

Advances in Cardiac Surgery and Therapeutics

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Abstract

In this review, in regard to the treatment of congenital heart disease, coronary artery diseases, valve disease and atrial fibrillation, novel surgeries and therapeutics are introduced according to our experience and recent report. In addition, robotics has gained acceptance in cardiac surgery, which is utilized to perform mitral valve repairs, coronary revascularization, atrial fibrillation ablation, intracardiac surgery and atrial septal defect closures. Thus, cardiac surgeries assisted by robotics are briefly summarized.

Keywords: Cardiac Surgery; Therapeutics; Coronary revascularization; Mitral valve; Congenital; Heart disease

Background

Recently many new and important reports about advances in cardiac surgery have been presented. With respect to congenital heart disease, coronary artery diseases, valvular disease, atrial fibrillation, novel surgeries and therapeutics are introduced in this review according to recent report and our experience. Related medical apparatus and instruments are presented. In addition, some cardiac surgeries assisted by robotics are briefly summarized.

Congenital Heart Disease

Congenital Heart Defect (CHD) is a structure defect of the heart and great vessels at birth. There are different types of heart defects causing obstruction or abnormal pattern of blood flow. It is the leading cause of birth defect-related deaths. Thus complex congenital heart defects have to be treated actively with medication or surgery.

Development of CHD surgery mainly focuses on surgical techniques and advanced repair materials used during operations. According to experience from our hospital, CHD surgical techniques are introduced in terms of the treatment of Ebstein's anomaly, single ventricle and double-outlet right ventricle with pulmonary artery hypertension.

Anatomical repair for Ebstein's anomaly

Ebstein's anomaly has a variety of pathologies which actually involves not only tricuspid valve, but also the right ventricle even whole heart. According to author's knowledge, satisfactory early and midterm results can be achieved with the anatomic repair technique. Therefore 98% of the patients can avoid tricuspid valve replacement which needs anticoagulation or reoperation.

Satisfactory results have been obtained from anatomical repair for Ebstein's Anomaly using autologous pericardium and autologous leaflet tissue in our hospital. From March 2004 to July 2013, 131 patients aged 1 to 63 years old (male 53, female 78) underwent anatomical repair. All of them have palpitations and shortness of breath, and activity limitation symptoms. Diagnosis was confirmed by ECG, X-Ray and echocardiography that tricuspid incompetence was moderate in 13 patients and severe in 118 patients. The main surgical technique includes excision of the atrialized right ventricle, detachment and reimplantation of the new leaflet which was created with autologous hypoplastic leaflet tissue (59 patients) or autologous pericardium (72 patients), transposition of the chordae or papillary muscles, and tricuspid valve annulus plication.

128 patients recovered smoothly and are doing well during the follow-up time (4 months to 9 years (37 ± 1.8 m)). 3 patient died (1.5%). Among them 1 died of pulmonary infection and hypoxemia three weeks post-operatively; one died of low cardio output syndrome 3 days after operation. Follow-up of echocardiography showed tricuspid competence in 83 patients, moderate regurgitation in 38 patients, and severe regurgitation in 6 patients. Re-operation in 2 patients (1.5%), TVR in 1 and annular placcation in 1.

All in all, more attention should be paid on the well understanding of structures and function of right atrium, tricuspid valve and right ventricle, which promotes successful anatomical repair.

Septation of single ventricle with double-patch procedure

Single ventricle is a congenital cardiac malformation in which both atria connect to only one ventricular chamber through two separate AV valves or a common AV valve. Fontan procedure was performed in most patients. But it is just a palliative procedure though good results could be achieved. Septation is considered to be the most desirable procedure when intracardiac morphology is suitable.

From Mar 2004 to May 2013, 5 patients (2 male and 3 female, 3-19 years old, 12-44 kg) with double inlet ventricle underwent septation procedure in our hospital. The classification is indeterminate ventricle type in 2 patients, left ventricle in 1 and common ventricle in 2. Associated defects of ASD were found in 2 patients, SA in 1, PDA in 1 and C-TGA+PS in 2 respectively. Concomitant procedures include ASD repair was required in 3 patients, PDA ligation in 1, RVOT reconstruction in 2, Rastelli procedure in 2, and Banding operation twice previously in 1.

