Journal of Advanced Zoology

ISSN: 0253-7214

*Volume **45** Issue 3**Year 2024** Page 936-**954***

Comparative Study Of Total Thoracoscopic Mitral Valve Surgery And Traditional Open Mitral Valve Surgery:Propensity Score Matching Study

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Abstract

Background: Conventional median open mitral valve replacement surgery usually requires a 20-30cm size incision to ensure adequate visual exposure. So, while we complete the valve replacement, it also brings about a series of problems. The appearance of TV thoracoscope changes the exposure of the surgical field. Because the microscopic field is enlarged, it not only makes the surgical vision clearer, but also greatly shortens the incision, reduces bleeding, and conceals the incision, minimizing the trauma and shortening the postoperative recovery time, which is in line with the concept of modern health.

Aim: All technological innovation is controversial in the early stage, and it is such debate that can promote the progress and development of technology.This study was conducted in the context of this debate to summarize the experience of Total thoracoscopic mitral valve surgery in our center.Total thoracoscopic mitral valve replacement surgery and traditional median incision mitral valve replacement surgery were compared by the propensity score matching method.Evaluate its safety and merits.

Methods: From January 2018 to December 2020, a total of 139 patients in the thoracoscopic group were eligible in the cardiothoracic surgery department of our hospital, and 1066 cases of traditional median sternotomy mitral valve replacement. After propensity score matching, 125 patients were selected in the thoracoscopic group, among 1066 patients with median incision MVR, 1:1 matched to 125, as the control group in the thoracoscopic group.

Results: The results showed that the mean operative time in the thoracoscopic MVR group was significantly longer than that in the control group (185.73 ± 43.04 vs. 164.58 ± 40.28, p=0.0016). Similarly, both the mean CPB time and aortic block time were significantly longer than those in the control group (108.37±30.57min vs. 79.18±17.65min, p

	<0.0001; 66.59±29.63min vs. 45.09±19.68min, p <0.0001. Moreover, the proportion of patients with CPB greater than 120min and aortic block greater than 90min was significantly higher than the control group (24.1% vs. 3.2%, p <0.0001,14.4% vs. 2.4%, p=0.0237). In addition, there was no significant difference in the mean ICU observation time between the two groups (49.35±34.51h vs. 48.72±25.89h, p=0. 8792). Differently, the mean endotracheal intubation time was significantly lower in the thoracoscopic MVR group compared to the control group (18.52±6.07h vs. 25.45±14.18h, p=0.0032). Similarly, the length of stay in the thoracoscopic group was 9.13 ± 4.58 days, which was significantly lower than 11.12 ± 5.76 days in the control group (p=0.0004). There was no significant difference in the postoperative hemoglobin concentration or platelet count between the two groups of MVR patients. Mean intraoperative bleeding volume in the thoracoscopic MVR group was significantly less than that in the control group (158.37±100.91ml vs.250.74 ± 81.34, P <0.0001). Similarly, the mean postoperative discharge in the thoracoscopic MVR group was significantly than in the control group (428.39±361.38ml vs. 514.07 ± 347.92ml, p=0.0383). For patients with postoperative blood products, there were 37 (29.6%) in the thoracoscopic group and 33 (26.4%) in the control group. There was no significant difference between the two groups. Similarly, there was no significant difference in the mean total hospital costs between the two groups. **Conclusion:** This study shows that it has feasibility and safety for total thoracoscopic mitral valve replacement for mitral valve lesions, which can reduce the time and stay of the hospital compared with conventional direct surgery, and obtain good minimally invasive and cosmetic effect, and lay a theoretical and clinical foundation for the application of thoracoscopic technology in cardiac surgery, which has important scientific significance.
CC License CC-BY-NC-SA 4.0	***Keywords Mitral valve surgery (MVS);Total thoracoscopic cadiac surgery;Propensity score matching(PSM);Minimally invasive valve surgery(MIVS)***

Introduction

In the 1980s, endoscopic surgery rose and gradually matured, from laparoscopic general surgery to laparoscopic gynecology, and then to thoracoscopic pulmonary lobe surgery is the law of its discipline development. Therefore, in the category of modern medicine, endoscopic surgery is a great revolution, but also the trend of the development of modern surgery. At present, it has become the mainstream of the whole minimally invasive surgery development. Attention to this trend is also growing in the field of cardiac surgery, especially in minimally invasive mitral valve replacement surgery. This great enthusiasm stems from the maturity and progress of surgical technology. In the academic circle, it is generally believed that truly minimally invasive is a concept, which mainly includes the following aspects: 1, the application of non-cardiopulmonary bypass technology 2, small incision 3, minimize the reduction of bone caution, muscle trauma 4, careful hemostasis [1]. Currently, mitral valve surgery still requires cardiac arrest, requires support from cardiopulmonary bypass, and cardiopulmonary bypass cannot be stopped in the near future. Therefore, the research focus of minimally invasive mitral valve surgery mainly focuses on small incision, TV thoracoscopic assistance, robot assistance and other aspects.

The complex and delicate structure of the mitral valve (MV) allows it to ensure the unidirectional flow of blood from the left atrium to the left ventricle. In the United States, MV degeneration, such as spinal cord rupture or prolonged lobular prolapse, is the leading cause of chronic mitral regurgitation (MR) [2,3]. Patients with mild MR are easily tolerant and often have no obvious discomfort symptoms for many years, but persistent moderate and severe MR can lead to severe left ventricular (LV) remodeling, impaired cardiac output, heart failure, and ultimately lead to death [4,5]. Moderate and severe MR account for a large proportion of heart valve disease in

the United States, and there is a trend towards increasing [3]. However, in China, another common cause of mitral valve disease is mitral valve stenosis (MS) caused by rheumatic heart valve disease. Severe rheumatic mitral valve disease is often difficult to repair, and only mitral valve replacement can be performed. And rheumatic lesions often involve the aortic valve.

Mitral valve surgery (MVS) is currently the only effective treatment for chronic severe MR and MS. Conservative treatment in internal medicine can temporarily relieve clinical symptoms, but often accompanied by a high mortality and higher complication rate [6]. Enriquez-Sarano et al reported 456 severe MR patients with a cumulative incidence of adverse cardiac events including death within 5 years of 33% [5]. In addition, a long-term follow-up study found that 90% of patients with conservative MR treatment died or had to undergo surgery 10 years after initial diagnosis[7]. Therefore, surgery is an inevitable treatment for patients with severe MR or MS. Once diagnosed, surgery is recommended as soon as possible.

Good exposure to the mitral valve is one of the key factors of smooth mitral valve surgery. Lillehei And his team began using mitral valve surgery in the 1960s[8].They were admitted from the right thorax and dissected through the left chamber behind the sulcus. While Effler and colleagues modified the previous surgical technique, they entered directly from the right atrium, cut the atrial septum and thus performed mitral valve surgery[9].Nowadays, median sternotomy and left atrial incision mitral valve surgery has become the standard procedure of mitral valve surgery, because the mitral valve is well exposed, incision and suturing are simple, and the low incidence of postoperative complications in patients. Especially in patients with left atrial enlargement, the mitral valve exposure is clearer using this surgical approach.

Median incision heart valve surgery has been performed for decades, and the surgical technique has long since changed from novel to mature and common now.Although the surgical technology is mature, the mortality and postoperative complications are very low, the operation itself has some shortcomings.Heart surgery of median incision, long scar, obvious scar, affect the appearance; sternum saw, postoperative pain is obvious, and a longer duration; thoracic stability will also be affected, the postoperative recovery is slow, affect the quality of life of patients.With the progress of modern medicine and the improvement of people's quality of life, patients have put forward higher demands for medical services.On the premise of ensuring the safe and effective operation, how to reduce the trauma caused by the surgery itself is the direction that surgeons are always pursuing.With the progress of surgical technology and the long-term development of surgical equipment, cardiac surgeons have begun a new attempt of minimally invasive cardiac surgery.

