



Anesthetic management of heart and lung transplantation: analysis of 14 cases in a single center

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Background: Aggressive management of heart and lung transplant (HLT_x) requires a team of specialists with dedicated expert to improve long-term outcomes. This study aimed to summarize practical experiences of anesthetic management in HLT_x operations.

Methods: This study retrospectively analyzed the anesthesia-related clinical records of 14 cases of HLT_x performed from September 2015 to October 2019. Preoperative diagnoses included congenital heart disease with pulmonary arterial hypertension, idiopathic pulmonary arterial hypertension with right heart failure, end-stage cor pulmonale, dilated cardiomyopathy, end-stage heart failure with pulmonary arterial hypertension, congenital heart disease, and lung transplant failure. All recipients received intravenous-inhalation general anesthesia with single-lumen endotracheal intubation, Swan-Ganz catheterization, and transesophageal echocardiography (TEE).

Results: All 14 cases of HLT_x were completed successfully and the patients were transferred to the intensive care units (ICUs). The postoperative data of the 14 patients were collected from 1 month to 4 years: seven cases survived the first year, four cases died in the short term (within 30 days), and one case died within 24 h. As at the end of November 2019, eight cases were reported dead (the longest survival was 2 years 1 month and 22 days). Four cases used extracorporeal membrane oxygenation (ECMO) for cardiopulmonary support.

Conclusions: The success of the HLT_x was attributed to the joint efforts of the entire transplantation team. The anesthesiology team was required for experiences in anesthesia for HLT_x. The key to anesthesia management was the in-depth participation in preoperative discussions and assessments. Preventing the exacerbation of right heart failure and pulmonary arterial hypertension is critical during the induction of anesthesia. Regulation and support are crucial from the withdrawal of cardiopulmonary bypass (CPB) to within 1 h of the circulation and respiratory functions undertaken independently by the donor heart and lungs.

Keywords: Heart and lung transplant (HLT_x); anesthetic management; trans-esophageal echocardiography (TEE); extracorporeal membrane oxygenation (ECMO)

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Introduction

Heart and lung transplantation (HLT_x) is an effective and evolving treatment for end-stage cardiopulmonary diseases. Over the past four decades, HLT_x has been developed strenuously in the departments of cardiothoracic surgery internationally. According to the International Society for Heart and Lung Transplantation (ISHLT), a total of 4,884 cases of HLT_x have been completed worldwide from January 1982 to June 2018, among which 284 cases were completed in a single year in 1989, which was the peak of completion (1). From 2005 to 2015, only 46 cases were reported by the ISHLT (2); and from 2016 to 2018, the total number of HLT_x globally was 33, 52, and 70, respectively (1). From 2015 to 2019, the Heart and Lung Transplantation Center of the First Affiliated Hospital of Guangzhou Medical University has completed a total of 14 cases of HLT_x, 15 cases of heart transplants, and 223 cases of lung transplants (including single and bilateral lung transplants). The anesthesia operations of 14 cases of HLT_x are reported below. We present the following article in accordance with the STROBE reporting checklist (available at <https://jtd.amegroups.com/article/view/10.21037/jtd-22-30/rc>).

Methods

General information

The general information and perioperative data of patients were obtained from electronic medical records and electronic anesthesia records of the First Affiliated Hospital of Guangzhou Medical University. The data are illustrated in *Table 1*.

Pre-operative assessment and preparations

- (I) Multidisciplinary and dynamic assessment was required before HLT_x to determine the diagnosis, indications, and contraindications for surgery. The dynamics of medical history, pathological conditions, and psychological conditions of the patient should be comprehended to determine the optimal operation time.
- (II) Pre-operative investigations were required. For the comprehensive systemic investigation of the recipients, special attention should be paid to the pulmonary artery catheterization (PAC) and echocardiography, for the objective and accurate judgment of the pulmonary vascular resistance (PVR) of the heart and the pulmonary arterial hypertension in a resting state.

