Totally endoscopic atrial septal defect closure using robotic techniques: report of two cases

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Key words:
Atrial septal defect closure; Minimally invasive; Port-access; Robotic surgery.

Background. **The development of minimally invasive cardiac surgery has shown good clinical results with shorter recovery time and better cosmetic results. We report 2 cases of totally endoscopic atrial septal defect (ASD) closure using a robotic system. Open-heart closure of an ASD without opening the chest has never been previously reported.**

Methods. **Following percutaneous cannulation for cardiopulmonary bypass, aortic occlusion and delivery of cardioplegia, 2 patients with an ASD were successfully operated on using a robotic surgical device. After exclusion of the right lung, two robotic arms and an endoscopic camera were inserted through ports in the right hemithorax. A fourth port was inserted for an accessory endoscopic instrument. The ASD closure was carried out with interrupted stitches in one case and with a continuous suture in the other.**

Results. **Cardiopulmonary bypass and cardioplegic arrest times were respectively 130 and 75 min in the first and 87 and 60 min in the second case. Extubation was carried out 3 and 5 hours postoperatively. Both patients resumed a totally normal lifestyle 1 week after the operation.**

Conclusions. **Totally endoscopic open-heart ASD closure can be carried out safely using robotic techniques with rapid postoperative recovery and excellent cosmetic results. This modality of treatment can be considered an alternative to the transcatheter closure of ASD.**

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Introduction

Minimally invasive cardiac surgery has gained acceptance following the introduction of new surgical instruments, peripheral techniques for cardiopulmonary bypass[1,2], three-dimensional video assistance[3-5], and robotic devices[6-8].

Less invasive surgical approaches have recently been developed to close an atrial septal defect (ASD)[9-12], and the conventional midline sternotomy has been replaced by a small right antero-lateral thoracotomy, in order to reduce the overall surgical trauma and to improve esthetic results[13,14].

Moreover interventional cardiologists have developed percutaneous techniques for ASD closure in selected patients using a variety of devices[15-20].

We report 2 cases of totally endoscopic direct ASD closure with the aid of a robotic surgical device (da Vinci; Intuitive Surgical, Inc., Mountain View, CA, USA) and of the Heartport system for cardiopulmonary bypass, aortic occlusion and delivery of cardioplegic solution. No case of open-heart closure of an ASD with a completely closed chest has previously been reported.

Methods

The robotic system. During computer-assisted or robotic cardiac surgery, the surgeon sits at a console located at a distance from the patient and looks at a high-resolution three-dimensional binocular display of the operative field, manipulating instrument controllers positioned under the display (Fig. 1). The telemanipulated instruments supported by mechanical arms are articulated at their distal extremity so as to reproduce the motion of the surgeon's hands. One arm is used to position a three-dimensional endoscope and the two others are used to hold the removable articulated instruments (Fig. 2). In terms of motion, the mechanical wrist of the instruments has 7 degrees of freedom and is able to mimic the flexibility of the human wrist. Instrument tips in the display are electronically aligned with the instrument controllers to ensure the hand-eye orientation and

Figure 1. *The surgeon sitting at the console.*

Figure 2. *The robotic unit with the endoscope and the surgical instruments.*

natural operative feeling found in conventional surgery. Electronic systems allow for the use of motion scaling and the surgeon's hand movements are transmitted to the corresponding instruments with a 3:1 or 5:1 reduction ratio.

Lack of tactile feedback is a limitation inherent in robotic surgery at present.

Clinical material. The first patient was a 50-year-old man with a large patent foramen ovale (PFO), aneurysm of the atrial septum and recurrent episodes of cerebral embolism. Since several case-control studies had previously established a strong association between cerebrovascular accidents and the presence of PFO in adults, particularly with a coexisting aneurysm of the atrial septum, closure of PFO and plication of the aneurysm of the atrial septum were considered advisable.

