Cadaver Surgical Training for Brain-Dead Donor Lung Procurement: Educational Note

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Disclosure Statement: The authors do not have any conflicts of interest

Funding statement: No funding was obtained for the conduct of this study

IRB/ERB number and date of approval: Institutional review board number and date of approval: 2017-0487; September 28th 2022.

Informed consent statement: Informed consent was waived because of the retrospective design of the study.

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This communication provides an educational video for training for donor lung procurement at cadaver training laboratory. This study is expected to facilitate the utilization of donor lung for transplantation.
Introduction

The paradigm for surgical training has changed from the traditional “mentorship through actual surgical operations” as on-the-job training to off-the-job training, involving simulation or cadaver surgical training (CST).\(^1\)

Better survival and quality of life outcomes for most patients with end-stage pulmonary disease are achieved with lung transplantation compared with conservative alternative treatments.\(^2\) The event of organ procurement from a brain-dead donor occurs suddenly in many cases, sometimes under harsh and unfamiliar circumstances. Lung procurement is always performed by surgeons who are younger and less experienced than lung transplant surgeons.\(^3\) However, improper donor lung procurement can make implantation difficult for the surgeon.\(^2\) Therefore, brain-dead donor lung procurement requires a certain amount of knowledge and training for the better or improved quality of life of subsequent lung transplant patients.

The young surgeons have improved their surgical skills by observing the senior surgeons’ techniques. Thereafter, the young surgeons perform surgical procedures including lung procurement without off-the-job training. This traditional model involves some risk to patients’ improvement or lung procurement and requires extensive supervision, although it remains an indispensable part of the training. New technologies and resources to expand and facilitate surgical training have become widely available recently.\(^4\) However, training opportunities for cadaveric donor organ procurement are limited, particularly in the human body. Conversely, methods of fixing donated cadavers have been evolving, and fixing cadavers in a special preservation solution is similar to fixing a living body that can be used for surgical training and is developing into an off-the-job training method.

CST has been performed for more appropriate organ procurement. This communication provides an update on our training for donor lung procurement using updated near-living
body fixation by Thiel methods.

Methods

CST was performed in the Clinical Anatomy Laboratory Nagoya (CALNA) at the Nagoya University Graduate School of Medicine. The cadaver chests were fixed in a Thiel solution containing formalin and propylene glycol (Thiel’s fixation solution, A.S. Chemical, Osaka, Japan). This research was performed in the clinical anatomy laboratory at the authors’ institution and was approved by the institution’s Ethics Committee (no. 2017-0487, September 28th 2022). Informed consent was waived because of the retrospective design of the study.

Lung procurement

Video file shows the training for the brain-dead donor lung procurement. Assessing several points that cannot be practiced during CST is essential in an actual organ procurement. However, these points should be verbally confirmed among the trainees before the procurement training. The arterial blood gas values and airway pressures (peak and mean) should be evaluated first. Thereafter, a bronchoscopy is performed to examine the airway for any damage, and the location, characteristics, and volume of the responsible bronchus are determined if sputum is present. Additionally, the chest radiographs and central venous pressure values are assessed. The training was initiated with a median sternotomy and was conducted in collaboration with cardiac surgeons. Once the training commences the cardiac surgeon proceeds to evaluate the heart following a pericardiotomy and a median sternotomy is performed. Subsequently, a mediastinal pleural incision is made, allowing the thoracic surgeon to evaluate the lungs. All participants must verbally confirm the procedure and evaluation components due to the limitations of CST. Firstly, a lung visual examination is
conducted to ensure the absence of evident atelectasis, pneumonia, or any significant congestion. Secondly, the chest cavity is manually palpated to assess for adhesions, pleural effusion, and dorsal extension of the lungs. The following aspects are collectively confirmed during the actual procedure depending upon the condition of the brain-dead donor: 1) the anesthesiologist will apply manual pressure to alleviate atelectasis if present and 2) the presence of any tumors will be examined while palpating the chest cavity. The cardiac surgeon inserts a catheter for cardiac plegia into the ascending aorta after evaluating the heart and lungs, while the thoracic surgeon inserts a pulmonary arterial cannula into the trunk of the pulmonary artery and prepares the pulmonary preservation fluid perfusion circuit. A systemic heparinization is performed in the actual procurement after the placement of the catheter or cannula, followed by the cannulation of the ascending aorta with cardioplegia and initiation of the pulmonary preservation fluid perfusion circuit. Prostaglandin E1 (PGE1) is administered before cross-clamping; however, during training, a saline solution or a similar substitute is used. These procedures need to be verbally reviewed with everyone involved after the insertion and placement of the catheter or cannula during the CST, as they are challenging to perform in practice. The inferior vena cava was encircled, and the superior vena cava and azygos vein were isolated and encircled. The ascending aorta and the main pulmonary artery were separated and encircled. A cardioplegia cannula was placed in the ascending aorta. Thereafter, a thoracic surgeon placed a perfusion cannula on the main pulmonary artery, securing it with a suture and tourniquet. The cannula was placed at the main pulmonary artery bifurcation. The cross-clamping steps were as follows: (1) saline solution assuming prostaglandin E was administered into the main pulmonary artery; (2) the superior vena cava was ligated and the inferior vena cava is clamped; (3) the inferior vena cava was transected above the clamp; (4) the aorta is cross-clamped and saline solution assuming cardioplegia solution was administered; (5) the tip of the left atrial was amputated;
thereafter, the lung flush was commenced. Afterwards, the heart was procured. The pericardium was incised from one side to the other near the diaphragm, the pulmonary ligaments were divided, and the ventral side of the esophagus was exposed. The ventral layer of the esophagus was dissected, and the tracheal bifurcation was identified. The mediastinal pleura was detached on both sides. The distal side of the aortic arch was cut on the left side, and the arch of the azygos vein was cut on the right side to expose the lateral wall of the trachea. The infraclavicular veins and arteries, as well as other surrounding tissues around the trachea, were cut. The final assessment criteria for the lungs were confirmed after the trachea was encircled. The trachea was doubly stapled using a stapling device and divided between the staple lines.

