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Robotic Aortic Valve Replacement: Case Report

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ABSTRACT

We have developed a technique that enables robotic aortic valve replacement with port access via a small right anterior thoracotomy and minimally invasive aortic cross clamping. The procedure is performed under video guidance with all the annular sutures placed with the robot. In the case we report, the patient's postoperative course was extremely simple and pain was minimal. We believe that this is the first reported aortic valve replacement using robotic technology and that it opens a new field of application for robotic assisted surgery.

INTRODUCTION

In the last 10 years cardiac surgery developed from a complete sternotomy approach to minimal thoracic or sternal incisions to perform either coronary or valve surgery. Then endoscopic cardiac surgery was developed. We started initially with patent ductus closure in children as we described the original technique, which is still being used [Laborde 1995]. This type of total endoscopic approach was then followed for saphenous vein harvesting and coronary surgery, using a robotic approach for the latter procedure.

Endoscopic valve surgery is generally performed through a working port for valve and suture placement, as for mitral valve plasty or replacement [Vanermen 2000] or aortic valve replacement [Gersak 2003]. Telerobotic surgery has also been used for mitral valve surgery with success and encouraging results [Loulmet 1999, Mohr 2001, Nifong 2003, Tatooles 2004]. These previous results encouraged us in performing a case of telerobotic aortic valve replacement with small right anterior thoracotomy.

CASE REPORT

A 52-year-old Caucasian man was admitted to our institution with aortic insufficiency and normal coronary angiography, in sinus rhythm. The echocardiography revealed leaflets with no aortic calcifications, hemodynamic 4+ aortic insufficiency, ejection fraction of 50% with an ascending aortic diameter of 3.2 cm, and a normal mitral valve.

The decision to replace the aortic valve with a mechanical valve was made because of the patient's dyspnea and significant regurgitation. Preoperative pulmonary measurement was normal.

The patient had the choice between a median sternotomy or an endoscopic and robotic approach. He chose the latter procedure and signed an informed consent.

With the patient in supine position we placed a double-lumen endotracheal tube. Cardiopulmonary bypass (CPB) was established using a 2-cm skin incision in the right groin. Peripheral cannulation using Seldinger technique was performed in the right femoral artery (17 Fr arterial cannula; Medtronic, Minneapolis, MN, USA), the right femoral vein (21 Fr venous cannula; Medtronic) and the right internal jugular vein (17 Fr venous cannula; Medtronic). Vacuum-assisted venous drainage was used throughout CPB, and mild-moderate hypothermia to 29°C was maintained.

A right thoracic skin incision (5 cm) was made over the third intercostal space starting right of the sternum and continuing to the midaxillary line.

A 30°-angled endoscope upside oriented and attached to the robotic camera arm was placed at the internal extremity of the thoracotomy. A left ventricular vent was placed through the right superior pulmonary artery. A Portaclamp (Cardio Life Research, Brussels, Belgium) was placed around the aorta through a 12-mm thoracic port placed in the second intercostal space posterior to the axillary line. A cardioplegia needle was placed on the ascending aorta. Cardioplegia was given after aortic cross clamping as a single dose of cold crystalloid solution. A cold saline pericardial drip was introduced through the thoracotomy and maintained throughout aortic cross clamp.

The da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) used in this case is comprised of a surgeon console with an integrated 3-dimensional (3D) display stereo viewer, a surgical cart with a camera arm, and 2 instrument arms as well as a vision cart. The surgical cart was positioned at the left side of the patient, next to the surgical table and partially within the sterile field, and locked in position. This unit consists of 3 robotic arms: 2 instrument arms for Endowrist instruments and 1 camera arm for 3D stereoscopic camera positioning.

While the surgeon at the patient's side is within the sterile field, the operative surgeon sits at the console, manipulating 2 masters positioned directly under a magnified 3D display. He rests his head between head sensors on either side of the view port in order to see the 3D display in the stereo viewer.

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Figure 1. Postoperative incisions and port placements for robotic aortic valve replacement.

