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Early Clinical Experiences of Robotic Assisted Aortic Valve Replacement for Aortic Valve Stenosis with Sutureless Aortic Valve

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Abstract

Robotic assisted aortic valve surgery is still challenging and debatable. We retrospectively reviewed our cases of robotic assisted aortic valve replacement utilizing sutureless aortic valve with following surgical technique: 3 ports, 1 for endoscope and 2 for the robotic arms were inserted in the right chest and da Vinci Si robotic system (Intuitive Surgical, Sunnyvale, CA, USA) was adapted to these ports. Cardiopulmonary bypass was initiated through peripheral cannulations. A vent cannula was placed through the right superior pulmonary vein and a cardioplegia cannula in the ascending aorta. After cardioplegic arrest following aortic cross-clamp, the aortic valve was exposed through a clam shell aortotomy. Valvectomy along with decalcification was performed. Next using 3 guiding sutures the Perceval S valve (LivaNova, London, UK) was parachuted down and deployed. After confirming valve position, the aortotomy was closed. There were no major complications during the procedures and no conversion to sternotomy. Exposure of aortic valve was of high quality. Valvectomy required assistance with long scissors by the bedside surgeon for excision of the severely calcified valve cusps and effective decalcification of annulus. Postoperative convalescence was uncomplicated except for postoperative atrial fibrillation in 1 patient. Robotic assistance in aortic valve procedure enabled excellent exposure of the aortic valve and improved manipulation and suturing of the aortic annulus and aorta. There needs to be improvement of instrumentation for valve debridement and removal of calcium from the annulus. In addition, the sutureless valve technology contributes to the feasibility and the efficacy of this procedure.

Keywords

robotic surgery, minimally invasive aortic valve replacement, sutureless aortic valve

Introduction

Robotic assisted mitral valve surgery has been validated and widely used.[1] Meanwhile, robotic assisted aortic valve surgery is still challenging and debatable for the point of methodology. Robotic surgery requires enough thoracic cavity space to handle robotic arms. Aortic valve is anatomically closer to the chest wall than mitral valve, therefore making aortic valve surgery more challenging. Another reason is that the present robotic instruments are not built for aortic valve surgery. Majority of aortic valve replacement (AVR) is for aortic stenosis. Robotic scissors and forceps are not strong enough to remove the heavily calcified aortic valve.

Case Series

We retrospectively collected data from 2 patients who underwent robotic assisted AVR in our institution between May and June 2018. Patient profiles are summarized in Table 1. Both of the patients had severely calcified aortic valve.

Patient Selection

Patients who have suitable aortic anatomy could be a candidate for robotic AVR. To confirm the anatomy, preoperative computed tomography (CT) scan with contrast is mandatory. Aorta and peripheral vessels assessment is necessary. In general

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Table 1. Preoperative Patient Characteristics.

	Case 1	Case 2
Age	74	78
Height (cm)	177	179
Weight (kg)	92	80
BMI (kg/m^2)	29.2	25.6
BSA (m^2)	2.12	1.99
NYHA class	II-III	I-II
Comorbidity	Previous PCI	Parkinson's disease
Ejection fraction (%)	45-50	60
Aortic valve area	0.7	0.9
Aortic valve gradient (peak/mean; mmHg)	93/50	125/69
Aortic insufficiency	Mild to moderate	Mild
Ascending aortic diameter (cm)	3.2	3.8
Length of ascending aorta (cm)	9.8	9.7

BMI, body mass index; BSA, body surface area; NYHA, New York Heart Association; PCI, percutaneous catheter intervention.

considerations, patients with calcified or atherosclerotic aorta and peripheral vascular disease should be excluded. A history of right thoracotomy or severe lung disease is also contraindication of AVR through right thoracotomy approach. Position of ascending aorta is important. From our cadaveric experiences, distance from back wall of sternum to ascending aorta at the level of second or third intercostal space should be preferably more than 3 cm deep to get enough space to handle robotic arms. The length of ascending aorta more than 6 cm will provide easy exposure of aortic valve in the setting of robotic AVR.