In the mid-1990s, Cohn, Navia and other cardiac surgeons took the lead in minimally invasive mitral valve surgery. At the same time, the improvement of instruments, visual equipment and cardiopulmonary bypass technology for minimally invasive mitral valve surgery also accelerated the development of minimally invasive mitral valve surgery。On the premise of ensuring the surgical effect, the application of total thoracoscopic technology for mitral valve replacement surgery is the goal of minimally invasive mitral valve field. At present, in the field of minimally invasive mitral valve, the application of thoracoscopy is mainly as follows:

1. Thoracoscopic assisted mitral valve replacement: In 1996, Kaneko first applied television thoracoscopic assisted mitral valve replacement in the median incision, and Carpentier completed the world's first thoracoscopic assisted mitral valve replacement through a small anterior chest incision in early 1996. Thoracoscopy-assisted mitral valve replacement surgery is a surgical using a 10cm incision in the right lateral anterior chest wall using thoracoscopy as an auxiliary tool[10]. Although the sternum is not required, a wide range of intercostal muscle separation and transection is required. The intraoperative application of hard retractor, the bone, muscle trauma is still very large. Moreover, due to the abundant muscle blood supply, there is more bleeding in the wound surface after transection muscle, resulting in more hemostasis difficulties and postoperative drainage, which cannot reach the highest level of minimally invasive field of mitral valve surgery.
2. Total thoracoscopic robotic assisted mitral valve replacement surgery: In 2002, Torracca et al. reported 7 cases of Total thoracoscopic atrial septal defect repair assisted by the "Da Vinci" robotic system. During this kind of surgery, peripheral cardiopulmonary bypass and four holes in the chest wall were used to complete the operation. With the greater clarity of endoscopic images, this technique has been applied to the field of minimally invasive mitral valve. So far, there has great defects, such as complex preoperative installation system, long operation time, lack of visual and tactile feedback from surgeon, high technical difficulty, very expensive equipment, rapid attenuation of consumables, high operation cost, and heavy patient burden. Although this technique can help surgeons to overcome the small incision to the maximum extent, it is not in line with China's national conditions, and at least it is not suitable for routine development in hospitals at all levels.

3.Total thoracoscopic mitral valve replacement surgery:Total thoracoscopic mitral valve replacement surgery is a set of chest wall three-hole mitral valve replacement surgery explored by Professor Cheng Yunge of Xijing Hospital in 2000. On the premise of fully using the technology of laparoscopic surgery, combined with China's national conditions, the contemporary high-tech achievements are fully applied[11].This technique requires no chest wall perforation, no free intercostal muscle removal, or a hard retractor. Theoretically, its minimally invasive effect is significantly better than the traditional median thoracotomy.In 2009, Ma Zengshan team of Qilu Hospital of Shandong University changed the position of the left and right hand operating holes and the position of the hole of the cavity, and improved the minimally invasive surgical instruments, and achieved satisfactory results.

Conventional median open mitral valve replacement surgery usually requires a 20-30cm size incision to ensure adequate visual exposure. So, while we complete the valve replacement, it also brings about a series of problems. The internal steel wire was left after surgery. Body surface surgical scar is significant, sternum development deformity, etc. Although the patient's life is saved, it has a huge impact on the physiological and psychological aspects, so that the patient returns to society slowly and the long-term quality of life is poor.In today's rapid development of society, the concept of modern health is not only no organic diseases, but also in the physical, psychological, social aspects of patients and completely good state. Therefore, the goal pursued by surgeons should be to minimize the adverse effects of surgery in physiological, psychological and social aspects on the premise of ensuring the surgical effect[12].The appearance of TV thoracoscope changes the exposure of the surgical field. Because the microscopic field is enlarged, it not only makes the surgical vision clearer, but also greatly shortens the incision, reduces bleeding, and conceals the incision, minimizing the trauma and shortening the postoperative recovery time, which is in line with the concept of modern health.In terms of thoracoscopic application, thoracoscopic assisted mitral valve replacement surgery still belongs to the category of direct surgery, which requires a hard retractor to reveal the field of vision, serious damage to bone and muscle, obvious postoperative pain, and more bleeding. The Total thoracoscopic mitral valve replacement is a hole surgery, without hard retractor and light tissue damage. Compared with traditional thoracotomy and thoracoscopic assisted surgery, it has obvious technical advantages.For example, the skin incision is small, when entering the chest cavity, there is no need to cross the muscle, no need to pull the hard retractor, to avoid skeletal muscle damage to the greatest extent, postoperative pain is light, less bleeding, quick recovery.However, because the thoracoscopic field of view is a two-dimensional image, it is difficult to suture under the microscope, requiring a long training time under the stage. Compared with the traditional median thoracotomy, the trauma to the body is different, and whether the operation can really achieve the purpose of "minimally invasive". At present, there is still a lack of systematic research in China.All technological innovation is controversial in the early stage, and it is such debate that can promote the progress and development of technology.This study was conducted in the context of this debate to summarize the experience of Total thoracoscopic mitral valve surgery in our center.Total thoracoscopic mitral valve replacement surgery and traditional median incision mitral valve replacement surgery were compared by the propensity score matching method.Evaluate its safety and merits.

1.Study subjects and methods 1.1 Study subjects

The surgical indications for thoracoscopic cardiac surgery are basically the same as those for conventional open vision surgery, and the preoperative evaluation criteria are roughly the same as those for conventional cardiac surgery. Patients with a previous history of right thoracic surgery or a history of pleural adhesion are not suitable for endoscopic surgery. Chest X-ray or chest CT excluded chest problems while observed the right diaphragm. Before surgery, color Doppler ultrasound examined the iliac, femoral artery and vein and ruled out the malformation. Pulmonary function was routinely measured before surgery to excluding patients who cannot tolerate single-lung ventilation.

Selection criteria: (1) cardiac function grade I-II in New York; (2) age over 15 years and weight greater than 45 kg; (3) no left atrial thrombus; (4) pulmonary artery pressure <60 mmHg; (5) no history of pulmonary disease and chest surgery; (6) no femoral motor and venous Doppler ultrasound before surgery.

From January 2018 to December 2020, a total of 139 patients in the thoracoscopic group were eligible in the cardiothoracic surgery department of our hospital, and 1066 cases of traditional median sternotomy mitral valve replacement.

1.2 Propensity score matching

The propensity score matching method was used in both groups. Matching clinical baseline indicators: age, gender, BMI value, smoking history, preoperative left ventricular ejection fraction (LVEF), previous congestive heart failure, severe cerebrovascular disease, severe peripheral vascular disease, previous history of myocardial infarction, previous history of cardiovascular surgery, whether with hypertension, diabetes, chronic renal failure, chronic obstructive pulmonary disease. Using the propensity matching scoring method, according to the thoracoscopic and thoracotomy groups, the caliper value 0.2 was selected for matching. The ratio was 1:1, and the matching tendency score (Ps value) and PSweight were calculated, and the statistical analysis between thoracoscopic group and control group was conducted. This means that the patients in each thoracoscopic group will be paired with one patient in the control group, so that the characteristics between the two groups will match as well as possible.

After propensity score matching, 125 patients were selected in the thoracoscopic group, among 1066 patients with median incision MVR, 1:1 matched to 125, as the control group in the thoracoscopic group. The basic data of the patients after matching is shown in Table 2.

1.3 Operative procedure A： Total thoracoscopic group （1） Anesthesia management

The patient was placed in the supine position with a right chest pad 20-30 degrees high, and external defibrillation electrodes attached to the left anterior and left posterior chest wall, respectively.

Use general anesthesia and single-lumen endotracheal intubation. During intrathoracic operation, left single lung ventilation was performed using a bronchial occluder; 100% pure oxygen was ventilated with a fixed tidal volume (Vt) of 6-8 ml / kg. The respiratory rate was at 12-16 breaths / min, depending on regulating the respiratory rate and keeping Sa 02 greater than 97%. Mechanical ventilation was stopped after blockade of upper and inferior vena cava. After successful anesthesia, the esophageal ultrasound probe was inserted and mitral valve replacement and left heart system exhaust were routinely monitored.

2）Establishment of peripheral cardiopulmonary bypass

The femoral artery and femoral vein cannula were used to establish cardiopulmonary bypass. The longitudinal incision was the right inguin femoral artery, about 2. 5-3cm long. The femoral artery and femoral vein were separated and packed with 5-0proleen suture respectively.Heparinized, puncture the femoral artery, insert a hard wire, insert the investment artery cannula along the wire to the appropriate part, pull out the wire and the inner core of the tube, fully exhaust the air bubble connected with the extracorporeal circulation pipe before fixing.In the same way, the femoral vein was punctured and a hard guide wire was inserted. Through the upper vein under the guidance of esophageal ultrasound, and the bipolar femoral vein cannula was inserted along the guide wire. Under esophageal ultrasound, the femoral vein cannula was inserted into the superior vena cava, and the inferior pole was retained in the inferior vena cava. The inner core and guidewire were drawn out and connected and fixed with the extracorporeal circulation venous pipe. The central venous pressure was maintained up to 15 cmH 20. Extracorporeal circulation management to maintain blood access and exit balance, maintain full flow circulation, and maintain arterial blood oxygen partial pressure above 120mmHg, otherwise peripheral cardiopulmonary circulation should be abandoned for direct intubation and drainage of the superior vena cava.

