial septal defect in all patients. The totally endoscopic computer-enhanced technique yielded excellent cosmetic results.

Conclusion: Totally endoscopic atrial septal repair is a feasible and safe procedure with good clinical results and excellent cosmetic outcomes. It may be considered as perfect adjunct to interventional treatment options. Further studies with larger cohorts and randomized trials are necessary to document potential benefits. Evolution in robotic technology and refinement of procedural flow may shorten procedural time and decrease costs.

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Several methods have been described to close an atrial septal defect (ASD) in adult cardiac surgery. The first successful ASD closure was performed by Lewis and Taufic¹ in 1953. Since then standard surgical closure of an ASD via sternotomy or thoracotomy has been a safe and effective procedure with low morbidity and mortality.^{2,3}

Considering that young female patients are frequently operated on for ASDs, a minimally invasive approach avoiding sternotomy is convincingly desirable and led to the development of right anterolateral minithoracotomy procedures with submammary incision.⁴⁻⁶ Length of incision can be reduced to 4 to 5 cm when cardiopulmonary bypass (CPB) is instituted via femoro-femoral access using different techniques.⁷⁻⁹

In parallel, closure of small ostium secundum and patent foramen ovale types of ASD by different percutaneous catheter techniques have been developed by interventional cardiologists.^{10,11} This led to a dramatic reduction of surgically performed ASD closures.

The recent clinical introduction of robotically assisted surgery finally enables totally endoscopic procedures through ports. This article reports on our first series of ASD closure in a totally endoscopic closed chest technique using a computer-enhanced telemanipulation system.

Patients and Methods

After institutional ethical committee approval was obtained (No. 141/99 B), and each single patient gave written informed consent, we performed totally endoscopic atrial septal repair (TEASR) in 10 consecutive adult patients with the da Vinci surgical system (Intuitive Surgical, Mountain View, Calif).^{12,13} The first TEASR was performed at Frankfurt University on August 24, 1999.¹⁴ Median age was 45.5 ± 10.0 years, and preoperative New York Heart Association functional class was 1.8 ± 0.1 . Two patients had a history of paradox embolism. There were no other comorbidities. Left ventricular ejection fraction was within the normal range in all patients and mean pulmonary artery pressure was 35 ± 7 mm Hg. Shunt volume ranged from 24% to 70%.

All patients had a fossa ovalis type of ASD, multiperforated in 2 of them. Effectiveness of ASD repair was assessed intraoperatively and documented via transesophageal echocardiography.

Operative Technique for TEASR

Anesthesia was induced by a standard technique with a double-lumen tube for single lung ventilation. A 19F or 21F venous drainage cannula was inserted percutaneously into the right jugular vein by the anesthesiologist for selective drainage of the superior vena cava (SVC).

A right-side approach was used. The patient was placed on the operating table with the right side of the chest elevated by 40°. After deflation of the right lung and insufflation of the chest with carbon dioxide, a 0° endoscope was inserted into the fourth intercostal space (ICS) between the midclavicular and anterior axillary line. The robot arms were placed through the third and sixth ICS

TABLE 1. Intraoperative time measurements with regard to particular steps of the procedure

Intraoperative data	Median $\pm$ SD
Skin to skin time (min)	262 $\pm$ 37
CPB (min)	161 $\pm$ 26
Balloon clamp (min)	67 $\pm$ 21
Defect closure (min)	19 $\pm$ 3
Port placement (min)	10 $\pm$ 2

in the anterior axillary line. After initiating CBP via femoro-femoral cannulation with the Heartport Port-Access System (CardioVations of Ethicon, Inc, Norwalk, Conn) in 8 patients or the Estech System (Estech, Danville, Calif) in 2 patients, the pericardium was incised and the SVC and inferior vena cava (IVC) were dissected endoscopically. An additional 8-mm stab incision was necessary in the fifth ICS in the midaxillary line for transthoracic instrumentation. This included suction and the use of a special long endoflex clamp (Snowden Pencer, Tucker, Ga) to circumplace loops around the SVC and IVC, which were secured transthoracically for total CPB before atrial incision. The endoaortic balloon clamp was insufflated and cardiac arrest was achieved by delivery of cold blood cardioplegic solution.

After incision of the right atrium, a stay suture was placed on the atrial roof and tied to expose the defect of the interatrial septum. The orifices of the pulmonary veins and the coronary sinus, respectively, were verified. The defect was closed directly with either a 4.0 polypropylene running suture or a Dacron patch after deairing of the left side of the heart. The atriotomy was then closed with a double running 4-0 polypropylene suture. The endoaortic crossclamp was desufflated and the patient was weaned from CPB. Procedures were performed at moderate systemic hypothermia (28°C).

Results

There was no perioperative morbidity. Eight of 10 patients were treated in the described fashion. Two patients were converted due to issues associated with Port-Access technology.¹⁵

In 1 patient stabilization of the balloon in the ascending aorta was not possible (Heartport system). In another patient cardioplegic delivery was obstructed, probably because of kinking of the cardioplegia line, which is integrated in the arterial return cannula (Estech system). In both patients a transthoracic clamp was used for aortic occlusion,¹⁶ and the procedure was performed through a minithoracotomy in the fourth ICS.