Anesthesia induction and management

- (I) Radial artery puncture and catheterization were performed under local anesthesia, and the induction started under invasive blood pressure (IBP) monitoring. Intravenous injections of midazolam, sufentanil, etomidate (propofol), and rocuronium (cisatracurium) were conducted sequentially, followed by the insertion of a single-lumen endotracheal tube through the mouth. The triple-lumen central venous catheter, Swan-Ganz catheter, Picco catheter, and the transthoracic echocardiography (TEE) were placed to monitor the corresponding indicators, including the central venous pressure (CVP), invasive blood pressure (IBP), pulmonary blood pressure (PBP), continuous cardiac output (CCO), systemic vascular resistance (SVR), pulmonary vascular resistance (PVR), and extravascular lung water (EVLW). Anesthesia and muscle relaxation were maintained using propofol + sevoflurane + sufentanil (remifentanil) + cisatracurium.
- (II) During induction, for patients with intracardiac shunts and severe pulmonary arterial hypertension, special attention should be paid to maintain high systemic blood pressure and reduce the left-to-right cardiac shunt as much as possible; drugs with specific therapeutic effects should be selected to treat the pulmonary arterial hypertension (prostaglandin E1, treprostinil) with continuous administration. When choosing non-specific antihypertensive drugs, attention should be paid to prevent systemic blood pressure decrease, with a focus on preventing the increase of abnormal pulmonary arterial pressure.
- (III) For management during general anesthesia, analgesia should be fully administered to maintain sufficient depth of anesthesia, reduce the sympathetic reflex, and prevent the elevation of PVR. Mild hyperventilation should be maintained (pressure arterial carbondioxide, PaCO₂ =25–35 mmHg). Dynamic blood gas monitoring should be performed for the timely adjustment of the internal environment. Attention should be paid to all indicators monitored. The abnormality of individual indicators should be confirmed and clarified prior to adjustment and control.
- (IV) Regarding circulation, stable systemic blood pressure should be maintained and dopamine, dobutamine, and milrinone should be selected as appropriate. The effective circulating blood volume should be appropriately maintained by a non-restrictive fluid

Table 1 General information and outcomes of HLTx recipients

Patient information	Value (N=14)
Age (years)	34±14.5
Sex (male)	8
BMI (kg/m ²)	20.8±3.3
Preoperative diagnoses	
Congenital heart disease with pulmonary arterial hypertension	4
Idiopathic pulmonary arterial hypertension with right heart failure	3
End-stage cor pulmonale	3
Dilated cardiomyopathy	1
End-stage heart failure with pulmonary arterial hypertension	1
Lung transplant failure	1
Congenital heart disease (pulmonary artery atresia, VSD, systemic-to-pulmonary shunt)	1
Operation records	
Operation duration (min)	566.6±169.9
CPB duration (min)	278.5±66.4
Cold ischemic time of the donor (min)	316.6±91.9
Post-operative ECMO support	4
Inpatient deaths or deaths within 30 days	4
Number of survival cases in year 1	7

HLTx, heart and lung transplant; BMI, body mass index; VSD, ventricular septal defects; CPB, cardiopulmonary bypass; ECMO, extracorporeal membrane oxygenation.

management strategy. The key for pre-transplantation care was the protection of brain and renal functions, instead of cardiac and pulmonary functions. TEE was used to monitor the pre-transplantation function of the recipient, which was superior in fluid management.

Surgery coordination and treatments

The surgical approach and techniques are the key to the success of HLTx. The basic approaches of HLTx were as follows: A midline sternotomy was performed and the cardiopulmonary bypass (CPB) was established by placing conventional tubing (cannulation of the ascending aorta, superior and inferior vena cava). Incisions were made to remove the heart (transections were made on the ascending aorta and the main pulmonary artery at the sinotubular junction. An incision was made into the left atrium along the mitral valve annulus. The heart was removed along the incision on the coronary sinus). The left and right

lungs were also removed. Special attention should be paid to protect the left and right phrenic nerves, the recurrent laryngeal nerve, and the vagus nerve. The trachea was transected at 1–2 cricoid cartilages above the carina tracheae.

Following dissection of the mediastinum, the autologous pericardium should be sutured to the wound. Anastomosis was performed for the trachea and the bronchi sequentially. The surrounding soft tissues should be used to reinforce the anastomosis. The anesthesiologist was required to observe the anastomosis via bronchoscopy (*Figure 1*). Anastomosis was performed for the ascending aorta as well as the superior and inferior vena cava sequentially.