3）Surgical methods

a）Make three 1.5 cm long holes in the right chest wall (selected according to the disease): Left hand operating device hole: take the fourth interrib of the right axillary midline, insert superior vena cava blocking band, perfusion needle, ascending aortic blocking forceps and surgical instruments, right atrial traction line and superior vena cava cuff band;

Right hand operating device hole: take the fourth interrib of the right midline clavicle, and place the surgical instrument and atrial traction lines;

Thoracoscopic operation hole: take the 7th intercostal of the right axillary midline. During the operation, the movement of the right phrenic nerve could be identified by thoracoscopy, and the pericardial incision was made from the longitudinal direction, from the length to the root of the ascending aorta and down to the root of the inferior vena cava.(Fig. 1)

(b)The order of the three holes is as follows:

First, the thoracoscope hole was cut and the blade protective sleeve was placed. Enter the thoracoscope and adjust its angle, position, brightness, contrast, white balance, and focal length. Press the position of the left hand hole, determine the position of the chest through the thoracoscope, observe whether it is appropriate, then cut

the left hand hole and place the incision protective sleeve; the right hand hole should be completed by the same method.

(c)Pericarotomy and suspension:
The thoracoscope was inserted through the thoracoscopic hole, adjusting the angle and position, and comprehensively scanning the right thoracic aspect of the mediastinum. The pericardium was cut oblique at about 2cm above the right phrenic nerve, up to the reverse folding of the pericardium at the beginning of the aortic arch and down to the root of the inferior vena cava. Two traction wires were stitched at the pericardial margin and pulled out through the left hand and right hand.(Fig. 2)

d）Caval snares were placed in the superior and inferior vena cava：
Tissue forceps gently lift the upper vena cava through the left hand hole; the tissue scissors separate the upper vena cava from the right pulmonary artery space through the right hand hole; Apply right Angle forceps, take out the upper vena cava through the left hand operating hole and cover the blocking band, and then draw the blocking belt through the left hand operating hole to complete the upper vena cava cuff band operation; Tissue forceps pulled the pericardium to the right through the left hand operating hole, and tissue scissors separated the right pericardial fold of the inferior vena cava through the right hand operating hole. The renal pedicle forceps then separated the inferior vena cava through the right hand operant hole. The blocking band was sent in through the left hand operating hole and pulled out of the thoracoscopic hole, and the inferior vena cava cuff band operation was completed. (Fig. 3) (Fig. 4)

e）Left heart drainage.
The left heart drain was placed through the endoscopic hole. After blockade of the ascending aorta, the left heart drain was inserted directly into the left atrium after cutting the left atrium or atrial septum.

f）Infusion tube in the aortic root
Adjust the position of Thoracoscopy to expose the root of Ascending aorta. The left hand operation hole is inserted into the forceps, the right hand operation hole is inserted into the needle holder, the double ended needle with gasket is lifted on the Ascending aorta to suture the "U" shaped purse, and the blocking cannula is sleeved and led out from the left hand operation hole. The perfusion needle was inserted into the root of the ascending aorta through the left operating hole, tightening the blocking line and connecting the perfusion tube. (Fig. 5)(Fig.6)

g）Blocking the ascending aorta
Tighten the blocking line of superior and Inferior vena cava, switch to cardiopulmonary bypass, conduct left atrial drainage, and cool down. Insert the blocking clamp of Ascending aorta through the left hand operation hole. Temporarily reduce the perfusion flow of cardiopulmonary bypass, and block the Ascending aorta in the far horizontal direction of the perfusion needle. Restore flow, infuse needle with cold blood cardioplegia, and cause cardiac arrest.(Fig.7)

h）Right atrial approach and atrial sulcus approach
Adjust the angle and position of Thoracoscopy to expose the right atrium. Hold tweezers with the left hand operating hole and scissors with the right hand operating hole, parallel to the direction of the atrioventricular sulcus, and cut open the right atrium. The traction line of the right atrial upper margin suture is led out from the right hand operating hole, exposing the atrial septum. Hold tweezers with the left hand operating hole, and scissors with the right hand operating hole, cutting open the atrial septum. The traction lines on both sides of the incision edge of the atrial septum are led out from the right hand operating hole to expose the mitral valve and explore the condition of mitral valve disease(Fig.8)
Interatrial sulci approach： The left hand hole holds the tweezers, and the right hand hole holds the scissors.
After cutting the interatrial sulci, respectively, the traction line is sewn on both sides of the interatrial sulci incision. Two traction wires on the upper edge are drawn and suspended by the right hand operating hole, and one traction wire at the lower edge is drawn and fixed by the left hand operating hole to perfectly expose the mitral valve without any hard pull hook.(Fig.9)

i）Mitral valve and tricuspid valve processing

Cut the mitral valve leaflets and take 2-0 gasket suture to the mitral annulus. After pulling the suture through the right hand operating hole and intermittently suturing the artificial valve, push the artificial valve from the right hand operating hole. Observe the mitral annulus. After complete implantation, knot and rinse to check whether the artificial valve is normal and the leaflets are flexible(Fig. 10)(Fig.11).

The left hand operating hole was inserted into the tissue forceps, the right hand operating hole was inserted into the needle holder, and the 3-0prolene suture was continuous suture of interatrial septum. The thoracoscope was adjusted to expose the tricuspid valve and watered to determine the severity of tricuspid regurgitation. The operation is the same as the mitral valve, the sutures suture the ring, tighten the suture, push into the ring to the tricuspid ring, observe satisfactory, knot one by one. The water drawing experiment determined that it closed well and the right atrial incision was continuously closed with 4~ 0prolene suture.

j）Rewarming; opening of the ascending aorta

Inform the perfusion operator to start reheating after the critical operation is basically completed. The ascending aorta perfusion needle connects with the negative pressure drainage and exhaust, adjusts the Angle and position of the thoracoscope, exposes the ascending aorta root, slowly opens the ascending aorta blocking clamp after the low head, and the heart rejumps. If no return jump, external defibrillation can be used.

k）Cardiopulmonary bypass stop; tube removal and hemostasis

Adjust the angle and position of the thoracoscope, expose the panorama of the mediastinum, expose the inner surface of the chest wall cavity, and check for any blood. After the rewarming of cardiopulmonary bypass, rearterial and venous blood and gas analysis, normal indicators, adjust the flow, and gradually stop. The femoral vein was cannulated and neutralized with heparin. After adjusting the thoracoscope to observe again for bleeding in the holes of the heart, pericardium and chest wall, the thoracoscope was removed and the chest wall holes were sutured. After hemodynamic stabilization, the femoral artery cannula was removed, the femoral artery and femoral vein incisions were sutured, and the skin was sutured. The thoracic closed drainage tube was placed in the thoracoscopic hole. The operation was over .

B: Traditional median thoracotomy group

Single lumen endotracheal tube was performed in supine position, high chest pad, median incision, longitudinal splitting of the sternum, and sternum opening with a sternal distraction. The heart was exposed under direct vision, and cardiopulmonary bypass was established via the aorta, superior and inferior vena cava. A left atrial drain was routinely placed in the left superior pulmonary vein; mitral valve replacement was performed by exposing the mitral valve via the left atrial approach or the right atrial-atrial septal approach. After surgery, the aorta was opened, vented, parallel circulation, stopped, evacuation of cardiopulmonary bypass, protamine neutralized heparin, inddrainage, the sternum was closed with steel wire, and the chest was closed layer by layer.

1.4 Statistical analysis

Data of minimally invasive group and control group were processed and analyzed using SPSS22.0 software. All continuous measures were expressed in the form of mean ± standard deviation or median and quartile; chi-square test was used for categorical variables in the data; t-test or non-parametric test for continuous variables. If the P-value is less than 0.05, the difference between the two groups is considered statistically significant.