1 patient died of repeat bleeding of esophagus and renal failure 16 days after operation. Other 4 patients survive and are doing well, including 1 with pacemaker. Following up for 6 months-7 years, all survivors were in sinus rhythm, cardiac function class NYHA I-II.

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Surgical treatment of double-outlet right ventricle with pulmonary artery hypertension

Double-Outlet Right Ventricle (DORV) can be divided into two types: DORV with Pulmonary Artery Hypertension and DORV with Pulmonary Artery Hypotension (PH). Their operation methods and postoperative are quite different. Little literature has reported about DORV with PH.

From June 2004 to August 2013, our hospital had treated a total number of 55 DORV with PH (judged by aortic overriding 50%). Previously Banding surgical treatment was performed in 3 patients, 2 of which underwent second phase corrective surgery and Switch procedure respectively. DORV intracardiac channel surgery was accomplished in 31 patients, 7 of which required widen right ventricle outflow tract using autopericardium patch. Switch procedure was performed in 20 patients and Rastelli procedure in 1. To reduce anoxia, Senning procedure underwent in 3 patients and Mustard in 1.

49 of 55 patients (89.1%) were cured and discharged with excellent results and 6 (10.9%) died perioperatively. DORV is still a challenge for surgical treatment because the wide variety of pathology. The indication of operation and the age of patients are very important factors to the success of operation

Advanced repair materials

During operation procedure of complex congenital cardiac defect, to fill the defect or replace the diseased structure, additional tissue, such as patches and valves, are frequently needed. These foreign tissue will accompany a lifetime with patients. Using effective materials or devices can improve long-term outcomes and avoid reoperation.

The CorMatrix (CorMatrix Alpharetta, GA) patch has entered into cardiac surgery recently. It is made of decellularized porcine small intestinal submucosa extracellular matrix (ECM), which is the acellular component that surrounds cells in native tissues and is mainly composed of elastin, collagen (structural proteins), glycans (glycosaminoglycans, proteoglycans) and adhesion glycoproteins [1]. Approval of Porcine SIS-ECM for use in humans has currently been confirmed by the American Food and Drug Administration (FDA).

These new patches have been used in animal models of cardiac surgery effectively. A porcine ECM patch and Dacron patch were used to reconstruct a full-thickness right ventricular outflow tract (RVOT) defect in a rat model with end points of structural remodeling function at 16 weeks, reported by Wainwright et al. [2]. The ECM patch remodeled into dense, cellular connective tissue with scattered small islands of cardiomyocytes and the Dacron patch was encapsulated by dense fibrous tissue and showed little cellular infiltration. In conclusion, the C-ECM patch was associated with better functional and histomorphological outcomes compared to the Dacron patch in this rat model of RVOT reconstruction

In human experimental studies, good results have been confirmed in congenital heart surgery for cardiac and vascular reconstructions using SIS-ECM [3-5]. Scholl et al. [3] reported one case of an explanted patch used for augmentation of the tricuspid valve. No pericardial effusions or intracardiac or intravascular thromboses occurred related to the SIS-ECM. The patches did not shrink or calcify. 4 months after the implant, SIS-ECM was replaced by organized collagen and populated with endothelial-like cells. In conclusion, repair of congenital heart defects using SIS-ECM is feasible and safe.

Similar advanced materials will be used more extensively. And, longer-term follow-up results and comparison are required to assess the potential for growth of different tissue engineering materials.

Coronary Artery Disease

Coronary artery disease remains the leading cause of death nowadays. Coronary Artery Bypass Grafting (CABG) is the conventional surgical treatment with good results. Compared with conventional CABG with cardiopulmonary bypass, some patients benefit from off-pump CABG. On-pump or off pump? That should be determined according to the situation of patients. Especially, indications of CABG with on-pump and off-pump are quite different. Usually, CABG with on-pump is appropriate for severe patients especially whose vessels are narrow and locate deeply in fat. That will lead to difficulty to find the target vessel if with off-pump. Although some disadvantages exist, for example larger wound, more blood loss during operation, inflammation and damage for lung and brain, on-pump bypass operation has no more complications compared with off-pump procedure. In term of the long term results on-pump is better.

To find suitable target vessels and its right fit position and to protect the heart and other body organs are key features in CABG and should be paid more attention. To reduce the invasive of surgery, some minimally invasive direct or coronary artery bypass grafting (MIDCAB) and hybrid MIDCAB technologies have been under development.