Although postoperative hemorrhage is not a major complication, it was still one of the key factors determining the success of the HLTx in the past (3). Adequate hemostasis after the cardiopulmonary resection of the recipient, especially the embedding of the posterior mediastinum, was our experience for a successful operation (4) (*Figure 2*).

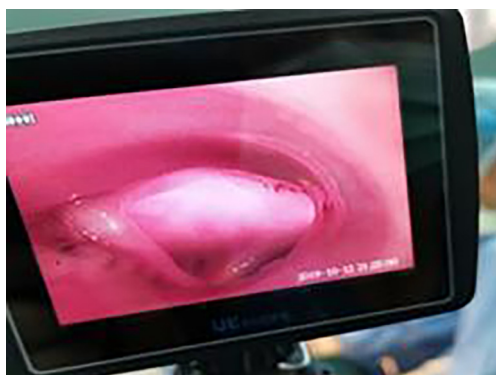


Figure 1 Trachea anastomosis under fiberoptic bronchoscope.

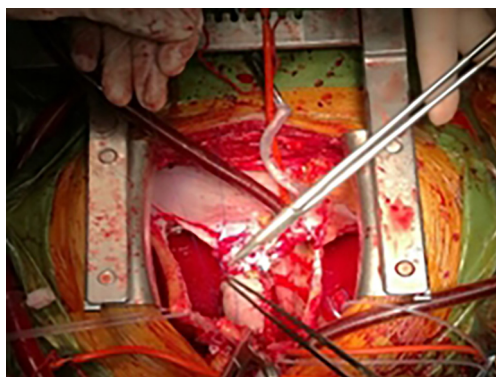


Figure 2 Mediastinal embedding for hemostasis after cardiopulmonary excision.

Management of CPB withdrawal

Reperfusion of the aorta

TEE was crucial for the thorough removal of the retained gas in the cardiac cavity before and after reperfusion of the aorta. Following anastomosis of the aorta, the clamp should be released to restore the blood flow in the aorta as soon as possible, so as to minimize the total ischemic and warm ischemic times (5). The cardioversion after reperfusion of the aorta was mainly supported and regulated by anti-arrhythmic drugs, placement of temporary pacemakers, and the use of vasoactive drugs.

CPB withdrawal

The withdrawal of CPB usually required the use of multiple vasoactive drugs. It is more important to know how to use these vasoactive drugs timely and accurately rather than which kind of drugs you intend to use. Commonly-used medications included: dopamine 4–8 $\mu\text{g}/\text{kg}/\text{min}$, epinephrine 0.005–0.02 $\mu\text{g}/\text{kg}/\text{min}$, isoproterenol 0.005–0.02 $\mu\text{g}/\text{kg}/\text{min}$,

nitroglycerin 0.2–1.0 $\mu\text{g}/\text{kg}/\text{min}$, and prostate E_1 5–30 $\text{ng}/\text{kg}/\text{min}$. The CPB withdrawal may be performed under the regulation of these drugs.

Protective lung ventilation was implemented (tidal volume of 4–6 mL/kg, respiratory rate 14–18 bpm, positive end expiratory pressure (PEEP) 3–10 cmH_2O , inspiration pressure <20 cmH_2O , minimum acceptable fraction of inspiration oxygen (FiO_2), and permissive hypercapnia) to prevent and reduce pulmonary edema and pleural effusion, and involved the administration of high doses of methylprednisolone (500–1,000 mg) and an appropriate amount of mannitol (1–2 mL/kg). The increase of colloidal osmotic pressure by conventional ultrafiltration during CPB and the increase of the hematocrit were effective measures (6).

After CPB withdrawal

A restricted fluid management strategy and protective ventilation strategy were adopted based on multi-parameter hemodynamic monitoring for the regulation and support of circulation and respiratory functions. Among these, TEE was significantly superior in fluid management and dynamic cardiac assessment. Dynamic blood gas monitoring was adopted for the timely adjustment of the internal environment. Adequate surgical hemostasis supplemented with effective coagulating agents were important for reducing postoperative hemorrhage and maintaining stable hemodynamics.

After chest closure

Re-evaluations of the hemodynamics and the respiratory functions were important, since the chest closure would usually result in a change of the heart filling and the lung compliance, which may lead to fluctuations in circulatory and respiratory functions.