2.Research results 2.1 Comparison of the basic data between the two groups

Detailed basic preoperative information and clinical data of both groups are shown in Table 1. As can be seen from the data that there are obvious differences in the basic information between the two groups. The mean age of patients in the thoracoscopic group was 48.63 ± 10.98 years, significantly less than 53.28 ± 12.39 in the control group (p=0.0000); also, the proportion of patients older than 60 years was lower in the thoracoscopic group (18.7% vs. 39.4%, p=0.0163). Of the proportion of patients with mitral stenosis, the thoracoscopic group was significantly higher than the control group (84.8% vs. 71.8%, p=0.0154). Other preoperative clinical data, such as past history (including the history of stroke, coronary heart disease, diabetes mellitus, and atrial fibrillation), NYHA grade, and preoperative LVEF, were not significantly different.(Table 1)

Table

Table 1: Comparison of basic data between thoracoscopic and control groups (before propensity score matching)

Parameter	Thoracoscopic group (n=139)	Control group (n=1066)	P value
Gender (male / female)	55/84	507/559	0.0141
Age (year)	48.63±10.98	53.28±12.39	0.0000
≥60year	26（18.7%）	421（39.4%）	0.0163
BMI (Kg/m^2)	23.41±7.68	23.45±9.98	0.896
History of smoking	20（14.4%）	558（52.3%）	0.0000
History of diabetes	6（4.3%）	52（4.8%）	0.5376
History of hypertension	14（10.0%）	252（23.6%）	0.0000
History of hyperlipemia	7（5.0%）	220（20.6%）	0.0000
History of chronic kidney failure	1（0.7%）	3（0.2%）	0.1881
History of stroke	1（0.7%）	3（0.2%）	0.1881
Peripheral vascular disease	2（1.4%）	6（0.6%）	0.4052
Atrial fibrillation	39（28.1%）	22（2.0%）	0.2578
NYHA(III or IV)	25（17.9%）	6（0.6%）	0.0940
History of previous cardiovascular surgery	2（1.4%）	56（5.2%）	0.0020
History of coronary heart disease	1（0.7%）	7（0.6%）	0.8221
LVEF	63.63%±7.77	62.59%±8.47	0.3605
Mitral stenosis	118（84.8%）	766（71.8%）	0.0154
Mitral regurgitation	21（15.2%）	300（28.2%）	0.7681

Propensity score matching, 125 patients were selected in the thoracoscopic group. Among the patients with median incision MVR, 125 patients were 1:1 matched as the control group of the thoracoscopic group. The matching model was: gender + age + BMI + NYHA + LVEF + AF, etc. There were no significant baseline differences between the matched groups (Table 2).

Table 2: Comparison of basic data between thoracoscopic and control groups (after propensity score matching)

Parameter	Thoracoscopic group (n=125)	Control group (n=125)	P value
Gender (male / female)	48/77	55/70	0.1948
Age (year)	49.83±11.28	50.28±10.97	0.8972
≥60year	26（20.7%）	24（18.8%）	0.8063
BMI (Kg/m2)	23.05±9.46	23.05±8.97	0.956
History of smoking	20（14.4%）	21（16.8%）	0.7456

History of diabetes	6 (4.8%)	7 (5.6%)	0.6753
History of hyperlipemia	12 (9.6%)	12 (9.6%)	1.0000
History of hyperlipemia	7 (5.6%)	9 (7.2%)	0.4142
History of chronic kidney failure	1 (0.8%)	2 (1.6%)	0.5646
History of stroke	1 (0.8%)	1 (0.8%)	1.0000
Peripheral vascular disease	1 (0.8%)	3 (2.4%)	0.3173
Atrial fibrillation	55 (44.0%)	65 (52.0%)	0.4576
NYHA(III or IV)	24 (19.2%)	24 (19.2%)	1.0000
History of previous cardiovascular surgery	1 (0.8%)	2 (1.6%)	0.5020
History of coronary heart disease	0 (0.0%)	1 (0.8%)	0.3576
LVEF	63.67%±6.39	63.19%±7.85	0.8052
Mitral stenosis	108 (86.4%)	88 (70.4%)	0.0386
Mitral regurgitation	20 (16.0%)	22 (17.6%)	0.7769

Surgery-related clinical results in the two groups

The results showed that the mean operative time in the thoracoscopic MVR group was significantly longer than that in the control group (185.73 ± 43.04 vs. 164.58 ± 40.28, p=0.0016). Similarly, both the mean CPB time and aortic block time were significantly longer than those in the control group (108.37±30.57min vs. 79.18±17.65min, p <0.0001; 66.59±29.63min vs. 45.09±19.68min, p <0.0001. Moreover, the proportion of patients with CPB greater than 120min and aortic block greater than 90min was significantly higher than the control group (24.1% vs. 3.2%, p <0.0001,14.4% vs. 2.4%, p=0.0237). In addition, there was no significant difference in the mean ICU observation time between the two groups (49.35±34.51h vs. 48.72±25.89h, p=0. 8792). Differently, the mean endotracheal intubation time was significantly lower in the thoracoscopic MVR group compared to the control group (18.52±6.07h vs. 25.45±14.18h, p=0.0032). Similarly, the length of stay in the thoracoscopic group was 9.13 ± 4.58 days, which was significantly lower than 11.12 ± 5.76 days in the control group (p=0.0004).(Table 3)

There was no significant difference in the postoperative hemoglobin concentration or platelet count between the two groups of MVR patients. Mean intraoperative bleeding volume in the thoracoscopic MVR group was significantly less than that in the control group (158.37±100.91ml vs.250.74 ± 81.34, P <0.0001). Similarly, the mean postoperative discharge in the thoracoscopic MVR group was significantly than in the control group (428.39±361.38ml vs. 514.07 ± 347.92ml, p=0.0383). For patients with postoperative blood products, there were 37 (29.6%) in the thoracoscopic group and 33 (26.4%) in the control group. There was no significant difference between the two groups. Similarly, there was no significant difference in the mean total hospital costs between the two groups.(Table 3)

All 250 MVR patients had no deaths during hospitalization or within 1 month of surgery. There was also no significant difference in the incidence of major postoperative complications between the two groups (9.6%vs. 10.4%, p=0.8895). Four of the patients in the thoracoscopic group underwent another thoracotomy for hemostasis due to more postoperative bleeding, compared with three patients in the median incision group. As for infection-related complications, there were two lung infections and one incision infection in the thoracoscopic group. Pulmonary infection improved after anti-infection and symptomatic supportive therapy; two patients in the control group developed pulmonary infection, one of whom was complicated with pneumothorax and recovered after prolonged anti-infection treatment, and two patients developed chest incision infection, which also improved after treatment. Four patients in both groups developed a slow arrhythmia and recovered sinus rhythm within 14 days of temporary pacemaker therapy. One of the patients in the thoracoscopic

group had postoperative cerebral infarction, which showed headache and nausea, no obvious limb movement and sensory disorders, and improved after symptomatic treatment without obvious sequelae. One case in the control group developed new renal failure, which recovered after dialysis treatment.

Table 3: Comparison of perioperative clinical outcomes and complications in thoracoscopic and control patients (after propensity score matching)

Parameter	Thoracoscopic group	Control group （n=125）	P value
Total operative time（min）	185.73±43.04	164.58±40.28	0.0016
>200min	33 (26.4%)	18 (14.4%)	0.0546
CPB time（min）	108.37±30.57	79.18±17.65	<0.0001
>120min	30 (24.1%)	4 (3.2%)	<0.0001
Aortic block time（min）	66.59±29.63	45.09±19.68	<0.0001
>90min	18 (14.4%)	3 (2.4%)	0.0237
Intraoperative bleeding（ml）	158.37±100.91	250.74±81.34	<0.0001
Postoperative ICU observation time（h）	49.35±34.51	48.72±25.89	0.8792
Postoperative time of endotracheal intubation（h）	18.52±6.07	25.45±14.18	0.0032
Postoperative hemoglobin（g/L）	109.67±25.33	109.70±27.45	0.9534
Postoperative platelets（10'9/L）	153.84±63.19	156.45±48.65	0.7985
Postoperative drainage volume （ ）	428.39±361.38	514.07±347. 92	0.0383
Use of blood products	37 (29.6%)	33 (26.4%)	0.7653
RBC（U）	0.63±1.32	0.41±1.08	0.3829
Plasma（ml）	78.49± 128.56	108.61 + 325.52	0.5761
Postoperative complications	12 (9.6%)	13 (10.4%)	0.8895
Infection (incision and lung)	3 (2.4%)	4 (3.2%)	0.7749
Reoperation for bleeding	4 (3.2%)	3 (2.4%)	0.7749
Arhythmia	4(3.2%)	4 (3.2%)	1
Postoperative new cerebrovascular accident	1 (0.8%)	0 (0%)	0.3415
Hematopneumothorax	0 (0%)	1 (0.8%)	0.3415
New renal failure after surgery	0 (0%)	1 (0.8%)	0.3415
Death	0 (0)	0 (0)	-
Postoperative hospital stay（d）	9.13±4.58	11.12±5.76	0.0004
Total hospitalization cost (RMB) (median)	115963	103897	0.3894

