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ORIGINAL ARTICLE

Robotic repair of partial anomalous pulmonary venous connection: the initial experience and technical details

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Abstract
This study reports our initial experience with robotic-assisted partial anomalous pulmonary venous connection (PAPVC) repair. From May 2013 through September 2018, 20 patients (12 male and 8 female) underwent robotic-assisted repair of a right-sided ($n = 19$) or a left-sided ($n = 1$) PAPVC. The mean age was 24.6 ± 9.4 years (range 14–44) and the mean body mass index was 22.3 ± 4.6. Seventeen patients had a right-sided supra-cardiac PAPVC with sinus venosus atrial septal defect, two had a right-sided cardiac PAPVC to the right atrium and one had a left-sided cardiac PAPVC to the coronary sinus. Associated anomalies included patent foramen ovale ($n = 2$) and left persistent superior vena cava ($n = 1$). All patients were operated on successfully. No conversion to mini-thoracotomy or sternotomy was needed. Cardiopulmonary bypass and aortic clamping times were 114.8 ± 17.3 (range 90–150) and 66.5 ± 15.8 (range 44–90) minutes, respectively. Repair techniques included the single-patch repair with baffle through right atriotomy ($n = 16$), the 2-patch repair ($n = 1$) using lateral transcaval incision and intracardiac re-routing ($n = 3$). The mean ventilation time was 4.2 ± 1.2 h and hospital stay was 3.1 ± 0.1 days. No phrenic nerve injury, sinus node dysfunction, re-exploration or blood transfusion was noted. No residual shunting or venous obstruction was found on echocardiograms. Follow-up was a mean of 1.7 years (range 3–36 months). There was no follow-up mortality. Totally, endoscopic robotic-assisted PAPVC repair is a feasible procedure in selected adult patients. It is a less invasive alternative to traditional incisions, mini-thoracotomy and endoscopic approaches. In the future, new generation robotic devices may offer an alternative for younger patients with this pathology.

Keywords Robotic cardiac surgery · Partial anomalous pulmonary venous connection

Introduction

Technological advances and surgical experience have allowed the development of robotic-assisted procedures as an alternative to traditional and endoscopic techniques in cardiac surgery. Since the initial use of the DaVinci system in the early 2000s, totally endoscopic robotic cardiac procedures have been performed in more than 3 million patients worldwide [1–11]. However, the use of robotic technology in congenital heart pathologies has remained limited to ASD procedures. In 2001, Toracco and associates reported the first series on ASD repair [2]. Then, Argenzino, Bonaros and Xiao and their associates [3–5] reported the safety of robotic ASD repair. There are several reports on the application of robotic technique in patients with PAPVD [9–11]. Surgical repair of PAPVCs is traditionally done through sternotomy or thoracotomy [12–19]. Minimally invasive thoracotomy or thoracoscopic surgery can also be performed in selected patients with PAPVC [17, 18]. Nevertheless, the feasibility, repair technique and safety of robotic PAPVC repair have remained unclear. This may be related to technical complexity of most operations and surgical experience on congenital heart procedures. With the use of new generation systems, robotic surgery can be a less invasive alternative to the other techniques in selected patients.

In this study, we analyzed our initial experience in performing totally endoscopic robotic surgery in patients with

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PAPVC. We also discuss surgical technique and feasibility of robotic procedures.

Patients and methods

Patients

The institution's Clinical Review Board of the Hospital approved this study. Between May 2013 and September 2018, 463 patients underwent totally endoscopic robotic-assisted cardiac operations at the Department of Cardiovascular Surgery of our hospital. A total of 20 patients (12 males and 8 females) underwent robotic-assisted PAPVC repair operations. Preoperative diagnosis was established using two-dimensional echocardiography and computed tomography angiography. The type, number and location of PAPVCs with associated defects were ascertained. Nineteen patients presented with right-sided (17 supra-cardiac and 2 cardiac) PAPVCs. One patient presented with a left-sided upper PAPVC to the coronary sinus and intact interatrial septum. All right-sided supra-cardiac PAPVCs were associated with a sinus venosus type ASD.