Discussion

Lung transplantation has been established as one of the essential treatment options for end-stage respiratory failures worldwide. It is an established technique that has essentially remained unchanged since the first successful lung transplantation in the 1950s. However, the procedure is more difficult to learn than most general surgical procedures, and it needs to be thoroughly learned and practiced to be proficiently executed. However, the clinical setting offers relatively few and largely nonschedulable opportunities to practice. CST offers the best compromise between learning on live patients in the operating room and on animals in the laboratory or inanimate simulators. CST was held 10 times at CALNA for brain-dead donor lung procurement in 4 years. Herein, we provide our training for donor lung procurement using updated near-living body fixation using Thiel methods.

Preservation is one of the most crucial factors to be considered regarding the use of human cadavers for surgical training. Kaliappan et al. summarized several preservation methods,
including fresh-frozen cadaver, formalin, Thiel, and saturated salt solution methods. The fresh-frozen cadavers provide a realistic model, but they do have challenges, such as the need for freezer storage, limited working time due to rapid putrefaction, and risk of infection.

Formalin is widely used due to its affordability and availability, but it is not ideal because of the adverse health effects of formaldehyde and lack of living organ qualities in the formalin-embalmed cadavers. The Thiel method produces soft and flexible cadavers with natural colors and has gained recognition in various medical disciplines. However, it is relatively expensive and technically complex. The cadaver Thiel embalming method, developed by Walter Thiel at Graz Medical University in Austria in the 1990s, was particularly devised to preserve the natural, fresh consistency, texture, volume, shape, color, and echogenicity of organs and tissues, enabling a dissension experience. Thiel embalming method provides multiyear durability and does not need cooling; just periodic cadaver immersion in a preserving solution allows their use in different surgical simulations, thereby optimizing costs. Vessels remain permeable because of osmotic hemolysis. Soft tissues are as flexible as the living body. It is an extremely useful fixation method for pulmonary procurement, except for tunneling under the pulsation of large vessels and perfusion cannulation of the main pulmonary artery. Eisma R et al. compared formalin and Thiel-embalmed cadavers in a senior trainee and consultant course on thyroid surgery. The trainees were asked to score various aspects for each cadaver type, including the tissue quality. Thiel-embalmed cadavers provided a more realistic model than formalin method for training thyroid surgical skills. Kennel et al. examined students’ attitudes toward dissection with Thiel-embalmed cadavers compared with formalin/ethanol-embalmed cadavers. Attitudes between the cohorts using Thiel-embalmed and formalin-embalmed cadavers demonstrated significant differences, indicating the advantageous learning experience offered by Thiel embalming in certain areas. Hayashi et al. reported about the efficacy of the saturated salt solution method for cadaver preservation.
They emphasized the simplicity, low infection risk, and relatively low cost of this method.
The authors concluded that the saturated salt solution method is highly useful for surgical training, thereby expanding the possibilities of clinical training. Its implementation will contribute to the broader utilization of cadavers in surgical training. In our study, we selected the Thiel method and saturated salt solution method due to their advantages of long-term preservation and resemblance to the living body characteristics. The Thiel method was used to preserve all the remains utilized in this report, and we have provided a detailed description of this method.

There are certain limitations in CST. Size matching is a crucial aspect in lung transplantation, as it involves aligning the size of the donor’s lung with recipient’s chest cavity. However, achieving this is not feasible during CST. Evaluating atelectasis and its release through ventilation or pressurization, performing bronchoscopy for expectoration, and evaluating expectorant culture in CST present challenges due to lung fixation using the Thiel method, which includes formalin in small amounts. Additionally, we have concerns about the potential health hazards for participants if ventilating lungs are fixed using the Thiel method and the associated cost implications of acquiring a ventilator. Moreover, the sputum in the airway may not be effectively released through bronchoscopy due to degeneration. We are aware that further research is necessary to address these challenges and enhance training methodologies.

The anatomy and procedures in lung procurement have been meticulously confirmed through our CST. We had in-depth discussions to confirm crucial points in the procurement, including the left atrial incision, by collaborating with the cardiac surgical team during the training. The CST at CALNA for lung procurement was extremely useful in learning the technique and procedure. This study is expected to facilitate the maximum utilization of
donor organs for cardiac and lung transplantation.
REFERENCES


VIDEO LEGENDS

Video file: Video file shows the training for the brain-dead donor lung procurement. The thoracic dissection was initiated after placing the pericardial stay sutures. The inferior vena cava was encircled, and the superior vena cava and azygos vein were isolated and encircled. The ascending aorta and the main pulmonary artery were separated and encircled. A cardioplegia cannula was placed in the ascending aorta. Thereafter, pulmonary perfusion cannulation was placed on the main pulmonary artery. After the cross-clamp, the procurement of the heart was performed. The pericardium was incised from one side to the other near the diaphragm, the pulmonary ligaments were divided, and the ventral side of the esophagus was exposed. The ventral layer of the esophagus was dissected, and the tracheal bifurcation was identified. The mediastinal pleura was detached on both sides. The distal side of the aortic arch was cut on the left side, and the arch of the azygos vein was cut on the right side to expose the lateral wall of the trachea. The infraclavicular veins and arteries, as well as other surrounding tissues around the trachea, were cut. After the final assessment for the lungs, the trachea was doubly stapled and divided between the staple lines.