3.Discussion

Minimally invasive valve surgery is not a special form of surgery, but rather minimizes the trauma of traditional surgery itself through a series of new techniques and special surgical methods. Different from the "minimally invasive" method of coronary surgery, which can be used by continuous jumping, most minimally invasive valve surgery still needs cardiopulmonary bypass assistance. So the goal of minimally invasive valve surgery is to use the smallest surgical incision possible to achieve the smallest surgical trauma, while performing the operation safely and effectively. Because of this, there was no accepted, authoritative and accepted definition of minimally invasive cardiac surgery. Until 2003, the American Association of Thoracic Surgeons (STS) defined minimally invasive cardiac surgery as any cardiac surgery that does not require total sternum resection and is not performed under cardiopulmonary bypass. Similarly, Chitwood and Gulielmos et al suggest that the definition of minimally invasive cardiac surgery should not be a specific procedure, but a patient-centered approach to the idea of minimizing trauma to health by using new methods and techniques.[13]

In recent years for patients with mitral valve disease, although the conventional splitting sternum approach of mitral valve surgery has its own advantages such as perioperative and postoperative early mortality is low and excellent medium and long term effect [14-17], but minimally invasive mitral valve surgery is increasing, especially with some thoracoscopic assisted mitral valve surgery reported [18-27], through the right chest small incision under minimally invasive mitral valve surgery and axillary incision mitral valve surgery gradually mature [28-32], and can see da Vinci robot assisted mitral valve replacement reported [28,30]. Compared with conventional open-chest surgery, total thoracoscopic atrial septal defect repair achieved a faster recovery after surgery and a higher quality of life [33-37]. In recent years, we have achieved great development in non-robotic total thoracoscopic mitral valve replacement, exploring the feasibility and safety of full thoracoscopic mitral valve surgery.

The promotion of any micro-innovative technology should first be compared with the traditional "gold standard" surgery to evaluate its safety and effectiveness. Due to the long learning curve of the thoracoscopic technique, the mortality rate of thoracoscopic minimally invasive mitral valve surgery reported earlier abroad was higher, approaching 10% [38]. With the improvement of devices and the accumulation of experience, the mortality rate widely reported abroad has decreased significantly compared with the earlier stage, with less than 1%, especially in the treatment of mitral valve disease caused by degeneration [39,40-42]. The thoracoscopic technology was developed late in China, and the composition of valvular disease is still mainly rheumatic heart disease. Therefore, it still needs to be clear whether the thoracoscopic mitral valve surgery has the same safety in China. At present, most of the studies on thoracoscopic mitral valve surgery in China are single center, and there is no strict matching when comparing the prognosis index of traditional thoracotomy surgery.

This study used propensity score matching to strictly match the baseline clinical indicators of patients undergoing total thoracoscopic mitral valve surgery with those undergoing traditional thoracotomy, and compared with the early prognosis of patients undergoing traditional median thoracotomy at the same period. The results showed that the surgical mortality and the reoperation rate were not different compared with the control group. This result is in line with foreign studies, which suggests that the minimally invasive thoracoscopic technique of mitral valve disease is also a safe and reproducible operation in China.

The center is also mainly adopted by total thoracoscopic three incision mitral valve surgery, after more than 10 years of experience, combined with technical experience at home and abroad, summarized more rapid and effective full thoracoscopic mitral valve replacement key points are the following 10 points: 1: The main incision for the right anterior chest lateral 3 or 4 intercostal chest, mitral valve exposure is good, convenient Y tube insertion and aortic block, skin pattern incision hidden and beautiful.2:For patients with good peripheral vessels (including iliac vessels and femoral arteriovein), direct inguinal cannulation can reduce the operation time.3:The intercostal separation can be slightly larger than the skin incision, which can minimize the damage to the ribs during the intercostal opening.4:The use of soft tissue protector, on the one hand, is to protect the incision during the operation, on the other hand, can avoid tissue debris falling into the heart, resulting in adverse consequences.5:After the 4th intercostal chest entry, if the right diaphragm top is found high, use wire suspension and downward traction to ensure the clear surgical field.6:The pericardial incision should be 2cm in front of the phrenic nerve to avoid damage to the phrenic nerve.7:After the left atrial incision, the traction line can be used to lift the atrial septum and fix in the anterior chest to make the optimal exposure of the mitral valve.8:We use ordinary long needle holder, long vascular clamp and long straight blocking clamp, without the need for special minimally invasive instruments.9:Double-lumen endotracheal intubation, left single lung ventilation, intraoperative intermittent expansion of the right lung, reduce the occurrence of postoperative

pulmonary ede**ma.1**0:Continuous intraoperative low-flow CO2 perfusion in the thoracic cavity can effectively reduce the occurrence of perioperative stroke in patients.

On length of stay: Almost all studies of minimally invasive valve surgery now have shown it to significantly reduce the length of stay[43]. Sharony et al in order to avoid selection offse compared the clinical outcomes of 233 minimally invasive AVR patients and the same number of median incision AVR by PSM method[44].Found that the median length of stay in the minimally invasive AVR group was significantly lower than in the median incision group (6d vs. 8d, p <0.001). This paper also compared the postoperative hospital stay of patients in the thoracoscopic minimally invasive group and the median incision control group by PSM. The results showed that the postoperative hospital stay was significantly lower than those in the thoracoscopic minimally invasive group (MVR,9.13±4.58d vs. 11.12±5.76d, p=0.0004), which is consistent with the results of previous studies. In thoracoscopic minimally invasive cardiac surgery, patients have lower intraoperative and postoperative bleeding, shorter endotracheal intubation time and ICU observation time, and faster postoperative recovery, so the postoperative hospital stay is obviously shorter. The results of this study show that there is no significant difference in the total hospitalization cost of mitral valve surgery and median incision group, there is no precise study on the cost of thoracoscopic minimally invasive surgery, but from the lower hospital days, thoracoscopic minimally invasive valve surgery can better save the limited medical resources and costs[45].

Regarding surgical complications: Since thoracoscopic mitral valve surgery used peripheral cardiopulmonary bypass and insufficient surgical field, early studies reported increased risk of postoperative stroke (RR 1.79,95% CI=1.35-2.38) [46]. With the progress of technology, the incidence of stroke reported abroad in recent years [42]. In this study, the selected thoracoscopic patients and the control group were strictly matched for clinical indicators of cerebrovascular history, hyperlipidemia and hypertension, and the postoperative results showed no difference in new stroke between the two groups. At the same time, there was no significant statistical difference between the two groups in the early serious complications such as postoperative arrhythmia and new renal insufficiency, which further proved the safety of thoracoscopic minimally invasive mitral valve surgery.

On perioperative bleeding and blood transfusion: most foreign clinical studies and meta-analyses have shown that thoracoscopic mitral valve surgery is better than thoracotomy, but this advantage is related to the surgeon's operating experience. Some studies have reported that when the number of surgery exceeds 300 cases, the proportion of bleeding can decrease from 8.2% to 1.9% [47]. There are now more studies comparing many aspects of thoracoscopic and median incision valve surgery, and the results have consistently found a significant reduction in postoperative blood loss in the thoracoscopic group. In a prospective randomized controlled trial of two surgical procedures, Dogan et al found that postoperative pleural drainage in the thoracoscopic group was significantly lower than in the conventional median incision group (240 ± 69ml vs. 495 ± 165ml, p=0.008) [48]. In this study, statistical analysis of intraoperative bleeding and postoperative drainage in MVR, and found that the mean intraoperative blood loss and postoperative drainage volume were significantly lower than those in the control group. The essence of the postoperative drainage flow reflects the postoperative bleeding situation, so it is not difficult to understand that thoracoscopic cardiac surgery avoids the median incision of the sternum, and the intraoperative bleeding and postoperative drainage flow are obviously reduced.