The preoperative characteristics are demonstrated in Table 1. The mean ages of the patients were 24.6 ± 9.4 years (range 14–44 years; median, 20 years). Six patients were less than 18 years old. The mean ejection fraction and Q_p/Q_s ratio were 61.7 ± 2.4 and 2.0 ± 0.4, respectively. Technical feasibility of a robotic repair was evaluated in each patient according to their chest anatomy, body size and presentation of the pathology. Patients with severe chest wall deformity, small body size, moderate-to-severe aortic regurgitation, severe pulmonary hypertension, previous cardiothoracic procedures, chest trauma and concomitant cardiac anomalies such as a ventricular septal defect or pulmonary stenosis were excluded.

Table 1 Preoperative characteristics

Variable	Value
Total number of patients	20
Male	12 (60.0)
Female	8 (40.0)
Age (years)	24.6 ± 9.4 (14–44)
Body mass index (kg/cm^2)	22.3 ± 4.6
Left ventricular ejection fraction (%)	61.7 ± 2.4
Q_p/Q_s	2.0 ± 0.4
Pulmonary artery pressure (mmHg)	25.2 ± 4.5
EuroSCORE	0.7 (0–1)
PAPVC, type	
Right supra-cardiac	17 (85.0)
Right cardiac	2 (10.0)
Left cardiac (via coronary sinus)	1 (5.0)
Concomitant pathology	
Sinus venous-type atrial septal defect	17 (85.0)
Patent foramen ovale	2 (10.0)
Left persistent superior vena cava	1 (5.0)
Absence of innominate vein	1 (5.0)

Variables are reported as mean ± SD; categorical variables as numbers and percentages

PAPVC partial anomalous venous connection

Surgical technique

The da Vinci Surgical System (Intuitive Surgical, Inc, Sunnyvale, CA USA) was used. After general anesthesia and single-lumen endotracheal intubation, a transesophageal echocardiography probe was placed. The patients were positioned in a slight left lateral position. A chest roll is placed under the right shoulder, the right arm is placed at the side of the operation table and the table is rotated approximately 20°–30° to the left. This position allowed optimal widening of the intercostal spaces, easier placement of the trocars for robotic instruments, retraction of the left lung and better exposure of the surgical field. The incision sites were marked on the chest wall and femoral area.

Following systemic heparinization, venous cannulation was done through the right internal jugular vein (17F) with the right femoral vein, and arterial cannulation was done through the right femoral artery under transesophageal echocardiography guidance. The diameters of the femoral vessels were measured intraoperatively and the sizes of the cannulas were confirmed. Right anterolateral mini-thoracotomy of 2–3 cm used as the working port was done in the fourth intercostal space. A 30° endoscope was placed through the working port. Two additional instrumental ports were inserted through the third and fifth intercostal space. Atrial retractor was introduced through the fifth intercostal space anteriorly. A transthoracic aortic clamp was introduced into the right hemithorax through the third intercostal space in the mid-axillary line. Carbon dioxide (2 l/min) was insufflated.

After initiation of cardiopulmonary bypass, ventilation of the lungs was terminated. The right and left-hand instruments, surgical endoscope and atrial retractor were inserted into the right hemi-thorax. Pericardiotomy was done 2 cm above and parallel to the right phrenic nerve to expose the ascending aorta, the right atrium and both vena cava. Pericardial stay sutures were placed. In right-sided supra-cardiac PAPVC repairs, the azygos vein was explored in the right hemithorax. The tissue between the azygos vein and pulmonary hilus was gently dissected to be able to place an atraumatic vascular clamp to occlude the superior vena cava during cardiopulmonary bypass (Fig. 1, upper view). A long-shafted cardioplegia cannula was placed at the right