Temporary left ventricular assist devices (LVAD) and the intra-aortic balloon pumps (IABP) were used in the past for poor postoperative cardiopulmonary functions. Recently, extracorporeal membrane oxygenation (ECMO) has been widely used for cardiopulmonary function support (7). For the three recent cases, the active and advanced use of ECMO (V-V in one case and V-A in two cases) achieved favorable results for the support of the donor cardiopulmonary functions.

Statistical analysis

Continuous data were expressed as the mean \pm standard

deviation (SD). The data used were retrospective statistical results.

Ethical statement

Informed consent was obtained from each patient or the legal guardian before either procedure. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the First Affiliated Hospital of Guangzhou Medical University (No. GYFYY-2022-29).

Results

A total of 14 cases of HLTx were completed in the First Affiliated Hospital of Guangzhou Medical University from Sep. 2015 to Oct. 2019. The surgical operations and the anesthesia were completed successfully without anesthesia accidents or uncontrollable circumstances. The patients were transferred to the ICU after the operations. The data of the 14 patients were collected from 1 month to 4 years postoperatively. The results showed that seven cases survived the first year, four cases died in the short term (within 30 days), and one case died within 24 h. As at the end of November 2019, eight cases were reported dead (the longest survival was 2 years 1 month and 22 days), and six cases were still alive. Four cases used extracorporeal membrane oxygenation (ECMO) for cardiopulmonary support (*Table 1*).

Discussion

HLTx is still recognized as an effective method for the treatment of end-stage cardiopulmonary diseases (8). According to ISHLT, the death rate in a short term (within 30 days) in the 1980s [1982–1991] was 25.4%, and the 1-, 2-, 5-, and 10-year survival rate were 56%, 49%, 37.7%, and 26%, respectively. Data from 2002–2012 showed that the death rate in the short term (within 30 days) was 16.8%, and the 1-, 2-, 5-, and 10-year survival rates were 69%, 62%, 51%, and 43%, respectively (9–14). In the past 30 years, with the development of immunosuppressants, the advancement in protective technologies, and especially the improvement in surgical techniques, the short- and long-term survival of HLTx has improved significantly (3).

The results showed that inpatient deaths or deaths within 30 days was 28.6%, number of survival cases in year 1 was 50%. The results were similar to those of the early (1980s)

HLTx internationally (9–13).

The perioperative administration and management of anesthesia is an important guarantee and prerequisite for successful HLTx and transfer to the ICU, which is closely related to postoperative survival. The following points should be noted for the administration of anesthesia in HLTx:

- (I) The anesthesia plan should be based on anesthesia for heart transplants and lung transplants. Attention should be paid to the cardiopulmonary functions of the donor organs following reperfusion, the protection of the brain and kidney, and the pulmonary arterial hypertension of the donor to prevent pulmonary arterial hypertensive crisis.
- (II) The hemodynamics during the induction phase should focus on maintaining the appropriate systolic blood pressure (SBP) and the SVR, while preventing a sharp increase in PVR. The specific administration is more important than the choice of the induction drugs.
- (III) TEE is helpful for the assessment of left and right cardiac functions, in order to identify the reason for hemodynamics change.
- (IV) The period after anastomosis of the donor lung and heart and reperfusion of the aorta until 1 h after the CPB withdrawal is of paramount importance in anesthesia management during the entire surgery. The denervated donor lungs usually depend on a certain concentration of adrenergic drugs to maintain basic excitability. However, in practice, the required drug concentration was low.
- (V) Following tracheal anastomosis, the anesthesiologist is required to observe the actual anastomosis and the exudation in the left and right bronchus and the lower bronchus using a bronchoscope, so as to promptly perform suction and remove possible exudate. After confirmation of the absence of air leak, low pressure with half tidal volume should be given to fill the two lungs, in order to mitigate pulmonary edema and atelectasis.
- (VI) After chest closure, it is necessary to re-evaluate the hemodynamics and respiratory function, as the compliance of the heart and lung changes significantly following chest closure. Vasoactive drugs and respiratory parameters should be adjusted based on the information provided by TEE, the Swan-Ganz catheter, and the Picco catheter.