About other perioperative problems: total thoracoscopic mitral valve surgery, because it is operated from the right thoracic cavity, single lung ventilation is required during the operation, so the right lung is in a tense state during the surgery, which may lead to recurrent pulmonary edema (RPE). Tutschka et al found that in 68 (25%) of 278 cases of thoracoscopic mitral surgery, the independent risk factors were chronic obstructive pulmonary disease, pulmonary hypertension, right ventricular dysfunction, and longer CPB time [49]. Similarly, Keyl et al. conducted a retrospective analysis of 484 patients undergoing thoracoscopic mitral valve surgery and found that 1.5% of these patients showed related symptoms of RPE, compared with 38 (7.9%), whose effect was not negligible [50].The mechanism by which postoperative RPE develops in patients with thoracoscopic mitral valve surgery is complex, mainly due to mechanical or biological damage to the microvessels in the lungs. Alternatively, free radicals and polymorphonuclear leukocytes play important roles in RPE production, and ischemia-reperfusion injury in the lung as well as the inflammatory response resulting from CPB may contribute to the progression of these mechanisms. The use of extracorporeal membrane oxygenation (ECMO) has been proven to be highly effective in patients with very severe RPE. It has been shown that a single dose of dexamethasone after induction of anesthesia is effective in preventing the emergence of postoperative RPE[50].In this study, no patients were found to have symptoms of obvious RPE, which to avoid prolonged

lung ischemia, and intermittent ventilation of the right lung during surgery had a certain effect on the prevention of RPE.

This paper is a single-center, retrospective study and has some limitations. Although the PSM method is used to balance the differences in preoperative clinical characteristics between the two groups, the level of evidence is inferior to that of a randomized controlled study (RCT). In addition, this study is only to analyze the perioperative clinical data of patients. In the future, long-term follow-up of all patients is needed in the future, and the long-term prognosis of the two groups of surgical patients should be compared in the later stage.

4.Conclusion

In this study, a propensity score matching study was conducted between patients with total thoracoscopic mitral valve surgery and traditional thoracotomy surgery, focusing on the early observation indicators in the perioperative period. The results showed that there was no significant difference in the thoracoscopic group and the control group in terms of early postoperative mortality and serious complications, which reduced the surgical pain and accelerated the treatment risk and economic burden of patients, and could be used as the surgical choice for patients with mitral valve lesions. This study shows that it has feasibility and safety for total thoracoscopic mitral valve replacement for mitral valve lesions, which can reduce the time and stay of the hospital compared with conventional direct surgery, and obtain good minimally invasive and cosmetic effect, and lay a theoretical and clinical foundation for the application of thoracoscopic technology in cardiac surgery, which has important scientific significance.

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Data Availability Statement

The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

Statements and Declarations

Funding

The authors declare that no fund, grant, or other support were received during the preparation of this manuscript.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Authors' Contributions

All the authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Xiaofei Zhang] and Bin Ni]. The first draft of the manuscript was written by [Xiaofei Zhang], and all the authors commented on previous versions of the manuscript. All the authors read and approved the final manuscript.

Ethical Standards
We declare that all human and animal studies have been approved by the ethics committee and have been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All patients provided informed consent prior to their inclusion in the study.

Consent to participate
Informed consent was obtained from all participants who were included in the study.

Consent to publish
The authors affirm that human research participants provided informed consent for publication of the findings.

Figure:

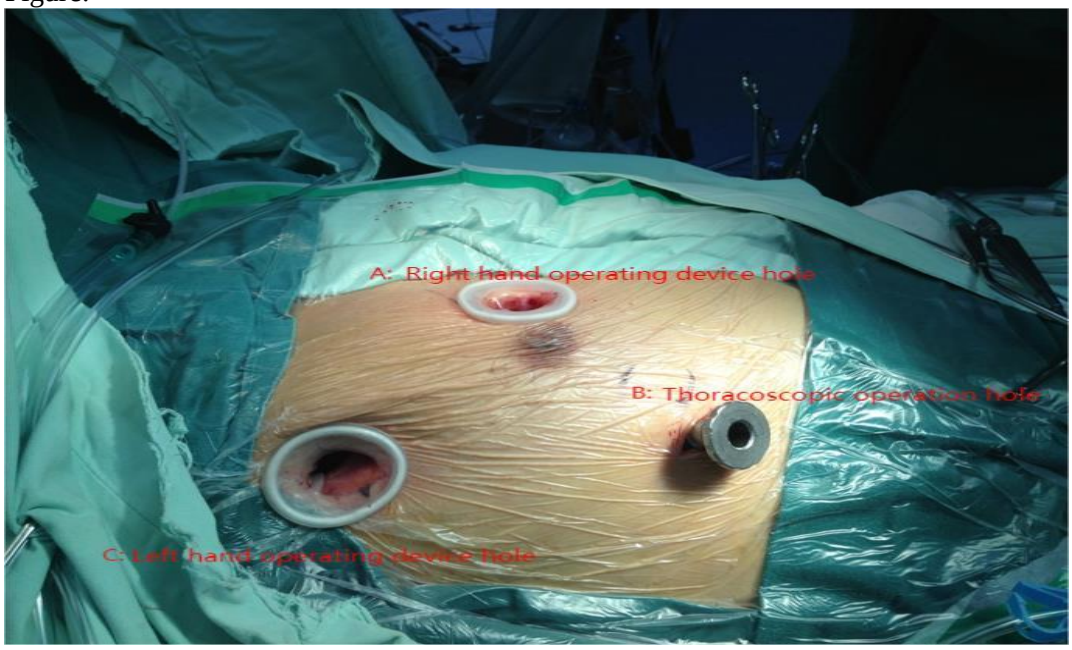

Fig. 1: Make three 1.5 cm long holes in the right chest wall. A: Right hand operating device hole
B:Thoracoscopic operation hole
C:Left hand operating device hole

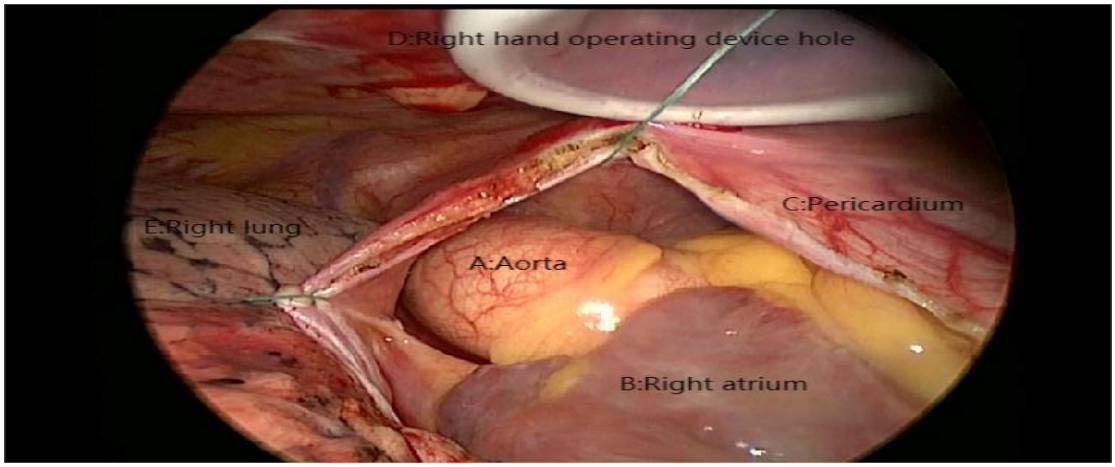

Fig. 2: Pericarotomy and suspension.
A:Aorta**B:**Right atrium**C:**Pericardium**D:**Right hand operating device hole**E:**Right lung

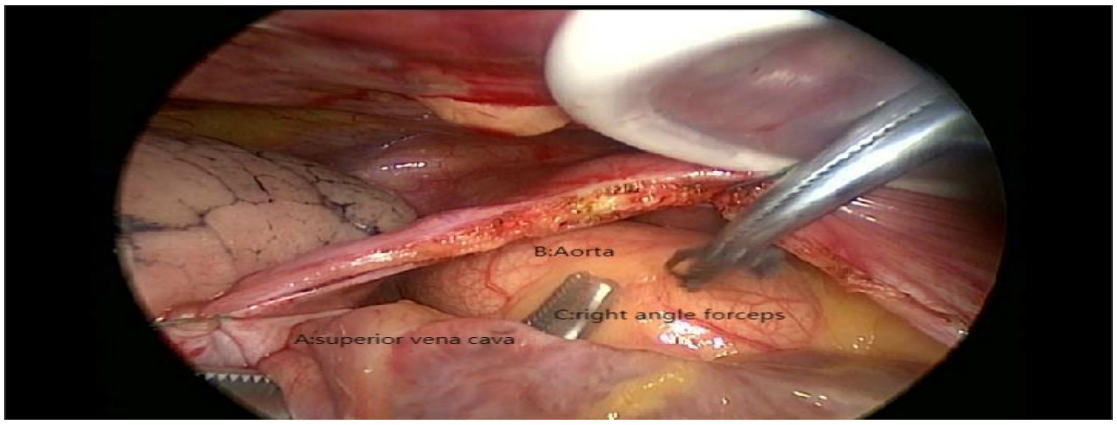

Fig.3: Caval snares were placed in the superior cava： A:superior vena cava B:Aorta C:right angle forceps