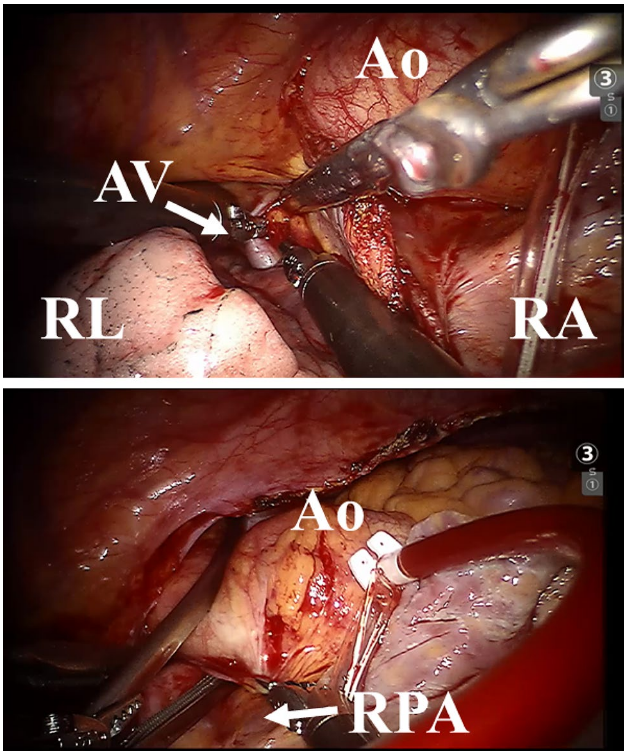

Fig. 1 Endoscopic views show the placement of an atraumatic bulldog clamp on the superior vena cava just below the azygous vein (upper view) and aortic clamp on the distal ascending aorta (lower view). *Ao* ascending aorta, *AV* azygous vein, *RA* right atrium, *RL* right lung, *RPA* right pulmonary artery

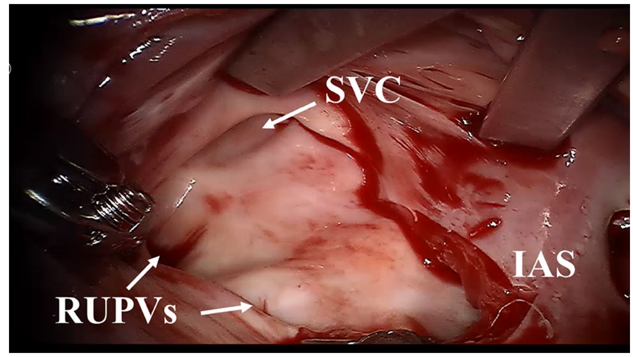

Fig. 2 Endoscopic view via right atriotomy shows anomalous pulmonary venous return to the cava-atrial junction. Note that a restricted sinus venosus atrial septal defect was enlarged with septectomy. *IAS* interatrial septum, *RUPVs* right upper pulmonary veins, *SVC* superior vena cava

anterolateral side of the ascending aorta. This cannula was inserted through the working port, snared and fixated. Before aortic clamping and delivery of antegrade cardioplegia, the tissue between the ascending aorta and right pulmonary artery was dissected, the aorta was mobilized anteriorly, and a Chitwood clamp (Scanlan International, Minneapolis, Minn, USA) was placed superiorly in the ascending aorta (Fig. 1, lower view). Both vena cava were occluded using atraumatic vascular bulldog clamps (Aesculap, Braun, Germany) before aortic clamping. Cardiac arrest was achieved using antegrade delivery of isothermic blood cardioplegia. Following cardiac arrest, intracardiac structures including the orifices of the superior vena cava and anomalous pulmonary veins were explored using atrial retractor and 30° endoscope (Fig. 2). If a left persistent superior vena cava draining to the coronary sinus was associated, a sump was placed in the coronary sinus.

Right-sided supra-cardiac PAPVC repair using the single-patch technique via right atriotomy

Right-sided supracardiac PAPVC repairs were done using either the single-patch technique with baffle via right atriotomy in 16 patients or the 2-patch technique using lateral transcaval incision in 1 patient. The single-patch technique was preferred in right-sided supra-cardiac PAPVCs if the diameter of the superior vena cava or cava–atrial junction was wide. If the superior vena cava was small, the 2-patch technique with lateral transcaval incision was performed to avoid an obstruction to the superior vena cava or pulmonary veins [13–15]. In right-sided PAPVCs, the size of associated sinus venosus ASD should allow an unrestricted communication for pulmonary venous return to the left atrium. If the diameters of both the proximal superior vena cava and associated sinus venosus septal defect were wide, we directly made an intracardiac routing using the single-patch technique with baffle through right atriotomy incision (Figs. 3, 4). If the diameter of sinus venosus ASD was small or restricted, we first performed septectomy towards the fossa ovalis (a cut-back incision) to enlarge interatrial communication and then perform intracardiac routing of the pulmonary veins to the left atrium. A bovine or autologous pericardial patch was used to baffle the anomalous drainage to the left atrium. A double-needle 5-0 polytetrafluoroethylene suture (W. L. Gore & Associates Inc., Flagstaff, AZ) was used, beginning at the superior border (at the 2 o-clock position) of the ASD and continuing cranially along the ASD rim to the lower border of the superior vena cava and then inferiorly along the superior border of the anomalous pulmonary veins. The other needle was run in the other direction along the inferior rim of the ASD. The left atrium was drained to have a bloodless exposure.

