Evolving Technology

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

Gerhard Wimmer-Greinecker, MD, PhD[a]
Selami Dogan, MD[a]
Tayfun Aybek, MD[a]
Mohammad Fawad Khan, MD[a]
Stephan Mierdl, MD[a]
Christian Byhahn, MD[b]
Anton Moritz, MD, PhD[a]

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.

From the Departments of Thoracic and Cardiovascular Surgery[a] and Anesthesiology,[b] Intensive Care and Pain Therapy, Johann Wolfgang Goethe University, Frankfurt, Germany.

Received for publication May 21, 2002; revisions requested Aug 26, 2002; revisions received Oct 23, 2002; accepted for publication Nov 1, 2002.

Address for reprints: G. Wimmer-Greinecker, MD, PhD, Department of Thoracic and Cardiovascular Surgery, Johann Wolfgang Goethe University Frankfurt, Theodor Stern Kai 7, 60590, Frankfurt, Germany (E-mail: wimmer-greinecker@em.uni-frankfurt.de).

J Thorac Cardiovasc Surg 2003;126:465-8

0022-5223/2003 $30.00 + 0

doi:10.1016/S0022-5223(03)00053-9

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 Taufic[1] 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.

ET

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 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).

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

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

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).

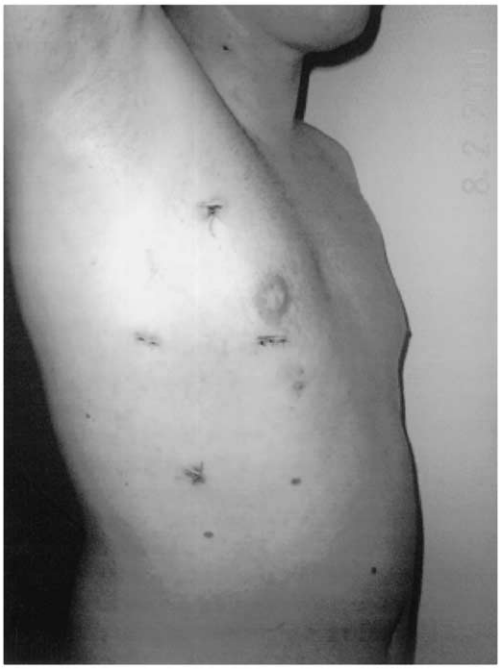

Figure 1. A patient after TEASR.

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 comorbities.

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 assisted[24] 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 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 circumscript 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.