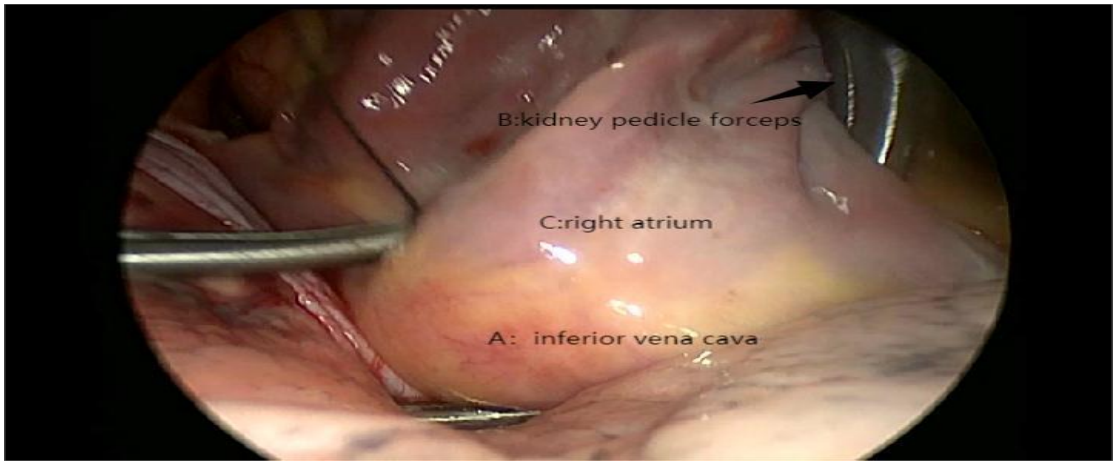

Fig.4: Caval snares were placed in the inferior vena cava： A： inferior vena cava B:kidney pedicle forceps C:right atrium

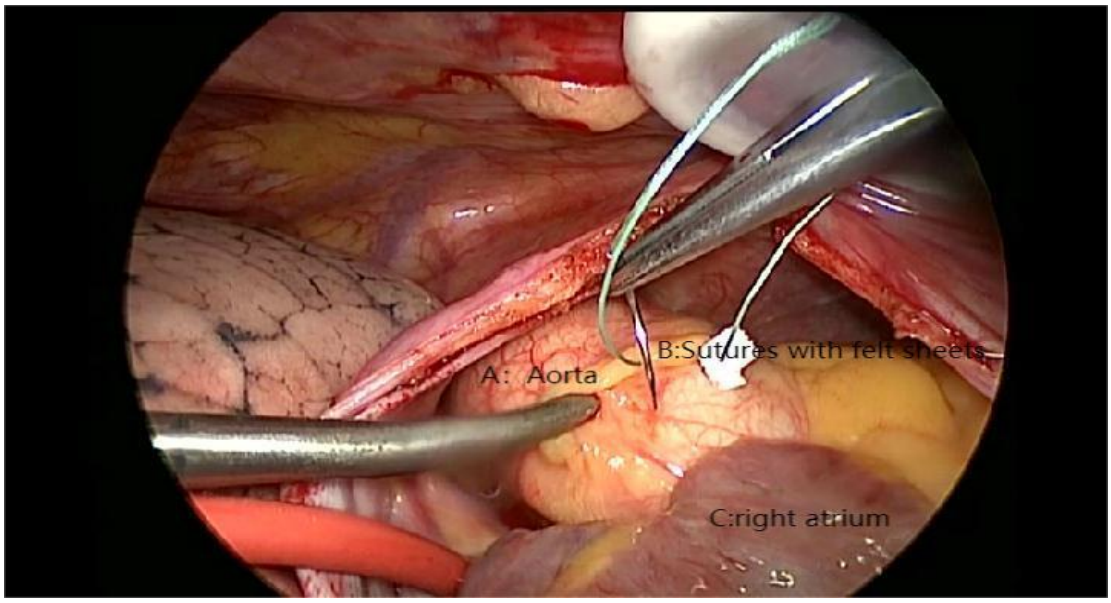

Fig.5: Page of the perfusion tube in the aortic root： A：Aorta B:Sutures with felt sheets C:right atrium

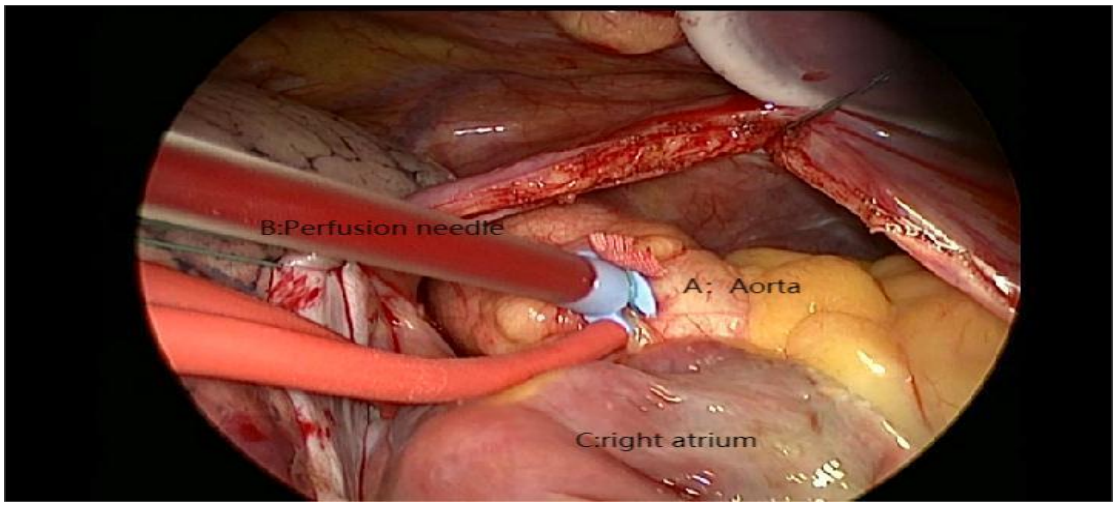

Fig.6: The perfusion needle was inserted into the aortic root： A：Aorta B:Perfusion needle C:right atrium

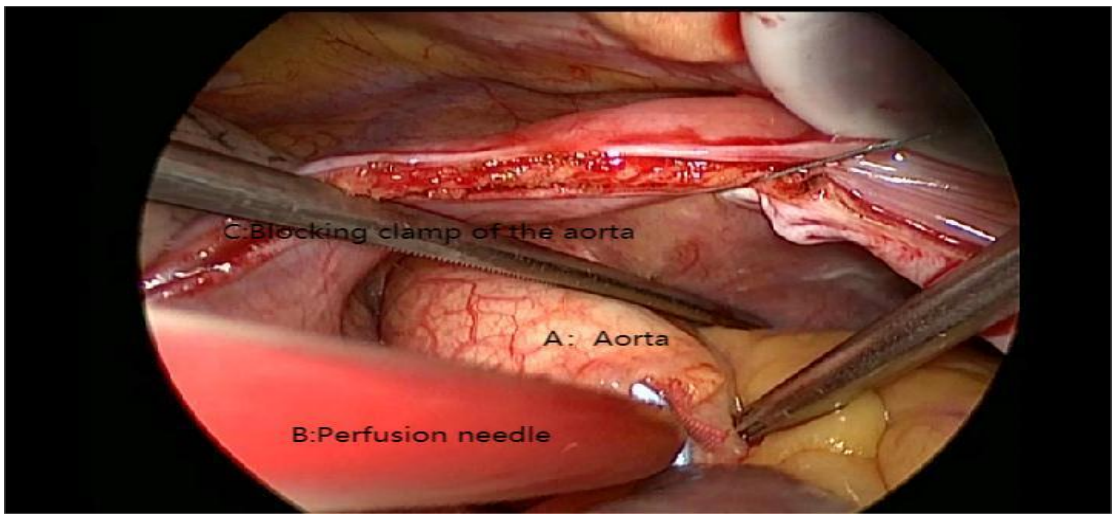

Fig.7: Blocking the ascending aorta： A：Aorta B:Perfusion needle C:Blocking clamp of the aorta