Right-sided supra-cardiac PAPVC repair using the 2-patch technique via transcaval incision

In this series, the 2-patch repair technique using lateral transcaval incision was used in only one patient, who was 14 years

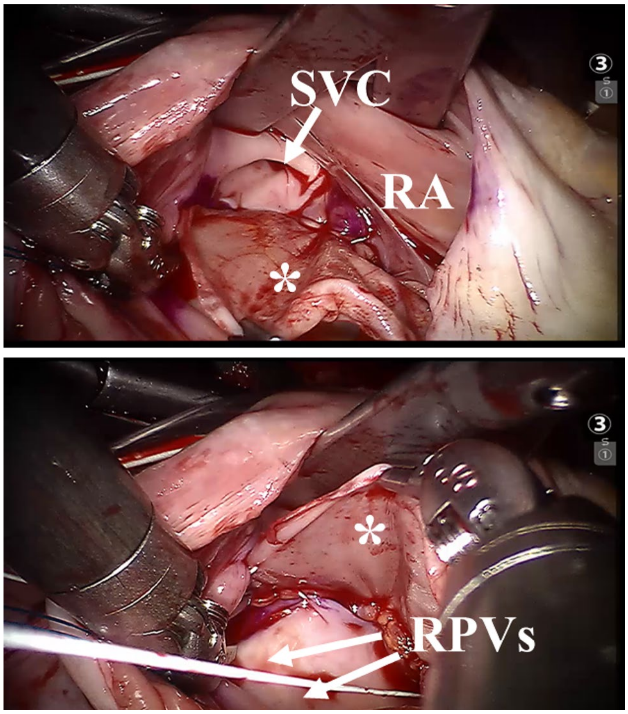

Fig. 3 The single-patch technique using a pericardial patch (*) with baffle for re-routing of anomalous pulmonary venous return to the left atrium. *RA* right atrium, *RPVs* right pulmonary veins, *SVC* superior vena cava

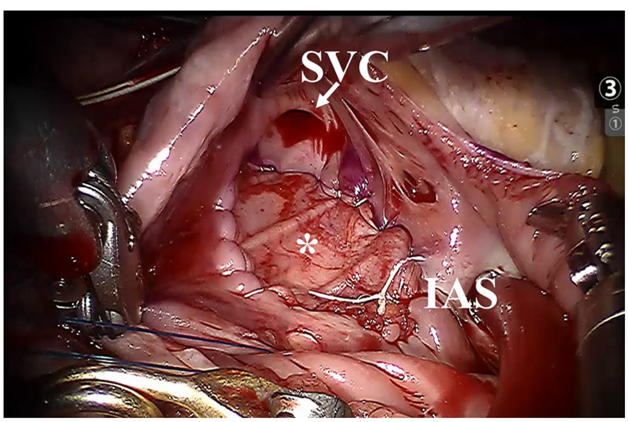

Fig. 4 Right-sided supra-cardiac partial anomalous pulmonary venous connection repair using pericardial patch (*) with baffle after septectomy. *IAS* interatrial septum, *SVC* superior vena cava

old. In this patient, the superior vena cava was narrow due to an associated left persistent superior vena cava. This technique was preferred to avoid an iatrogenic obstruction of the superior vena cava and associated symptoms due to small diameter of the superior vena cava. Otherwise, robotic repair would be impossible through right atriotomy. The superior vena cava was opened with a lateral craniocaudal venotomy incision that was started at the level of anomalous pulmonary venous connection down to the proximal right atrium. This incision was posterior to the sinus node and its feeding artery. The first patch was used for intracardiac routing and closure of sinus venosus atrial septal defect. The second patch was used for reconstruction of the superior vena cava that allowed unrestricted systemic blood return to the right atrium.

Right-sided cardiac PAPVC repair with intracardiac re-routing via right atriotomy

Two right-sided cardiac PAPVCs were repaired through right atriotomy incision. In these patients, a large interatrial communication was made first if the interatrial septum was intact. Otherwise, restricted ASDs were enlarged. Then, a neo-interatrial septum was reconstructed with a bovine pericardial patch for re-routing right pulmonary venous return to the left atrium [9].