In 7 patients direct ASD closure was performed with a running suture. In 1 patient the ASD was closed with a Dacron patch.

Intraoperative time measurements with regard to particular steps of the complex procedure are listed in Table 1, whereby defect closure is defined as the actual time of suturing the ASD. With intraoperative transesophageal echocardiography, complete closure of ASD was confirmed in all patients.

Twenty-four-hour chest tube drainage amount was 248 ± 89 mL, ventilation time was 11 ± 4 hours, ICU stay was 20 ± 33 hours, and hospital stay was 9.5 ± 1.9 days.

The totally endoscopic approach yielded excellent cosmetic results (Figure 1).

Discussion

Applying the standard techniques for surgical ASD closure, midline sternotomy is still the approach of choice in many institutions. Though this procedure yields recognized results with low morbidity and mortality and short hospital stay,² the nature of the technique carries the risk of wound infection,^{17,18} which can be the source of significant pain and is cosmetically not desirable. Right thoracotomy is used to avoid sternotomy, potentially decrease pain, improve cosmesis, and generate higher acceptance among patients. It is reasonably debatable, though, whether pain or wound infection can be reduced, especially in young patients with no comorbidities.

With the development of Port-Access technology for peripheral CPB induction and the use of a transthoracic clamp, skin incision could be further reduced.^{8,9,16}

The trade-off between longer CPB times and highly complex procedures for the sake of improved cosmesis only is still questionable. Associated risks with Port-Access technology such as aortic dissections and thromboembolic events^{15,19,20} do not advocate for the technique, but complication rate is assumed to be low in younger patient cohorts with no peripheral vascular disease. Some authors even discuss an increased risk of thrombus formation using a long venous femoral cannula in the IVC,⁷ which we have not experienced in our overall series of more than 200 Port-Access cases.

With the advent of telemanipulators in the late 1990s, a new powerful tool to perform totally endoscopic cardiac procedures has been added, enabling the surgeon to perform coronary artery bypass grafting^{12,21} and valve reconstruction.^{22,23} However, only few reports exist that describe robotically assisted²⁴ or totally endoscopic ASD repair.²⁵

The necessity for a Port-Access system that can perform TEASR in children and patients with very small femoral vessels is a major obstacle. Therefore, preoperative assessment of femoral vessel size is required. We do recommend dissection of femoral vessels before port placement to potentially avoid additional skin incisions in case of a necessary conversion. We have augmented the standard Port-Access technique by implementing a selective percutaneous drainage of the SVC and IVC to avoid impairment of visualization in the right atrium by a cannula. Total CPB was then induced by encircling both venae cavae, combining telemanipulated surgery with transthoracic instrumentation. Such a complex task requires special instruments and a precise coordination of the patient side and the console

Figure 1. A patient after TEASR.

surgeons. Both conversions that occurred were associated with Port-Access system failures and not with the totally endoscopic technique itself.

Since the advances of catheter technology enabled percutaneous closure of ASD, many centers have adopted this technique and it is considered a standard approach.^{10,26} Secundum-type ASDs with a circumscribed size and patent foramen ovale are well suited for percutaneous catheter closure. The success rate of the procedure is presently described around 80%.²⁷ Larger defects are beyond the scope of transcatheter treatment and a surgical treatment is required. Also, ASDs of the primum type or sinus venosus defects are not suitable for the interventional approach. Therefore, a totally endoscopic approach may be considered as an adjunct to the already existing interventional treatment options.

Complications such as intracardiac shunt recurrence,²⁸ device dislocation, and loosening or breaking off of upholding wires have been reported.^{10,29} These complications may even result in emergency operations to remove parts of the occluder.^{10,26} Therefore, rigorous patient selection is necessary. In addition intra-atrial prosthetic material may be a potential source of cerebral emboli.

TEASR gives the surgeon a free hand to close most types of ASD regardless of size, location, and shape. Only coincidence with extreme types of anomalous pulmonary veins is a contraindication since totally endoscopic snaring of SVC and IVC may not be feasible under special anatomic conditions.

In this patient collective there was no intraoperative or postoperative complication, although operative times were prolonged as compared with standard minimally invasive techniques. The main reason for this is the time-consuming placement of the endoaortic balloon, where the balloon is even more unstable in these kind of patients, who have healthy aortas, which are much more compliant than in patients, for example, with coronary artery disease. Echocardiographic follow-up on hospital discharge revealed normal atrial septum configuration without residual shunt. Postoperative recovery was uneventful, and patient satisfaction was high with excellent cosmetic results.

In summary, our experience confirms the data reported by Torracca and colleagues,²⁵ who are using almost exactly the same method. TEASR is a feasible and safe procedure with good clinical results. Further studies with larger cohorts and randomized trials are necessary to document potential benefits. Evolution in robotic technology and refinement of procedural flow may shorten procedural time and decrease costs.

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