In addition, Percutaneous Coronary Intervention (PCI) has been used to treat coronary artery disease. Comparisons CABG with PCI are introduced. Some other emerging is under development.

Minimally invasive direct coronary artery bypass grafting

Minimally Invasive Direct Coronary Artery Bypass Grafting (MIDCAB) refers to direct-vision Left Internal Thoracic Artery (LITA) grafting to the Left Anterior Descending Coronary Artery (LAD) on the beating heart through a 5 to 10 cm left anterolateral thoracotomy [6]. Initially MIDCAB was described for single-vessel bypass to the Left Anterior Descending (LAD) artery [7].

In the process of development, many variations have been generated, including the single Left Internal Mammary Artery (LIMA) to LAD bypass, the multivessel complete revascularization, and the saphenous vein graft from the axillary artery to the LAD. Mammary harvest variations include robotic and thoracoscopic takedown. Which is the best minimally invasive surgical techniques for Left Anterior Descending (LAD) coronary artery bypass grafting (CABG)? Jegaden et al. compared three different techniques: Port-Access surgery (PA-CABG), Minimally Invasive Direct CABG (MIDCAB) and off-pump totally endoscopic CABG (TECAB) [8]. It is noted that TECAB is associated with a higher rate of early bypass failure and reintervention. And MIDCAB is still the most reliable surgical technique for isolated LAD grafting and the least cost effective.

Throughout the overall reports about MIDCAB, surgery success rate is high and operative mortality is very low in most clinical series. Compared with conventional CABG, chest wound is smaller and complications occurred in 2%–3% [9]. In spite of promising results, candidate patient of MIDCAB should be selected carefully.

Percutaneous coronary intervention (PCI)

Percutaneous Coronary Intervention (PCI) involving Drug-Eluting Stents (DES) is increasingly used to treat complex coronary artery disease.

Most studies have found that CABG is better than PCI for reducing death and myocardial infarction. Patrick W have showed that CABG remains the standard of care for patients with three-vessel or left main coronary artery disease, since the use of CABG, as compared with PCI, resulted in lower rates of the combined end point of major adverse cardiac or cerebrovascular events at 1 year [10]. However, the coronary revascularization by Coronary Artery Bypass Graft (CABG) is associated with an increased risk of stroke.

PCI has proven to be as effective as and less costly than CABG in patients with medically refractory myocardial ischemia. However, more postoperative medication for PCI is needed than that for CABG. Especially, the reoperation rate will increase when the implanted stent is restenosis

Hybrid MIDCAB approach

Minimally invasive LIMA-LAD bypass procedures have been combined with transcatheter interventions, or percutaneous coronary intervention (PCI), which is called as a hybrid approach for the treatment of multivessel disease.

Aortic Stenosis

Aortic stenosis is associated with a high death rate if no action taken. Surgical Aortic Valve Replacement (SAVR) is the conventional golden treatment for patients with aortic stenosis. However, unfortunately, many patients are not eligible for surgery due to advanced age, poor left ventricular function or other complications. Transcatheter aortic valve replacement (TAVR) offers a new alternative option for patients with severe aortic stenosis who are classified as high-risk patients or patients not eligible for conventional aortic valve surgery [11-13].

As described in the literature, compared with medical treatment, TAVR reduces mortality by 20% in patients who are not suitable for surgery [11]. In addition, the first randomized controlled trial, the PARTNER trial, has demonstrated that TAVR is equivalent to SAVR in terms of 1-year survival for patients at high risk who are still candidates for surgical replacement [14].

However, for intermediate operative risk patient with severe AS, SAVR remains a clinically and economically attractive treatment option because the costs at 1 year are higher for TAVR than SAVR. The difference exists on the higher costs of transcatheter valve [15].

Beside, Grimaldi et al. evaluated 145 elderly patients (aged 84.7 ± 3.4) who underwent TAVR. It has been proved that, for octogenarians with symptomatic AS, TAVR improves clinical outcome and subjective health-related quality of life [16].

Implantation techniques of TAVR

Implantation techniques used during TAVR can be classified to transfemoral implantation, transapical implantation, transaortic implantation.