Left-sided cardiac PAPVC repair via right atriotomy

A left-sided cardiac PAPVC to the coronary sinus was corrected via the right atriotomy [11]. The roof of the coronary sinus was opened widely to the left atrium and a wide interatrial communication was composed. Interatrial septum was reconstructed with a bovine pericardium leaving the left pulmonary venous return to the left atrium.

All sutures were tied with the help of a knot-pusher. After deairing and closure of right atriotomy, the aortic clamps were released, and the hearts started beating spontaneously on sinus rhythm. Pericardial edges were approximated, the robotic instruments were removed, the lungs were ventilated and then the patients were weaned from cardiopulmonary bypass. Postoperative transesophageal echocardiography was made to assess the results of the procedure, and protamine sulphate (1:1) was administered. A 28-F chest tube was inserted in the right hemi-thorax through one of the port holes, and skin incisions were sutured.

Postoperative management and follow-up

The patients were transferred to the intensive care unit and extubated. They were transferred to the ward on postoperative day 1. Chest tubes were removed as drainage was less than 200 mL/24 h. All patients underwent control transthoracic echocardiography before discharge and at follow-up visits.

Statistical analysis

Data are given as mean (range) or when appropriate as mean ± deviation. SPSS 21.0 for Windows (Chicago, IL, USA) was used for statistical analysis.

Results

All patients were operated on successfully with the DaVinci Sİ surgical system. No conversion to mini-thoracotomy or median sternotomy was needed. Endoscopic exploration of the orifices of each anomalous pulmonary vein and the superior vena cava was excellent using three-dimensional visualization of a 30° endoscope. Robotic atrial retractor provided effective exposure for repair through oblique right atriotomy in all right-sided supracardiac PAPVCs and in the other procedures. The mean operation time was 210.0 ± 36.5 min (range 140–360). It was significantly decreased in the last 10 procedures (Fig. 5). The mean cardiopulmonary bypass and aortic clamping times were 114.8 ± 17.3 min (range 90–150) and 66.5 ± 17.3 min (range 44–90), respectively. All patients were weaned from cardiopulmonary bypass in sinus rhythm uneventfully. Central venous pressures were normal after the procedures. The intraoperative and postoperative transesophageal echocardiograms demonstrated no turbulence or pressure gradient that suspected a stenosis of systemic or pulmonary venous return. No residual left-to-right shunting was observed postoperatively.

The mean lengths of ventilation, intensive care unit stay, and hospital stay were 4.2 ± 1.2 h, 13.8 ± 1.8 h and 3.1 ± 0.1 days, respectively (Table 2). The mean drainage volume from chest tubes was 63.5 ± 45.2 ml (range 0–150). No blood transfusion was needed. No sinus node dysfunction, phrenic nerve injury, pleural effusion, re-exploration or wound infection developed during the postoperative 30-day follow-up. There was no operative and follow-up mortality. Follow-up was a mean of 1.7 years (range 3–36 months). Patients were healthy and no residual intracardiac defect was found on follow-up echocardiography examinations.

Comment

The innovations in medical devices and surgical techniques have allowed cardiac surgeons to adapt minimally invasive cardiac procedures. The DaVinci systems provide an enhanced visualization with a three-dimensional excellent view, ergonomic design and great dexterity with precise movements of the instruments. The dynamic atrial retractor greatly facilitates the exposure of intracardiac anatomy. Currently, 3D vision systems are also available for endoscopic procedures which may make robotic surgery a less likely choice, given the experience that most surgeons have with endoscopic procedures. However, the adaptation of the surgeon to a closed chest procedure is easier in robotic surgery when we consider adaptation to long-shafted instruments for endoscopic procedures.