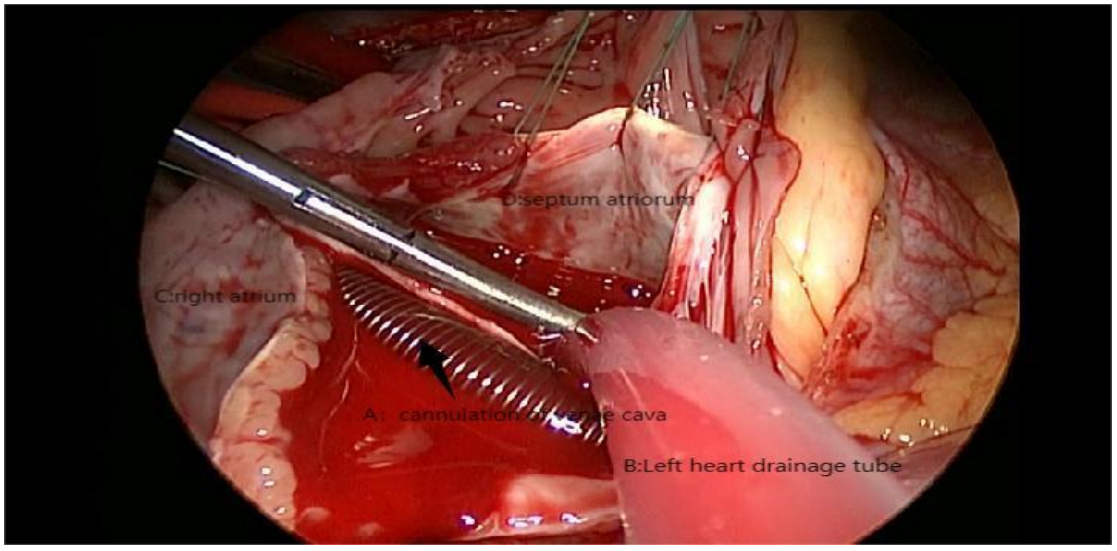

Fig.8:Right atrial approach ： A：cannulation of venae cava B:Left heart drainage tube C:right atrium D:septum atriorum

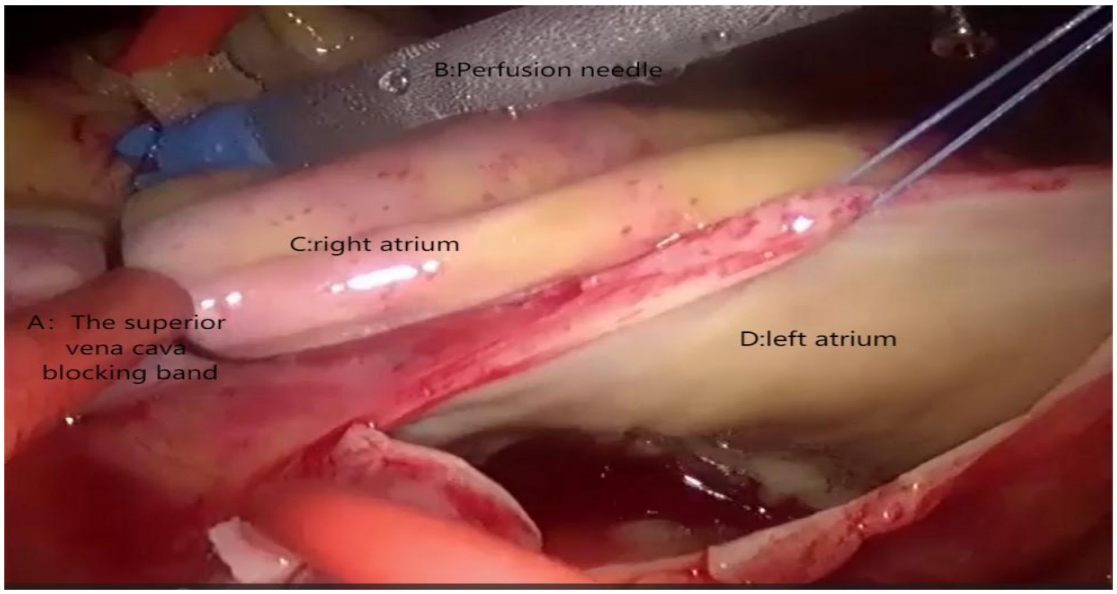

Fig.9:Interatrial sulci approach： A：The superior vena cava blocking band B:Perfusion needle C:right atrium D:left atrium

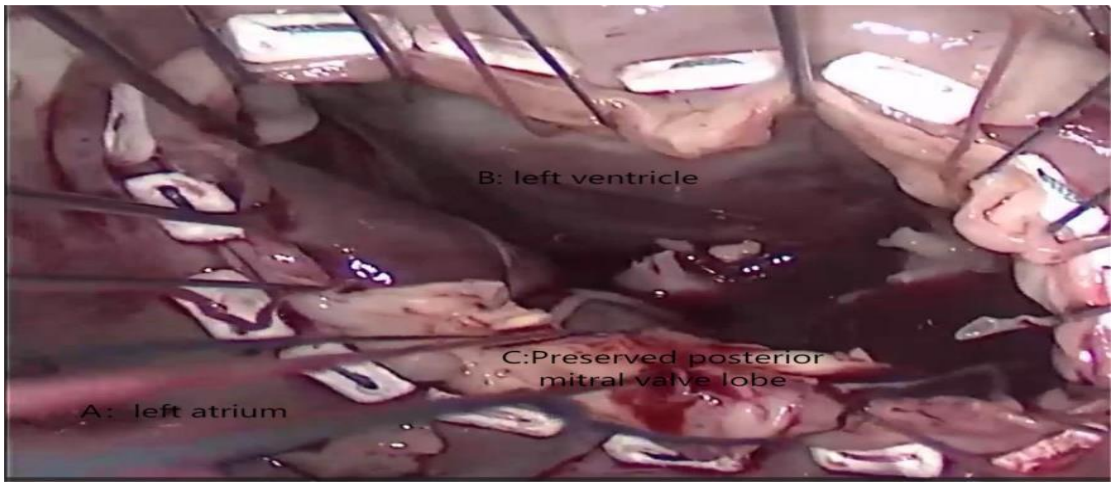

Fig.10: Cut the mitral valve leaflets and take 2-0 gasket suture to the mitral annulus： A：left atrium B: left ventricle C:Preserved posterior mitral valve lobe

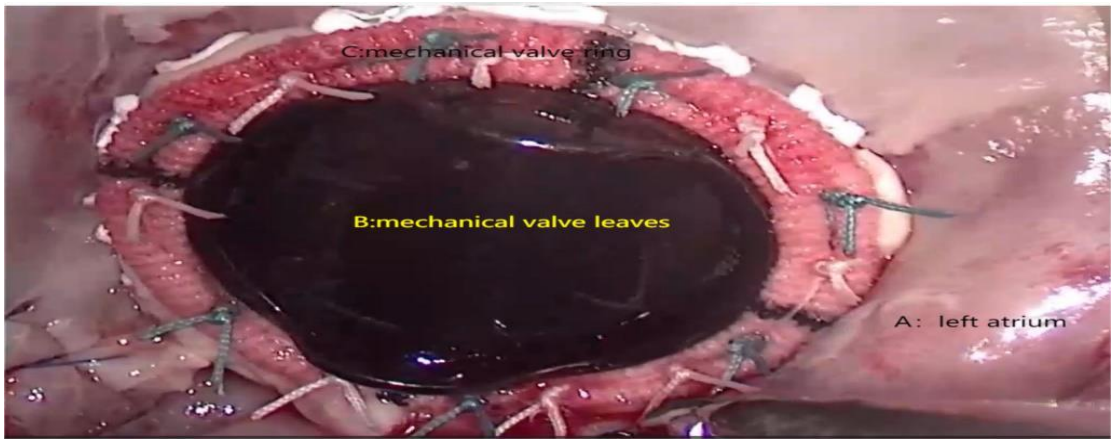

Fig.11: Status after a mechanical mitral valve replacement： A：left atrium B:mechanical valve leaves C:mechanical valve ring