The Edwards SAPIEN valve (Edwards Lifesciences, Inc., Irvine, CA, USA) is the first developed TAVI device, consisting of three bovine pericardial leaflets mounted within a balloon-expandable stainless-steel stent. It was first implanted inside with the antegrade transeptal approach to the left atrium and passage through the mitral valve to reach the aortic valve. With this approach there is a high risk of anterior mitral valve leaflet injury, causing severe mitral regurgitation [17]. An alternative transapical approach has been proposed: through a left anterolateral minithoracotomy, with the patient under general anesthesia, the pericardium is opened over the apex.

As the number of patients screened for TAVI increases, peripheral artery access hasn't been selected. Therefore, Latsios et al. tested the safety and efficacy of the retrograde, minimally invasive TAVR using the Medtronic CoreValve prosthesis (Medtronic, Minneapolis, MN, USA) as an alternative minimally invasive surgical implantation route [12]. The two carefully selected patients (aged 93 and 84 years) were at off-pump and without intra-aortic balloon pump. Both cases were reported to be successful. These may provide an alternative option when transfemoral TAVI is not viable due to some anatomical reasons. Bauernschmitt et al., who- based on a single case, also concluded that the "transaortic" approach might help to expand the implantation possibilities for those patients for whom the typical access sites are not available [13].

All in all, the transapical TAVI is still the major alternative for the transfemoral approach because it has lower rates of vascular complications. At the same time, it creates larger sheath diameters which may lessen the need for crimping the valves and thus improve durability.

Novel aortic valve prosthesis

Although TAVR is an alternative option for high-risk patients, some distinct TAVR-related disadvantages have been identified, for example periprosthetic Aortic Regurgitation (AR), paravalvular leakage incidence and the occurrence of significant conduction disturbances [18]. That is because transcatheter aortic valves are implanted inside without sutures, only using oversizing to expand a stent at the level of the aortic annulus. Since there is potential risk after TAVR, this aortic valve prosthetic must be taken seriously to develop and research deeply. Then it can be used more extensively with a longer time.

Some next generation transcatheter heart valves prosthesis, for example Sadra Medical Lotus™ Aortic Valve, Direct Flow Medical Aortic Valve, Symetis Acurate TA™ Aortic Bioprosthesis and St. Jude Medical Portico™ Aortic Valve, seem to be promising. However, long-term effects should be further test and verified in a number of clinical trials to improve TAVI outcomes.

Mitral Regurgitation

Mitral Valve Regurgitation (MR) is the most common valvular heart disease and often associated with worsening of symptoms and reduced survival. Surgical intervention is usually recommended for symptomatic severe MR or asymptomatic severe MR with left ventricular dysfunction or enlargement. Treatment of severe degenerative MR has evolved from mitral valve replacement to repair because valve repair produces more efficient long-term outcomes [19-21]. For functional MR, however, the benefit of repair over MVR is less certain. Because it can be achieved through minimally invasive approaches, in high-risk patients who are not referred for surgery and in those with functional MR, percutaneous transcatheter procedures are emerging as an alternative therapeutic option.

For percutaneous transcatheter procedures, several approaches and device are developing, as for multiple mitral transcatheter interventions technologies and diversified approaches. They bear the hope of reduce risks while preserving clinical efficacy. According to the different anatomical and pathophysiological target, procedures can be divided into leaflet procedures, annuloplasty procedures, paravalvular leak closure and mitral valve implantation.

Leaflet procedures

In order to improve leaflet coaptation and reduce the effective

regurgitant orifice, one approach is to plicate leaflet, based on the surgical Alfieri technique, which brings the anterior and posterior leaflets together with a suture, creating a “double orifice” MV. This technique is most suitable for degenerative MR, although it could be employed in functional MR. Recently, it has grown into edge-to-edge technology [22,23]. Using this technology, the most advanced technology is the MitraClip® System (Abbott Vascular, Inc., Menlo Park, CA, USA). It is the most widely used transcatheter mitral device (more than 8,000 procedures worldwide).

The MitraClip system consists of two components: the clip delivery system and the steerable guide catheter [23,24]. The clip delivery system consists of three major components: the delivery catheter, the steerable sleeve, and the MitraClip device. The clip delivery system is introduced into the body through a steerable guide catheter, which includes a dilator. The clip delivery system is used to advance and manipulate the implantable MitraClip device for proper positioning and placement on the mitral valve leaflets. And it's MitraClip device to make two leaflets to fit closely.