The anatomic presentation of PAPVCs is important for the feasibility of robotic repair. There are mainly five types

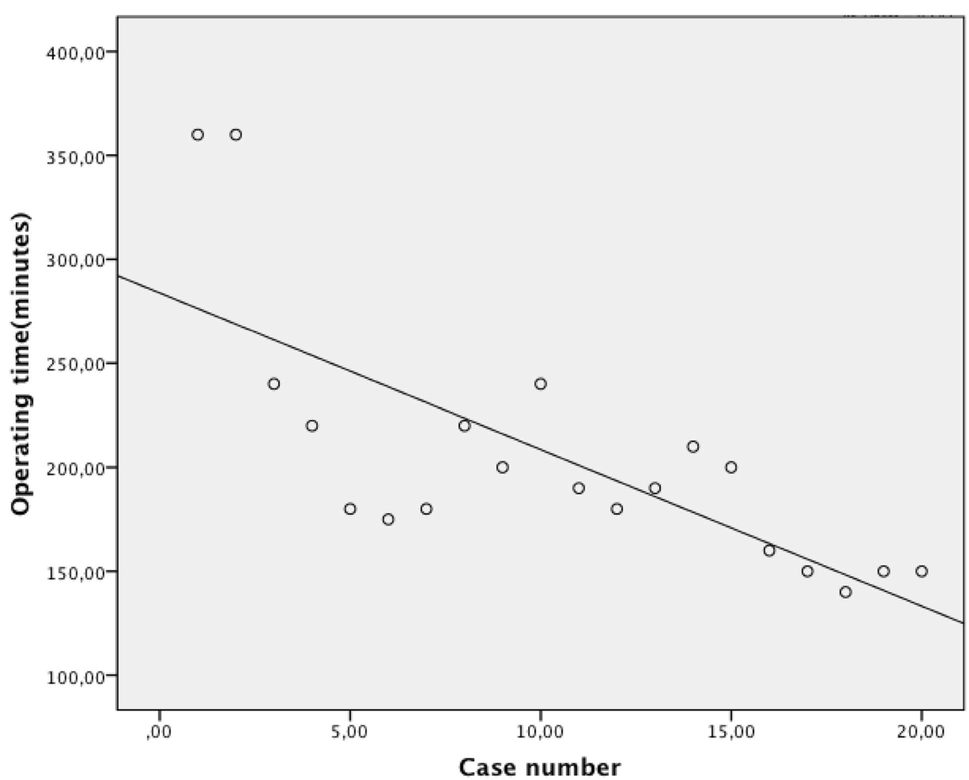

Fig. 5 The trend line of operating time for partial anomalous pulmonary venous connection repair

Table 2 Operative and postoperative data

Variable	Value
Total operative time (min)	210.0 ± 36.5 (140–360)
Cardiopulmonary bypass time (min)	114.8 ± 17.3 (90–150)
Cross clamp time (min)	66.5 ± 17.3 (44–90)
Closure technique (*n*)	
Single-patch repair	16
2-patch repair	1
Intracardiac re-routing	3
Blood product transfusion (unit)	
Red blood cells	0
Fresh-frozen plasma	0
Mechanical ventilation time (h)	4.2 ± 12
Length of intensive care unit stay (h)	13.8 ± 1.8
Drainage from chest tubes (mL/24 h)	63.5 ± 42.2 (0–150)
Total length of hospital stay (days)	3.1 ± 0.1
30-day mortality	0
Conversion to mini-thoracotomy or sternotomy	0
Re-exploration	0
Sinus node dysfunction	0
Residual septal defect	0
Turbulent flow or stenosis after repair	0

Variables are reported as mean ± SD; categorical variables as numbers and percentages

of PAPVCs including right-sided (supra-cardiac, cardiac and infra-cardiac types) and left-sided (cardiac and supra-cardiac types) PAPVCs [9–17]. The most common variant of PAPVC is supra-cardiac where there is a right upper pulmonary vein connecting to the right atrium or the cava-atrial junction. In most patients with PAPVC, there is an associated cardiac defect, which is usually a sinus venosus ASD. No study reported the feasibility of robotic PAPVC repair in right-sided supra-cardiac PAPVCs. Several reports showed that right-sided cardiac PAPVCs and some left-sided cardiac and supra-cardiac PAPVCs can be repaired robotically, but a considerable experience on robotic cardiac surgery is necessary [9–11]. Anomalous connection of the right pulmonary veins to the inferior vena cava (Scimitar syndrome) should be operated with conventional incisions, rather than robotic surgery. In such cases, robotic manipulations and endoscopic control of systemic and pulmonary venous return may be challenging.