The second patient was a 50-year-old woman with an ostium secundum ASD (Qp:Qs = 2:1). She was relatively asymptomatic, but an enlarged right heart was discovered by echocardiography and the ASD closure was indicated.

In both patients a coronary angiogram was carried out to exclude coexisting coronary artery disease. In addition, the entire aorta and the iliac-femoral arteries were meticulously studied by transesophageal echocardiography and echo-color-Doppler methods to rule out the presence of atherosclerotic plaques and to ensure safe application of the Heartport system for peripheral cardiopulmonary bypass and for the ascending aorta occlusion by means of an endoaortic balloon.

Both patients received detailed information concerning the new robotic surgical procedure and were aware of the possibility that the endoscopic operation could have been converted into conventional surgery at any moment should problems have arisen to ensure safety. A written consent was obtained by both patients.

Technique. After induction of anesthesia, the patients were intubated with a double-lumen endotracheal tube to exclude the right lung when necessary during the procedure.

Central lines were inserted as usual and both radial arteries were cannulated for arterial pressure monitoring. A multiple plane transesophageal echocardiography probe was placed to evaluate the correct position of the cannulas for cardiopulmonary bypass in the superior and inferior vena cava and of the endoaortic balloon for occlusion of the ascending aorta. External defibrillation pads were appropriately placed on the chest wall. The patients were placed in the supine position with the right hemithorax elevated approximately 30° and were covered so as to expose the entire chest and the groins.

Following exclusion of the right lung, a first port was created in the right fourth intercostal space on the anterior axillary line, in order to introduce the camera for the three-dimensional display of the operative field and to insert a line for carbon dioxide insufflation. Two additional ports were created (one in the third and the other in the fifth intercostal space) on the mid-axillary line for the introduction of the robotic instruments (Fig. 3). Moderately hypothermic cardiopulmonary bypass was established after cannulation of the right femoral artery, of the inferior vena cava (through the right femoral vein) and of the superior vena cava (through the right jugular vein using the Seldinger's technique). The venous drainage of the pump oxygenator was enhanced by a vacuum system. With appropriate robotic instruments, the pericardium was opened longitudinally 1.5 cm anterior to the right phrenic nerve. Both venae cavae were dissected and temporarily occluded by snared tapes. The endoaortic balloon was inflated to occlude the ascending aorta and cold crystalloid cardioplegic solution (St. Thomas) was delivered. After cardiac arrest, the right atrium was opened with an incision parallel to the interatrial groove and the intracardiac defect was inspected. In the first patient the PFO was closed and the

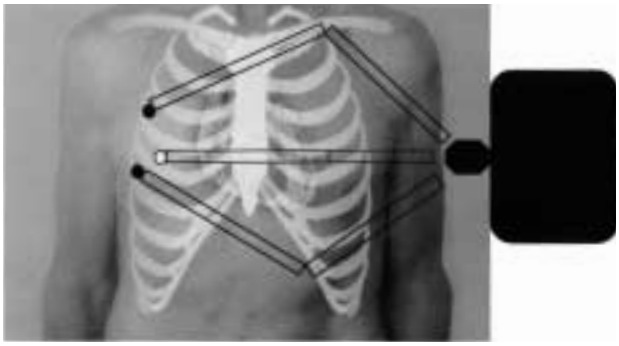

Figure 3. *The ports in the chest used for atrial septal defect closure.* White circle: *endoscope.* Black circles: *instruments.*

redundant atrial septum was plicated with interrupted stitches, while in the second patient the ASD was closed with a continuous suture.

The right atriotomy was closed with a continuous suture. At this point the endoaortic balloon was deflated and the cardiac activity resumed in sinus rhythm. After careful control of hemostasis, a chest tube was inserted in the right pleural space through one of the ports.

Results

The complete endoscopic operation was extremely smooth in both patients and no intra or postoperative complication was observed.