European guidelines assigned an indication class IIb, level of evidence C, signifying that MitraClip may be considered in patients with symptomatic severe MR despite optimal medical therapy, who are judged inoperable or at high surgical risk by a heart-team, and with life expectancy greater than 1 year [25]. The randomized RESHAPE and COAPT trials, respectively in Europe and the US, are currently evaluating the benefit of MitraClip compared to optimal medical therapy to support a higher recommendation class in the forthcoming guidelines.

A different approach to transcatheterly repair leaflet is off-pump adjustable chordal implantation, based on which several devices are currently under development, for example, the Babic device (Uros Babic, MD), the MitraFlex (TransCardiac Therapeutics, Atlanta, GA, USA), the NeoChord (NeoChord, Inc., Minnetonka, USA) and The V-Chordal (Valtech Cardio Ltd, Or-Yehuda, Israel) [26].

In addition, some other alternative techniques for leaflet repair have been proposed. The Percu-Pro (Cardiosolutions, Stoughton, USA) is a space-occupying buoy anchored at the LV apex through a transseptal approach that should fill the gap between leaflets. The Thermocool irrigation ablation electrode (Biosense Webster, Inc., Diamond Bar, CA, USA) delivers, in the context of degenerative disease, radiofrequency energy to the leaflets to provoke shrinking and reduced motion [26].

Annuloplasty procedures

To achieve effective and durable outcomes, transcatheter procedures should probably incorporate annular remodeling. In addition, the lack of a reliable annuloplasty device is impacting the eligibility for transcatheter interventions. Different devices address different anatomical and pathophysiological concepts. Based on their different mechanism, three main categories are under development and research: indirect annuloplasty, direct annuloplasty, cinching devices, energy-mediated annuloplasty.

Indirect annuloplasty procedures derives that Coronary Sinus (CS) encircles the posterior mitral annulus, and it may allow devices to be delivered to affect indirectly the posterior mitral annulus geometry [26]. And the Cardiac Dimension CARILLON (Cardiac Dimension, Kirkland, USA) belongs to this kind, composing of two nitinol anchors (distal anchor placed in the Great Cardiac Vein (GCV) and proximal anchor in the proximal CS) linked by a bridge element. Initial

results have been promising, and it is now available for commercial implantation in Europe within a Prospective Post-Market Registry (PRIME) on-going to assess long-term safety and efficacy in up to 300 patients [27].

Although the CS approach is a consolidated procedure, it has important limitations: the CS is variably located at a certain distance from the mitral annulus (frequently increased in case of severe MR with annular dilation), 30 and circumflex coronary artery compression has been frequently observed [28-30].

A more aggressive concept has been developed by the USA National Institute of Health [31]. The Mitral Cerclage (NIH, Rockville, USA) creates a loop around the mitral annulus and left ventricular out-flow tract (LVOT), entering through the CS ostium, passing through the anterior interventricular vein and returning near the CS ostium, perforating the myocardium either coming out in the right ventricle and passing through the anterior tricuspid commissure, or directly coming out through the septum in the right atrium; the loop is then tightened and secured near the CS ostium. Differently from the other coronary sinus devices, the Mitral Cerclage offers the opportunity of circumferential remodeling of the mitral annulus, using the coronary sinus as a support.

Cinching devices force septo-lateral annular reduction through the approximation of two devices connected by a bridge. The reduction of this dimension is expected to be particularly important for MR reduction and in the functional setting. Based on this principle, some devices are under development, for instance, the Ample PS3 System (Ample Medical, Inc., Foster City, CA, USA), the Myocor i-Coapsys (Edwards Lifesciences, Inc., Irvine, CA), the Mardil BACE (Basal Annuloplasty of the Cardia Externally; Mardil, Inc., Morrisville, NC) and so on.

Direct annuloplasty has the advantage that the implantation of devices directly into the mitral annulus closely reproduces surgical annuloplasty. Only the posterior annulus is usually targeted, since the anterior annulus remains a more challenging structure due to the close vicinity of the aortic valve. Annular calcification, circumflex artery, and the potential for leaflet damage remain of concern for direct annuloplasty approach. This kind of devices include the Accucinch System (Guided Delivery System, Santa Clara, USA), the Mitralign device (Mitralign, Tewksbury, USA), the Cardioband System (Valtech Cardio Ltd, Or-Yehuda, Israel).