Robotically-assisted repair of right-sided PAPVCs have some technical pitfalls and modifications when it is compared to a routine robotic ASD repair. During jugular venous cannulation, the tip of the cannula should be above the level of the azygous vein. If a left persistent superior vena cava is present, venous drainage is completed with cannulation of the left internal jugular vein or drainage of the coronary sinus [9, 11]. The placement of the trocars for robotic instruments can be done similarly to ASD procedures. But all robotic instruments and transthoracic aortic clamp can be placed through one upper intercostal space to have a better exposure and manipulation. When the lungs were deflated, pulmonary venous returns and azygos vein are explored first. The connective tissue between the azygos vein and the right upper pulmonary vein is gently dissected to be able to place an occluding clamp on the superior vena cava for establishment of total cardiopulmonary bypass. The use of an atraumatic vascular clamp is a simple and effective solution for occlusion of the superior vena cava [7–9, 11]. One arm of the clamp is placed on the superior vena cava intrapericardially, whereas the other arm is placed between the azygous vein and the right upper pulmonary vein posteriorly in the hemi-thorax. A transthoracic aortic clamp can be introduced through the second or third intercostal space in the mid-axillary line. This clamp can be placed on the distal ascending aorta or through the transverse sinus. The aortic clamp is placed on the distal ascending aorta after dissection of the epicardial tissue between the aorta and the right pulmonary artery. The inner curvature of aortic clamp is placed superiorly. If it will be placed through the transverse sinus, the inner curvature should be towards the aortic root. However, the second approach may cause iatrogenic injuries to the left main coronary artery, the main pulmonary artery and the left atrial appendage. Alternatively, endoaortic balloon occlusion can be used.

Median sternotomy incision is the standard approach in all types of PAPVC repair. Some authors reported the feasibility and safety of right thoracotomy and endoscopic approaches [17, 18]. Nevertheless, there has been no study to date that compare the outcomes of mini-thoracotomy and robotic procedures. We may speculate that the advantages of robotic approach over thoracotomy and endoscopic approaches are enhanced visualization, a better exposure for intracardiac single-patch technique and improved instrumentation. During PAPVC repair with single-patch technique through right atriotomy incision, the use of robotic 30 endoscope and atrial retractor significantly facilitates the repair of right-sided PAPVCs that open to the superior vena cava. We believe that this is the most important advantage of robotic approach with enhanced exposure and manipulations over endoscopic surgery.

This initial experience demonstrated that robotic PAPVC repair was technically feasible in selected patients. Traditional repair methods for PAPVCs include the single-patch, the 2-patch and caval division techniques. Robotic repair of right-sided supracardiac or cardiac PAPVCs can be done through oblique right atriotomy or transcaval incision. But, caval division techniques are demanding and complex for a robotic approach. Several operative challenges are necessary including dissection of the tissue between the ascending aorta and right pulmonary artery, superior clamping of the ascending aorta, exploration of the azygos vein superiorly to the pulmonary hilus, and occlusion of the superior vena cava just below the azygos vein. Because of these maneuvers, both console and patient-side surgeons should have a considerable experience in robotic procedures.

There are some limitations during robotic PAPVC repair. Patients with pulmonary veins draining high on the SVC should be excluded. Single or two-patch repair techniques may not be used in these cases due to the limited space in the cava-atrial junction for endoscopic exposure and instrumental maneuvers. In such cases, complex procedures such as a Warden procedure may be. The cost and availability of robotic systems are the other major limitations. The surgeons need experience on congenital heart procedures as well as robotic surgery. The procedures take longer times when they are compared to conventional procedures. But operative times can be decreased with experience (Fig. 5). Randomized trials between robotic, open and endoscopic techniques are needed to clarify the advantage of robotic surgery. Furthermore, patient population is arguably an adult one, with no patients less than 14 years, and most over 18. In younger children, new generation robotic devices can be used in the future for complex cases.

In conclusion, totally endoscopic robotic-assisted repair of PAPVCs is a safe approach in selected patients. The procedure is feasible and, with a very limited follow-up time, produces good results. The single-patch technique remains the procedure of choice for right-sided supra-cardiac PAPVC with sinus venosus ASD, whereas 2-patch technique with transcaval incision can be used in patients with narrow superior vena cava. Robotic surgery should be in the armamentarium of cardiac surgeons as a less invasive alternative to traditional incisions, mini-thoracotomy and endoscopic approaches.