Presently, the outcome of HLTx in China is not yet

satisfactory. Despite the low number of surgical cases, HLTx remains the ultimate effective treatment for end-stage cardiopulmonary diseases. The success of HLTx requires the joint efforts of the entire transplantation team. The cooperation between surgical team and anesthesia team is the prerequisite for the success of HLTx. In particular, close coordination between the anesthesiologist and the surgeon is a key factor in successful CPB withdrawal. The co-work of the donor acquisition team and the transplantation surgical operation team cannot be overstated. It is one of the key factors for the success of cardiopulmonary transplantation to shorten the donor ischemia time to the maximum. Anesthesia experiences in both lung transplants and heart transplants, especially rich anesthesia experiences in cardiac operations are required among the anesthesiologist team, so as to ensure the successful completion of the surgery and the postoperative transfer to the ICU. Postoperative ICU management and care is a critical support to the success of the operation.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at <https://jtd.amegroups.com/article/view/10.21037/jtd-22-30/rc>

Data Sharing Statement: Available at <https://jtd.amegroups.com/article/view/10.21037/jtd-22-30/dss>

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <https://jtd.amegroups.com/article/view/10.21037/jtd-22-30/coif>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Informed consent was obtained from each patient or the legal guardian before either procedure. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the First Affiliated Hospital of Guangzhou Medical University (No. GYFYY-2022-29).

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References

1. Chambers DC, Cherikh WS, Harhay MO, et al. The International Thoracic Organ Transplant Registry of the International Society for Heart and Lung Transplantation: Thirty-sixth adult lung and heart-lung transplantation Report-2019; Focus theme: Donor and recipient size match. *J Heart Lung Transplant* 2019;38:1042-55.
2. Chen ZG, Huang J, Hu SS. Progress on heart and lung transplant. *Practical Journal of Organ Transplantation (Electronic Version)* 2014;2:336-9.
3. Idrees JJ, Pettersson GB. State of the Art of Combined Heart-Lung Transplantation for Advanced Cardiac and Pulmonary Dysfunction. *Curr Cardiol Rep* 2016;18:36.
4. Yang C, Peng GL, Liu MY, et al. Eleven cases of heart- lung transplantation: a single centre experience. *Chinese Journal of Transplantation (Electronic Version)* 2019;13:284-7.
5. Toyoda Y, Toyoda Y. Heart-lung transplantation: adult indications and outcomes. *J Thorac Dis* 2014;6:1138-42.
6. Buckland M, Scarr B, Durkin C. Cardiopulmonary transplantation. *Anaesthesia and Intensive Care Medicine* 2018;19:546-51.
7. Durkin C, Buckland M. Cardiopulmonary transplantation: anaesthetic implications. *Anaesthesia and Intensive Care Medicine* 2015;16:7.
8. Organ Transplantation Branch of the Chinese Medical Association. Technical Specification for Combined Heart and Lung Transplantation in China (2019 edition). *Chinese Journal of Transplantation (Electronic Version)* 2020;14:129-35.
9. Yusen RD, Edwards LB, Kucheryavaya AY, et al. The registry of the International Society for Heart and Lung Transplantation: thirty-first adult lung and heart-lung transplant report--2014; focus theme: retransplantation. *J Heart Lung Transplant* 2014;33:1009-24.
10. Orens JB, Estenne M, Arcasoy S, et al. International guidelines for the selection of lung transplant candidates:

- 2006 update--a consensus report from the Pulmonary Scientific Council of the International Society for Heart and Lung Transplantation. *J Heart Lung Transplant* 2006;25:745-55.
11. Weill D, Benden C, Corris PA, et al. A consensus document for the selection of lung transplant candidates: 2014--an update from the Pulmonary Transplantation Council of the International Society for Heart and Lung Transplantation. *J Heart Lung Transplant* 2015;34:1-15.
 12. Christie JD, Edwards LB, Kucheryavaya AY, et al. The Registry of the International Society for Heart and Lung Transplantation: 29th adult lung and heart-lung transplant report--2012. *J Heart Lung Transplant* 2012;31:1073-86.
 13. Dawkins KD, Jamieson SW, Hunt SA, et al. Long-term results, hemodynamics, and complications after combined heart and lung transplantation. *Circulation* 1985;71:919-26.
 14. Stoica SC, McNeil KD, Perreas K, et al. Heart-lung transplantation for Eisenmenger syndrome: early and long-term results. *Ann Thorac Surg* 2001;72:1887-91.

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