Energy-mediated annuloplasty is totally different from above technologies obtaining annular remodeling by implanting a device. It is a little like the ablation. Energy-mediated annuloplasty aim to reduce annular length by collagen shrinking through delivering of different energies. Safety remains a concern in terms of damage to surrounding structures and thrombus formation.

Paravalvular leak closure

Paravalvular leakage is a complication of prosthetic valve implantation occurring in 5%–15% of cases. Surgical reoperation is associated with higher morbidity and mortality and does not always guarantee a definite solution since prostheses detachment recurrence is not infrequent. Although it remains more challenging than aortic leak closures, in recent years transcatheter mitral leak closure had emerged as a new valid option. Procedural success rate has improved over the years ranging from 60% to 90% in the different series, with different kinds of Amplatzer occluders (vascular plugs, atrial septal defect, patent ductus arteriosus) [26].

Mitral valve implantation

Mitral valve anatomy brings unique and complex features that make transcatheter valve implantation much more challenging than in the aortic position. The mitral annulus is asymmetrical, non-tubular, and frequently not calcified, so that the main problem for any kinds of mitral prosthesis remains anchoring, since radial force would not be effective and could cause serious complications. Left-ventricle outflow tract obstruction and aortic valve deformation is difficult problem as well. Moreover, leaks in the mitral position would be poorly tolerated, both hemodynamically and in terms of hemolysis because of the elevated pressure gradients. Mitral valve implantation is not yet routinely available in the clinical setting, but several devices are currently under development, for example, The CardiaQ (CardiaQ Valve Technologies, Inc., Winchester, MA, USA) prosthesis, the Lutter prosthesis (Tendyne Medical, Inc., Baltimore, MD, US), the Tiara (Neovasc, Inc., Richmond, British Columbia, Canada) and the EndoValve-Herrmann prosthesis (EndoValve, Inc., Princeton, NJ, USA) [26].

In briefly, to expand further field of transcatheter mitral valve treatment, above several devices based on different principles, are under development. Using these flexible and effective devices, transcatheter mitral techniques should be considered the natural and inevitable evolution of mitral surgery.

Atrial Fibrillation

As we all know, Atrial Fibrillation (AF) is the most common arrhythmia disease, especially with an increasing incidence in the aging population. And the morbidity associated with AF is significant without pharmacologic intervention [32]. In addition to medication, surgical approach, ablation technology and hybrid surgery have been applied and improved to treat different types of AF.

Percutaneous transcatheter ablation

Endocardial pulmonary vein (PV) isolation and left atrium linear lesion are the major missions of percutaneous catheter ablation for atrial fibrillation because it's widely considered that triggers from PV play an important role in the initiation of AF [33].

Up to now, most of the published studies show percutaneous transcatheter ablation is effective especially for paroxysmal AF [34-36]. In term of recurrence and post-operative quality of life, percutaneous catheter ablation is superior to medication. And in the ACC/AHA/ESC 2012 guidelines for the management of patients with atrial fibrillation, recommendation level of percutaneous transcatheter ablation was upgraded to I from IIa [37].

During ablation procedures, in order to kill tissue in the right location and induce conduction block, appropriate energy has to be used. Which is the most effective energy source, cryotherapy energy, radiofrequency energy, or microwave and ultrasound energy?

Actually, studies have shown that both cryotherapy and radiofrequency energy suit for ablation treatment of AF. For cryotherapy, main advantages include rapid and visual confirmation of transmural, and low risk to injure adjacent tissue [38]. And argon-based cryotherapy can achieve lower minimum temperature than nitric oxide based cryotherapy [39]. For radiofrequency energy, bipolar radiofrequency is superior to unipolar radiofrequency because bipolar can create transmural lesion more consistently, especially when working only with the ablation of pulmonary vein since the shape of the clamp allows easy placement around the pulmonary veins [40]. For

microwave and ultrasound energy, it's proved that they can't create transmural lesions persistently so long-term efficacy in keeping sinus rhythm is very low [41].

Hybrid surgery

Some new hybrid approaches for AF ablation has been introduced. Fiorenzo et al. [39] reported very long-term results of a new hybrid approach from 33 long-standing persistent AF patients with valvular heart disease. This approach combines surgical cryoablation consisting of pulmonary veins isolation and left atrial linear lesions with transcatheter radiofrequency ablation. In 19 of 33 patients (58%) the electroanatomic mapping showed a complete lesion scheme, which increased to 79% with the addition of radiofrequency ablation. At the mean follow-up of 10.7 ± 3.1 years, 73% of patients were in sinus rhythm, whereas 27% had permanent AF. At the end of follow-up 81% of patients with a complete lesion scheme in SR, while 43% with an incomplete one maintained SR. This approach is highly effective in maintaining SR or significantly reducing the AF burden in a very long-term follow-up [42].

