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

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Introduction

Minimally invasive cardiac surgery has gained acceptance following the introduction of new surgical instruments, peripheral techniques for cardiopulmonary bypass, three-dimensional video assistance, and robotic devices. Less invasive surgical approaches have recently been developed to close an atrial septal defect (ASD) with less invasive surgical trauma and to improve cosmetic results.

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. 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

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 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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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 ro-
botic 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 pre-
viously established a strong association between cere-
brovascular 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 rel-
atively asymptomatic, but an enlarged right heart was dis-
covered by echocardiography and the ASD closure was
indicated.

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

Both patients received detailed information con-
cerning 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 monitor-
ing. 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 oc-
cclusion 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 an-
terior 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 ad-
ditional 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 instru-
ments, 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 solu-
tion (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 in-
spected. In the first patient the PFO was closed and the

Figure 1. The surgeon sitting at the console.

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

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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 results17.

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.

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 patients9-11.

Moreover in the last decade, with the development of new occluder systems, the transcatheter closure of ASD has become a standard technique in some centers15-21. 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 reported23-26.

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 robot8,28-30. 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