ET

References

1. Lewis FJ, Taufic M. Closure of atrial septal defects with the aid of hypothermia: experimental accomplishments and the report of the one successful case. *Surgery*. 1953;33:52.
2. Murphy JG, Gersh BJ, McGoon MD, et al. Long-term outcome after surgical repair of isolated atrial septal defect. Follow-up at 27 to 32 years. *N Engl J Med*. 1990;323:1645-50.
3. Minale C. Atrial septal defect closure through a thoracotomy. *Ann Thorac Surg*. 1997;63:913-4.
4. Black MD, Freedom RM. Minimally invasive direct access for repair of atrial septal defect in adults. *Am J Cardiol*. 1998;65:765-7.
5. Byrne JG, Adams DH, Mitchell ME, Cohn LH. Minimally invasive direct access for repair of atrial septal defect in adults. *Am J Cardiol*. 1999;84:919-22.
6. Massetti M, Babatasi G, Rossi A, et al. Operation for atrial septal defect through a right anterolateral thoracotomy: current outcome. *Ann Thorac Surg*. 1996;62:1100-3.
7. Cremer JT, Boning A, Anssar MB, et al. Different approaches for minimally invasive closure of atrial septal defects. *Ann Thorac Surg*. 1999;67:1648-52.
8. Izzat MB, Yim AP, El-Zufari MH. Limited access atrial septal defect closure and the evolution of minimally invasive surgery. *Ann Thorac Cardiovasc Surg*. 1998;4:56-8.
9. Galloway AC, Shemin RJ, Glower DD, et al. First report of the Port-Access International Registry. *Ann Thorac Surg*. 1999;67:51-8.
10. Rao PS, Sideris EB, Hausdorf G, et al. International experience with secundum atrial septal defect occlusion by the buttoned device. *Am Heart J*. 1994;128:1022-35.
11. Ewert P, Berger F, Daehnert I, et al. Transcatheter closure of atrial septal without fluoroscopy. Feasibility of new method. *Circulation*. 2000;101:847-9.
12. Mohr FW, Falk V, Diegeler A, Autschbach R. Computer-enhanced coronary artery bypass surgery. *J Thorac Cardiovasc Surg*. 1999;117:1212-5.
13. Dogan S, Aybek T, Andreβen E, et al. Totally endoscopic coronary artery bypass grafting on cardiopulmonary bypass with robotically enhanced telemanipulation: report of forty-five cases. *J Thorac Cardiovasc Surg*. 2002;123:1125-31.
14. Dogan S, Aybek T, Mierdl S, Westphal K, Wimmer-Greinecker G, Moritz A. Atrial septal defect closure—first totally endoscopic intracardiac procedure. Abstract guide—3rd Ann. Scientific Meeting of Intl. Soc. for Minimally Invasive Cardiac Surgery (ISMICS), Atlanta, Ga, June 8-10, 2000. p. 18.
15. Wimmer-Greinecker G, Matheis G, Dogan S, et al. Complications of port-access cardiac surgery. *J Card Surg*. 1999;14:240-5.
16. Chitwood WR Jr, Elbeery JR, Moran JF. Minimally invasive mitral valve repair using transthoracic aortic occlusion. *Ann Thorac Surg*. 1997;63:1477-9.
17. Braxton JH, Marrin CA, McGrath PD, et al. Mediastinitis and long term survival after coronary artery bypass surgery. *Ann Thorac Surg*. 2000;70:2004-7.
18. Borger MA, Rao V, Wisel RD, et al. Deep sternal wound infection: risk factors and outcomes. *Ann Thorac Surg*. 1998;65:1050-6.
19. Mohr FW, Falk V, Diegler A, Walther T, van Son JA, Autschbach R. Minimally invasive port-access mitral valve surgery. *J Thorac Cardiovasc Surg*. 1998;115:567-76.
20. Mohr FW, Onnach JF, Falk V, et al. The evolution of minimally invasive valve surgery—2 year experience. *Eur J Cardiothorac Surg*. 1999;15:233-9.
21. Loulmet D, Carpentier A, d'Attellis N, et al. Endoscopic coronary artery bypass grafting with the aid of robotic assisted instruments. *J Thorac Cardiovasc Surg*. 1999;118:4-10.
22. Mohr FW, Falk V, Diegler A, Walther T, van Son JA, Autschbach R. Minimally invasive Port-Access mitral valve surgery. *J Thorac Cardiovasc Surg*. 1998;115:567-76.
23. Felger JE, Chitwood WR Jr, Nifong LW, Hobert D. Evolution of mitral valve surgery: toward a totally endoscopic approach. *Ann Thorac Surg*. 2001;72:1203-9.
24. Reichenspurner H, Boehm DH, Welz A, Schultze C, Zwissler B, Reichart B. 3D-video and robot-assisted minimally invasive ASD closure using the port-access technique. *Heart Surg Forum*. 1998;1:104-6.
25. Torracca L, Ismeno G, Alfieri O. Totally endoscopic computer-enhanced atrial septal defect closure in six patients. *Ann Thorac Surg*. 2001;72:1254-7.
26. Rome JJ, Keane JF, Perry SB, Spevak PJ, Lock JE. Double umbrella closure of atrial septal defects. Initial clinical application. *Circulation*. 1990;82:751-8.
27. Fischer G, Kramer HH, Stieh J, Harding P, Jung O. Transcatheter closure of secundum atrial septal defects with the new self-centering Amplatzer septal occluder. *Eur Heart J*. 1999;20:541-9.
28. Meijboom F, Hess J, Szatmari A, et al. Long term follow-up after surgical closure of atrial septal defect at a young age. *Am J Cardiol*. 1993;72:1431-4.
29. Arabia FA, Rosado LJ, Lloyd TR, Sethi GK. Management of complications of Sideris catheter devices for atrial septal defect closure. *J Thorac Cardiovasc Surg*. 1993;106:886-8.