A thoracoscopic epicardial approach is combined with a percutaneous endocardial ablation in a single-step or in a sequential-step procedure. Its efficacy of this procedure as well as its superiority over catheter ablation or standard surgical techniques has to be proven by large comparative studies with long-term follow-up. Even so, it should be advocated that a successful ablative treatment for AF has to be completed by the close cooperation of cardiac surgeon and electrophysiologist as a team.

Surgical treatment

As the basic of surgical treatment for AF, the cut-and-sew Cox Maze procedure has been proved to be the effective surgical solution. Despite its proven curative effect, Cox Maze procedure is limited by its invasiveness of median sternotomy, complexity and technology difficulty from interrupting all fibrillation circuits.

Fortunately, there are important improvements in surgical treatment of AF in the last decade with the development of AF ablation. The Cox-Maze procedure has evolved to an extensive use of surgical ablation technology where ablation lesions are created with alternative energy sources and specially designed device instead of a cut-and-sew surgery, where the maze was applied using surgical multiple cuts [43].

In North America, the number of surgical ablations increases significantly according to The Society of Thoracic (STS) Adult Cardiac Surgery Database [44].

Niv Ad et al. reported 104 stand-alone Cox-Maze procedures for non-paroxysmal AF through a right minithoracotomy (6 cm) with femoral cannulation using ablation with argon-based cryothermal energy [14]. Patient outcomes included no operative (30 days) deaths or renal failure, 1 pacemaker, and 1 transient ischemic attack. The return rate to sinus rhythm at 6, 12, 24, 36 months was 94%, 94%, 92%, 92%, and off antiarrhythmic drugs was 87%, 87%, 79%, 80%, respectively. The success rate at 6 months after the initial 20 patients improved from 89% to 94%. Besides, significant improvement was noted for health-related quality of life and decreased AF symptoms at 1 year. The results demonstrate that a Cox-Maze III/IV procedure performed minimally invasively through a right minithoracotomy can be accomplished safely and effectively [45].

Success of the minimally invasive procedures depends on

some other novel technologies, such as sternum-sparing incisions, alternative cannulation techniques, thoracoscopic visualization and robotic assistance.

Procedures Assisted by Robotics

Robotic cardiac operations evolved from minimally invasive operations. As minimally invasive cardiac operations gained favor, developments in tele-manipulation technology and optics fostered the evolution of robotic-assisted cardiac surgery. Nowadays, robotic systems have been utilized successfully to perform complex mitral valve repairs, coronary revascularization, atrial fibrillation ablation, intracardiac tumor resections, atrial septal defect closures, and left ventricular lead implantation. Up to now, the da Vinci™ surgical system (Intuitive Surgical, Sunnyvale, CA, USA) is the only US Food and Drug Administration (FDA)-approved robotic system used for cardiac surgical procedures. It offers some outstanding benefits including improved dexterity and degrees of freedom, tremor-free movements, ambidexterity, and the avoidance of the fulcrum effect [46].

Despite all of the benefits, several limitations have hampered the widely acceptance of robotic heart surgery. For instance, many surgeons rely on the haptic feedback during operation in some way. However, robotic surgeons rely on visual tissue deformation to judge the mount. In the future, robotic systems will likely incorporate strain sensors to the instruments arms, allowing for haptic feedback and precise control of force.

Conclusion

In terms of atrial fibrillation, aortic valve stenosis, mitral regurgitation and coronary heart disease, novel surgeries and therapeutics are introduced according to recent report and evidence. Related medical apparatus and instruments are presented. In addition, robotics has gained favor in cardiac surgery, which is utilized to perform complex mitral valve repairs, coronary revascularization, atrial fibrillation ablation, intracardiac tumor resections, atrial septal defect closures, and left ventricular lead implantation.

In short, any surgery and any therapeutic have better to be patient tailored and the curative effect should be considered in long-term. With advanced development of technology, cardiac surgery trends will be minimally invasive, safe and efficacy, close cooperation between surgeons and physicians.

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