The total time needed for the entire procedure was 4.55 hours in the first patient and 4 hours in the second patient. The duration of cardiopulmonary bypass was 130 and 87 min, while the duration of aortic occlusion was 75 and 60 min. Both patients were easily weaned from cardiopulmonary bypass and were extubated 5 and 3 hours after the operation.

Both patients experienced a totally uneventful hospital course with minimal chest pain and discomfort. They were discharged from the hospital on the sixth postoperative day and resumed a completely normal lifestyle 1 week postoperatively.

The absence of a linear incision in the thoracic wall accounted for an excellent esthetic result (Fig. 4). Successful correction of the intracardiac defect in both patients was documented by echocardiography 1 month after the operation.

Discussion

ASD closure can be carried out nowadays through conventional midline sternotomy with negligible operative risk, extremely low morbidity, short hospital stay (5 days or less), relatively low cost and excellent long-term results[17].

Many patients, however, particularly young females with no symptoms, are reluctant to undergo an operation resulting in a long vertical scar visible in the midline of the chest.

Figure 4. *Cosmetic result in the second patient.*

A better cosmetic outcome can be obtained when the operation is performed through a right thoracotomy, particularly in association with minimally invasive techniques.

Using these less traumatic approaches similar good clinical results have recently been reported in a large series of adult patients[9-11].

Moreover in the last decade, with the development of new occluder systems, the transcatheter closure of ASD has become a standard technique in some centers[15-21]. With increasing operator experience and the development of easy-to-handle devices, a larger expansion of the percutaneous approach can be expected in the future. Certainly the correction of the intracardiac defect without surgical incisions and extracorporeal circulation is attractive, although rigorous patient selection is mandatory and the success rate of the procedure is presently around 80%[22]. Recurrence of the intracardiac shunt as well as dislodgment of the occluder has been reported[23-26].

With the advent of computer-assisted robotic surgery, another option is offered for ASD closure without the opening of the chest. Certainly high sophisticated technology is required, and the procedure is complex, time-consuming and costly. The potential of the method, however, seems to be high. The possibility of closing every type of ASD, regardless of size and location is particularly appealing. Unfortunately, the operation cannot be carried out in small children, because peripheral cannulation for cardiopulmonary bypass is needed.

Since its introduction in May 1998, robotic cardiac surgery has mainly been applied to coronary surgery for single vessel disease (implantation of the left mammary artery on the left anterior descending coronary artery)[27]. Also valve reconstructive surgery has been performed by some surgeons with the aid of a computer-assisted robot[8,28-30]. As far as ASD closure is concerned, Reichenspurner et al.[6] reported a gratifying ex-

perience in 7 patients. A small thoracotomy (3.5-5 cm) however, was always needed to complete the intracardiac repair.

In this paper we report the first 2 cases in whom the totally endoscopic ASD closure was successful using robotic techniques.

The introduction of a completely new and futuristic technology is always associated with circumspect criticism and penetrating questions by the scientific community.

Are the initial results going to be suboptimal? Is the safety of the patient always respected? Is the cost of the procedure unacceptably high? The only way to favor the progress towards what may be a new future for cardiac surgery is to be fully aware of all these concerns.