Operative Technique

The patient is positioned supine and surgically prepped from the neck to mid-thigh. External defibrillator pads are placed. A 12-mm endoscopic port was inserted into right second or third intercostal space about 3 cm lateral to the sternal border. The camera port should be inserted in where the aortic valve can be seen in front. Two separate 7-mm robotic arm ports were inserted in the midclavicular line of each one up and below intercostal space from the 12-mm port. The endoscopic ports

Fig. 1. The trocar settings of a patient. In this case, the working port was connected to the camera port incision.

were adapted to the da Vinci Si robotic system (Intuitive Surgical, Sunnyvale, CA, USA; Fig. 1). Using robotic assistance, pericardium was opened and anchored to the skin from outside to expose the aorta. Around 4 cm of small working incision was made in the lateral side of the same intercostal space as the camera port and a soft tissue retractor were placed. After full heparinization, peripheral cannulation was achieved via the right femoral artery and vein. Cardiopulmonary bypass was initiated. A vent cannula through the working port was placed through the right superior pulmonary vein into the left ventricle. A cardioplegia cannula was placed in the ascending aorta. The aorta was separated from the pulmonary artery and then cross-clamped just below the pericardium reflection with a transthoracic aortic cross-clamp placed through the second intercostal space in the anterior axillary line. Del Nido cardioplegic solution was delivered through the aortic root cannula. During administration of cardioplegia, we monitored the size of left ventricle on transesophageal echocardiography to avoid distention. After cardioplegic arrest, the aortic valve was exposed through a clam shell aortotomy about 3.5 cm above the aortic root. Valvectomy along with decalcification of the annulus of the aortic valve was performed. To remove all of the bulky calcium, the bedside assistant had to use normal scissors under the robot guidance.

The insertion of the valve sizers into the thoracic cavity was challenging due to the length and the diameter of the rigid sizer. Three guiding sutures of 3–0 prolene were placed robotically in the nadirs of each aortic sinuses and brought out through the working port. The Perceval S valve was parachuted down with the guidance of the 3 guiding sutures and the valve was deployed. A standard balloon valvuloplasty was then performed at 4 mmHg for a total of 30 seconds. After visual confirmation of the valve position with the endoscope, the aortotomy was closed.

Clinical Results

Two male patients, with ages of 74 and 78, with severe aortic valve stenosis underwent robotic assisted AVR with previously described operative technique. Preoperative CT scan revealed that both patients have non-atherosclerotic ascending aorta of adequate length. However, in case 2, the retrosternal space was shorter than 3 cm (Fig. 2) making the procedures more challenging. There were no major intraoperative complications (Table 2). Although we had some difficulties with the setup in case 2 because of the smaller periaortic working space, we managed to complete the procedure successfully. Postoperative echo findings showed no aortic valve insufficiency, no paravalvular leak, and minimal gradients (Table 3). One patient had fluid overload postoperatively due to vasodilatation and required aggressive diuresis. Otherwise postoperative convalescence was uncomplicated. They were discharged home at days 4 and 10 after operation, due to postoperative atrial fibrillation, respectively (Table 3).

Table 2. Procedure.

	Case 1	Case 2
Valve	Perceval S medium	Perceval S extra large
CPB time (minutes)	252	234
Cross-clamp time (minutes)	118	111
Blood transfusion	No	No

CPB, cardiopulmonary bypass.

Discussion

The first minimally invasive AVR through a right thoracotomy was reported in 1993 by Rao et al.[2] Since then, this procedure has shown to result in reduction in transfusion rate, shorter duration of mechanical ventilation, and reduced intensive care unit and hospital stay despite longer cardiopulmonary bypass and cross-clamp times.[3,4] In addition, the first description of totally endoscopic AVR was reported by Vola et al.[5] They illustrated that the aortic valve can be much better visualized with the endoscope to enable valve excision and replacement. They also utilized Perceval S sutureless valve to minimize aortic