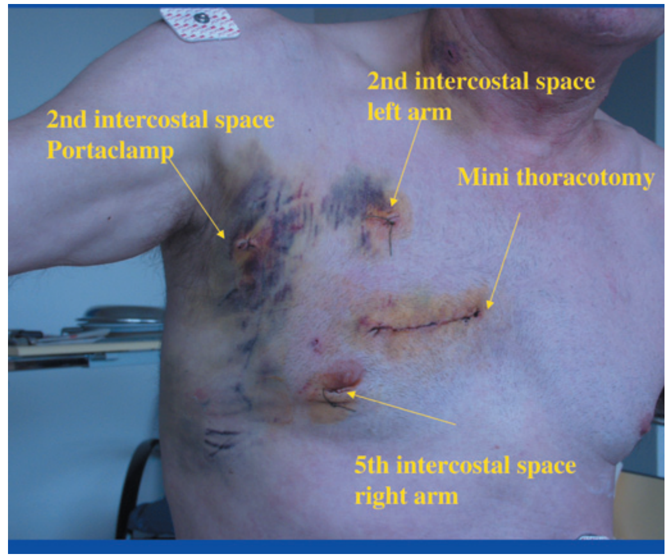

Figure 2. Patient 5 days after the operation.

Instrument tips viewed in the display are aligned with the masters to ensure natural and predictable instrument movements. The hand-eye orientation and natural operative feel found in open surgery are maintained for the surgeon. The da Vinci system electronics allow the use of motion scaling of surgeon hand movements. Motion scaling reduces hand movements to correspondingly smaller instrument-tip movements in the surgical field. Several settings allowed us to optimize scaling motion. Natural tremor of the surgeon's hand is eliminated through electronic filtering, which ensures stable, predictable, and high-precision instrument control. We used Endowrist technology instruments, which have a total of 7 seven degrees of freedom, 2 more at the tip than traditional thoracoscopic instruments. Tip articulations mimic the up/down and side-to-side flexibility of the human wrist. These articulations extended our minimally invasive surgery capabilities to a new level.

Two 8-mm robotic instrument trocars were placed in the second and fifth intercostal space midaxillary line in order to obtain a triangulation with the camera.

The aorta was opened through the working port and prolonged toward the noncoronary sinus commissure. The robotic Endowristed instruments enabled the placement with accurate precision of stay sutures on the aortic wall in order to expose the valve. The aortic leaflets were excised and the aortic annulus was measured to determine that it was large enough to accept a 23-mm mechanical valve (Sorin, Saluggia, Italy). Then 12 pledgeted 2/0 Ethibond sutures (Ethicon, Somerville, NJ, USA) were placed with the pledgets on the annulus and directly mounted on the artificial aortic valve. The valve was lowered in place through the working port, and knots were tied with a knot pusher. The mobility of the leaflets was tested before cutting the sutures.

The aorta was then closed with 2 running sutures of 5/0 polypropylene (Ethicon) and tied through the working port. Two ventricular wires were placed before declamping. The heart was then filled with blood, ventilation was resumed, and the heart was deaired through the cardioplegia needle in the aortic root. The aorta was declamped after 90 minutes, ventricular fibrillation was seen, and sinus rhythm was obtained after 1 shock given through external pads placed before draping. The patient was easily weaned from CPB with no inotropes after 100 minutes. Decannulation was performed, and protamin was given. Atrial wires were placed, and 2 pleural catheters were placed through the thoracostomies (Figure 1). The different incisions were closed with layered sutures.

The patient was extubated 6 hours later in the intensive care unit and transferred to the floor 48 hours later. He was then discharged 6 days after a controlled echocardiogram, which showed good cardiac function with no periprosthetic leak (Figure 2).

DISCUSSION

This case shows that it is possible to replace an aortic valve with telerobotic assistance. We chose to place the camera in the working port because it comes directly over the aortic valve once the aorta is opened. Placing the 2 robotic trocars in the second and fifth intercostal midaxillary line created good triangulation, which allowed us to work more easily with the da Vinci. The placement of the working incision is crucial, because there is minimal space between the incision and the annulus. Therefore it is important to accurately assess where the annulus is located, either by reviewing the chest x-ray or by computed tomographic scan. After preliminary work we feel the placement of the camera is optimized in this way because of the aortic valve orientation, which is parallel to the working line. Compared to an endoscopic approach, the robotic approach offers an increase in flexibility, which makes suturing much easier. Also, using a transthoracic aortic clamp for cross clamping is easier and simpler than the Heartport approach, which requires a transesophageal echocardiogram.

At 3 months follow-up this patient was active, with a normally functioning bileaflet valve.

Since then we have performed a similar procedure in a male patient with calcified bicuspid aortic valve, with similar results.

We believe this case is only the beginning of a broader application for telerobotic aortic valve surgery.

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