References

1. Stevens JH, Burdon TA, Peters WS, et al. Port-access coronary artery bypass grafting: a proposed surgical method. J Thorac Cardiovasc Surg 1996; 111: 567-73.
2. Strevens JH, Burdon TA, Siegel LC, et al. Port-access coronary artery bypass with cardioplegic arrest: acute and chronic canine study. Ann Thorac Surg 1996; 62: 435-40.
3. Carpentier A, Loulmet D, Carpentier A, et al. First open heart operation (mitral valvuloplasty) under videosurgery through a minithoracotomy. C R Acad Sci Paris Life 1996; 319: 221-5.
4. Chitwood WR Jr, Wixon CL, Elbeery JR, Moran JF, Chapman WH, Lust RM. Video-assisted minimally invasive mitral valve surgery. J Thorac Cardiovasc Surg 1997; 14: 773-82.
5. Chitwood WR Jr, Elbeery JR, Chapman WH, et al. Video-assisted minimally invasive mitral valve surgery: the "micromitral" operation. J Thorac Cardiovasc Surg 1997; 113: 413-4.
6. 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 Surgery Forum 1998; 1: 104-6.
7. Mohr FW, Falk V, Diegeler A, Autschback R. Computer-enhanced coronary artery bypass surgery. J Thorac Cardiovasc Surg 1999; 117: 1212-4.
8. Loulmet DF, Carpentier A, Cho PW, et al. Less invasive techniques for mitral valve surgery. J Thorac Cardiovasc Surg 1998; 115: 772-9.
9. Black MD, Freedom RM. Minimally invasive repair of atrial septal defects. Ann Thorac Surg 1998; 65: 765-7.
10. 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.
11. 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.
12. Levinson MM, Fonger J. Minimally invasive atrial septal defect closure using the subxiphoid approach. Heart Surgery Forum 1998; 1: 2875.
13. Massetti M, Nataf P, Babatasi G, Khayat A. Cosmetic aspects in minimally invasive cardiac surgery. Eur J Cardiothorac Surg 1999; 16 (Suppl 2): S73-S75.
14. Walther T, Falk V, Metz S, et al. Pain and quality of life in minimally invasive versus conventional cardiac surgery. Ann Thorac Surg 1999; 67: 1643-7.
15. Rome JJ, Keane JF, Perry SB, Spevak PJ, Lock JE. Double-umbrella closure of atrial defects. Initial clinical applications. Circulation 1990; 82: 751-8.
16. 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.
17. 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.
18. Ewert P, Berger F, Daehnert I, et al. Transcatheter closure of atrial septal defect without fluoroscopy. Feasibility of a new method. Circulation 2000; 101: 847-9.
19. Windecker S, Wahl A, Chatterjee T, et al. Percutaneous closure of patent foramen ovale in patients with paradoxical embolism. Long-term risk of recurrent thromboembolic events. Circulation 2000; 101: 893-8.
20. Berger F, Ewert P, Bjornstad PG, et al. Transcatheter closure as standard therapy of most interatrial defects: experience in 200 patients treated with the Amplatzer septal occluder. Cardiology in the Young 1999; 9: 468-73.
21. Walsh KP, Tofeig M, Kitchiner DJ, Perat I, Arnold R. Comparison of the Sideris and Amplatzer septal occlusion devices. Am J Cardiol 1999; 83: 933-6.
22. 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.
23. Lambert V, Losay J, Piot JD, et al. Late complications of percutaneous closure of atrial septal defects with the Sideris occluder. Arch Mal Coeur Vaiss 1997; 90: 245-51.
24. Hekmat K, Mehlhorn U, Rainer de Vivie E. Surgical repair of a large residual atrial septal defect after transcatheter closure. Ann Thorac Surg 1997; 63: 1456-8.
25. La Rosée K, Deutsch HJ, Schnabel P, Schneider CA, Burkhard-Meier C, Höpp HW. Thrombus formation after transcatheter closure of atrial septal defect. Am J Cardiol 1999; 84: 356-9.
26. Bohm J, Bittigau K, Kohler F, Baumann G, Konertz W. Surgical removal of atrial septal defect occlusion system-devices. Eur J Cardiothorac Surg 1997; 12: 869-72.
27. 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.
28. 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.
29. Autschbach R, Falk V, Walther T, Diegeler A, Mohr FW. Robotic techniques. Z Kardiol 1999; 88 (Suppl 4): S42-S46.
30. Reichenspurner H, Boehm DH, Gulbins H, et al. Three-dimensional video and robot-assisted port-access mitral valve operation. Ann Thorac Surg 2000; 69: 1176-81.