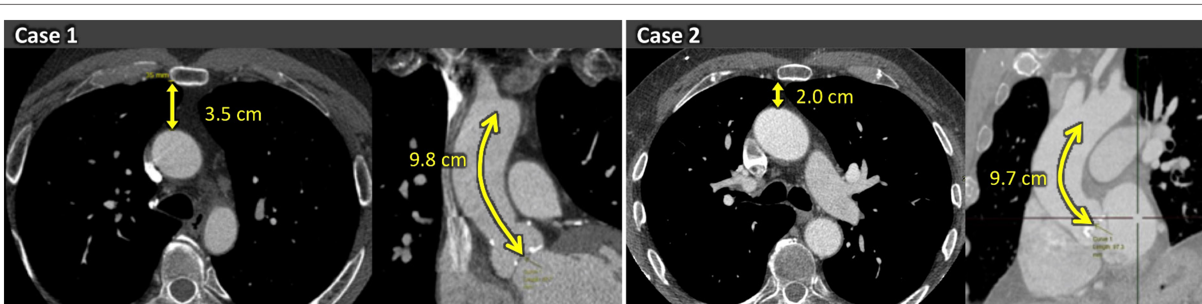

Fig. 2. Preoperative computed tomographic scan with contrast media. The length from sternum to ascending aorta (3.5 cm in Case 1 and 2.0 cm in Case 2) was measured at second or third intercostal space. The length between aortic valve and distal end of ascending aorta was used as a length of ascending aorta.

Table 3. Postoperative Outcomes.

	Case 1	Case 2
Aortic insufficiency	None	None
Aortic valve gradient (peak/mean; mmHg)	13/6	4/2
Ejection fraction (%)	50	60
Length of ICU stay	1	2
Complications	-	Postoperative atrial fibrillation Fluid overload
Discharge (day)	4	10

ICU, intensive care unit.

cross-clamp time and cardiopulmonary bypass time.[6] However, the exposure and instrument manipulation are not satisfactory in this minimally invasive setting, especially for patients with deep aortic valve position. Robotic assistance has the capability to provide much better visualization and outstanding instrument manipulation in a surgical field. The da Vinci system's 3-dimensional vivid image provides a very detailed image of the valve that is very beneficial for a successful procedure. Moreover, the flexible robotic arms with 7 degrees of freedom enhance reproducibility of the steps required in the valve replacement such as valve debridement and closure of the aortotomy. The robotic assisted aortic valve surgery would be specifically more beneficial for the patients with deep aortic valve position.

However, aortic valve surgery utilizing robotic assistance remains still challenging. The first reason is the anatomical feature of aortic valve. The aortic valve is closer to the chest wall than the mitral valve. Due to the small space, appropriate endoscopic port placement is essential to avoid the robotic arms from colliding during the manipulation of the instruments. Thus far, the patient selection is extremely important to ensure good outcome. Further improvements in robotic technology are required to apply robotic AVR to more patients.

The other challenge in robotic AVR is the robotic instruments. The instruments are not suitable for aortic valve surgery. Since majority of AVRs are for aortic stenosis, we need specialized instruments for the management of the calcium on the aortic valve. Presently the robotic scissors and forceps are not adequate in order to enable safe removal of the heavily calcified aortic cusps. In our present cases, the bedside surgeon had to use classical long scissors under robotic endoscopic guidance to debride the calcium. The robotic endoscope was helpful for confirming good collection of debrided tissues because the camera also can give us better and more detail visualization of the inside of the left ventricle.

To the best of our knowledge, there is only one previous publication reporting robotic AVR for aortic stenosis.[7] There is also publication on robotic assisted AVR for patients with aortic valve insufficiency.[8,9] Our report presents our experience with robotic AVR using sutureless valve technology for the patients with aortic stenosis. The Perceval S sutureless valve is a new bioprosthesis made of bovine pericardium mounted on a self-expandable nitinol stent. Its simple and quick implantation technique can shorten the aortic cross-clamping time in the setting of minimally invasive approaches. In addition, the absence of a sewing ring has resulted in better hemodynamic outcomes.[10] This new technology definitely contributes to practicability of robotic AVR. In the setting of robotic AVR, the working port has to be large enough to pass the sizer and the prosthetic valve itself. The present available valve sizer is not designed for minimally invasive surgery and can definitely be improved. An expandable or collapsible valve sizer would be much more advantageous.[11]

In the era of transcatheter aortic valve implantation (TAVI), robotic AVR provides an alternative treatment strategy for patients who are seeking a minimally invasive approach to their aortic valve who are not suitable candidates for TAVI, such as patients who are young (<60 years old), with bicuspid valve, or with large annuli.

In conclusion, we report our early experiences of robotic assisted AVR with the utilization of the Perceval S sutureless valve for patients with aortic stenosis. Robotic assistance provided us an excellent exposure of the aortic valve and desirable instrument manipulation for the procedure. Thus far, robotic technology looks promising in improving the performance of minimally invasive AVR; however, further improvements in valve sizers, robotic technology, and instrumentation would be required.

Declaration of Conflicting Interests

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