Compliance with ethical standards

Conflict of interest Burak Onan, MD, Unal Aydin, MD, Ersin Kadirogullari, MD, Ismihan Selen Onan, MD, Onur Sen, and Zeynep Kahraman declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Gillinov AM, Mihaljevic T, Javadikasgari H et al (2018) Early results of robotically assisted mitral valve surgery: analysis of the first 1000 cases. J Thorac Cardiovasc Surg 155:82–91
2. Torracca L, Ismeno G, Alfieri O (2001) Totally endoscopic computer-enhanced atrial septal defect closure in six patients. Ann Thorac Surg 72:1354–1357
3. Argenziano M, Oz MC, Kohmoto T et al (2003) Totally endoscopic atrial septal defect repair with robotic assistance. Circulation 108(Suppl 1):191–194
4. Bonaros N, Schachner T, Oehlinger A et al (2006) Robotically assisted totally endoscopic atrial septal defect repair: insights from operative times, learning curves, and clinical outcome. Ann Thorac Surg 82:687–693
5. Xiao C, Gao C, Yang M et al (2014) Totally robotic atrial septal defect closure: 7-year single-institution experience and follow-up. Interact Cardiovasc Thorac Surg 19:933–937
6. İyigün T, Kaya M, Gülbeyaz S et al (2017) Patient body image, self-esteem, and cosmetic results of minimally invasive robotic cardiac surgery. Int J Surg 39:88–94
7. Onan B, Kadirogullari E, Guler S, Kahraman Z (2018) Robotic-assisted removal of an Amplatzer atrial septal occluder device for residual shunting, closure of septal defect and simultaneous tricuspid annuloplasty. J Robot Surg 12:185–188
8. Onan B, Aydin U, Basgoze S, Bakir I (2016) Totally endoscopic robotic repair of coronary sinus atrial septal defect. Interact Cardiovasc Thorac Surg 23:662–664
9. Onan B, Aydin U, Turkvatan A, Bakir I (2016) Robot-assisted repair of right partial anomalous pulmonary venous return. J Card Surg 31:394–397
10. Pirelli L, Kliger CA, Patel NC et al (2017) Minimally invasive robotically assisted repair of partial anomalous venous connection. Innovations (Phila) 12:71–73
11. Onan B, Aydin U, Kadirogullari E, Ozturk E (2018) Robotic repair of left-sided partial anomalous pulmonary venous connection to the coronary sinus. J Robot Surg. https://doi.org/10.1007/s11701-018-0825-2 **(Epub ahead of print)**
12. Said SM, Burkhart HM, Schaff HV et al (2012) Single-patch, 2-patch, and caval division techniques for repair of partial anomalous pulmonary venous connections: does it matter? J Thorac Cardiovasc Surg 143:896–903
13. Nicholson IA, Chard RB, Nunn GR, Cartmill TB (2000) Transcaval repair of the sinus venosus syndrome. J Thorac Cardiovasc Surg 119:741–744
14. Okonta KE, Tamatey M (2012) Is double or single patch for sinus venosus atrial septal defect repair the better option in prevention of postoperative venous obstruction? Interact Cardiovasc Thorac Surg 15:900–903
15. Iyer AP, Somanrema K, Pathak S, Manjunath PY, Pradhan S, Krishnan S (2007) Comparative study of single- and 2-patch techniques for sinus venosus atrial septal defect with partial anomalous pulmonary venous connection. J Thorac Cardiovasc Surg 133:656–659
16. Stewart RD, Bailliard F, Kelle AM, Backer CL, Young L, Mavroudis C (2007) Evolving surgical strategy for sinus venosus atrial septal defect: effect on sinus node function and late venous obstruction. Ann Thorac Surg 84:1651–1655
17. Zubritskiy A, Arkhipov A, Khapaev T et al (2016) The Warden procedure can be successfully performed using minimally invasive cardiac surgery without cross clamping. Interact Cardiovasc Thorac Surg 22:225–227
18. Wang F, Li M, Xu X et al (2011) Totally thoracoscopic surgical closure of atrial septal defect in small children. Ann Thorac Surg 92:200 – 3
19. Onan B, Aydin U, Kadirogullari E, Onan IS, Sen O (2018) Totally endoscopic robotic-assisted cardiac surgery in children. Artif Organs. https://doi.org/10.1111/aor.13357 **(Epub ahead of print)**