Cadaver surgical training for brain-dead donor lung procurement: Educational note

Shota Nakamura, MD, PhD,[a] Harushi Ueno, MD,[a] Masato Mutsuga, MD, PhD,[b] and Toyofumi F. Chen-Yoshikawa, MD, PhD[a]

Video clip is available online.

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 to support better or improved quality of life of subsequent lung transplant recipients.

Young surgeons improve their surgical skills by observing 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.

This communication provides an educational video for training for donor lung procurement.

CENTRAL MESSAGE

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

PERSPECTIVE

We provided cadaver surgical training for donor lung procurement using updated near-living body fixation. We had discussions to confirm crucial points in the procurement by collaborating with the cardiac surgeons during the training. The cadaver surgical training 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 pulmonary transplantation.

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. Fixing cadavers in a special preservation solution is similar to fixing a living body that can be used for surgical training, and this is developing into an off-the-job training method.

CST has been performed for more appropriate organ procurement. This report provides an update on our training

From the Departments of [a]Thoracic Surgery and [b]Cardiac Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan.

Disclosures: The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

Received for publication May 9, 2023; revisions received July 17, 2023; accepted for publication July 26, 2023; available ahead of print Aug 11, 2023.

Address for reprints: Shota Nakamura, MD, PhD, Department of Thoracic Surgery, Nagoya University Graduate School of Medicine, 65 Tsurumai-cho, Showa-ku, Nagoya 466-8550, Japan (E-mail: shota197065@med.nagoya-u.ac.jp).

JTCVS Techniques 2023;21:261-4

2666-2507

https://doi.org/10.1016/j.xjtc.2023.07.026

program for donor lung procurement using updated near-living body fixation by the Thiel method.

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 fixation solution; A.S. Chemical Co, Ltd, Osaka, Japan). This research was performed at CALNA and was approved by the Nagoya University Ethics Committee (approval 2017-0487; September 28, 2022). The need for informed consent was waived because of the study's retrospective design.

LUNG PROCUREMENT

Video 1 shows the training program for brain-dead donor lung procurement. Assessing several points that cannot be practiced during CST is essential in actual organ procurement; however, these points should be verbally confirmed among the trainees before the procurement training. Arterial blood gas values and airway pressures (peak and mean) should be evaluated first. Then 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, chest radiographs and central venous pressure values are assessed.

The training is initiated with a median sternotomy and conducted in collaboration with a cardiac surgeon. 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 componenets of the procedure and evaluation due to the limitations of CST. First, a lung visual examination is conducted to ensure the absence of evident atelectasis, pneumonia, or any significant congestion. Second, the chest cavity is manually palpated to assess for adhesions, pleural effusion, and dorsal extension of the lungs.

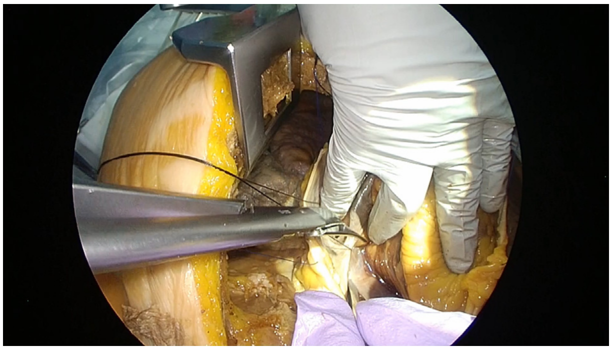
The following actions are collectively confirmed during the actual procedure depending upon the condition of the brain-dead donor: (1) the anesthesiologist will apply manual pressure to alleviate atelectasis if present, and (2) the presence of any tumors will be examined while palpating the chest cavity.

The cardiac surgeon inserts a catheter for cardioplegia 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. Systemic heparinization is provided during the actual procurement after placement of the catheter or cannula, followed by cannulation of the ascending aorta with cardioplegia and initiation of the pulmonary preservation fluid perfusion circuit. Prostaglandin E1 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 CST, as they are challenging to perform in practice. The inferior vena cava is encircled, the superior vena cava and azygos vein are isolated and encircled, and the ascending aorta and main pulmonary artery are separated and encircled. A cardioplegia cannula is placed in the ascending aorta, and then a perfusion cannula is placed on the main pulmonary artery at the main pulmonary artery bifurcation and secured with a suture and tourniquet.

The steps of cross-clamping are as follows: (1) saline solution assuming prostaglandin E is administered into the main pulmonary artery; (2) the superior vena cava is ligated and the inferior vena cava is clamped; (3) the inferior vena cava is transected above the clamp; (4) the aorta is cross-clamped, and in cadaver surgical training, it is not possible to administer a real cardioplegia solution, so saline solution is administered to train the patient to look like cardioplegia; and (5) the tip of the left atrium is amputated, and the lung flush is started.

After these steps, the heart is procured. The pericardium is incised from one side to the other near the diaphragm, the pulmonary ligaments are divided, and the ventral side of the esophagus is exposed. The ventral layer of the esophagus is



VIDEO 1. Training for brain-dead donor lung procurement. Thoracic dissection is initiated after placement of the pericardial stay sutures. The inferior vena cava is encircled, the superior vena cava and azygos vein are isolated and encircled, and the ascending aorta and the main pulmonary artery are separated and encircled. A cardioplegia cannula is placed in the ascending aorta, and pulmonary perfusion cannulation is placed on the main pulmonary artery. After the cross-clamping, the heart is procured. The pericardium is incised from one side to the other near the diaphragm, the pulmonary ligaments are divided, and the ventral side of the esophagus is exposed. The ventral layer of the esophagus is dissected, and the tracheal bifurcation is identified. The mediastinal pleura is detached on both sides. The distal side of the aortic arch is cut on the left side, and the arch of the azygous vein is 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, are cut. After the final assessment of the lungs, the trachea is doubly stapled and divided between the staple lines. Video available at: https://www.jtcvs.org/article/S2666-2507(23)00274-2/fulltext.

dissected, and the tracheal bifurcation is identified, and the mediastinal pleura is detached on both sides. The distal side of the aortic arch is cut on the left side, and the arch of the azygous vein is 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, are cut.

The final assessment criteria for the lungs are confirmed once the trachea is encircled. The trachea is doubly stapled using a stapling device and divided between the staple lines.

DISCUSSION

Lung transplantation has been established as an essential treatment options for end-stage respiratory failure worldwide.[2,5] The established technique has remained essentially unchanged since the first successful lung transplantation in the 1950s[6]; however, the procedure is more difficult to learn than most general surgical procedures, and it needs to be thoroughly understood and well practiced to be executed proficiently. The clinical setting offers relatively few and largely nonschedulable opportunities to practice, however. CST offers the best compromise between learning on live patients in the operating room and on animals in the laboratory or inanimate simulators. Ten CST programs for brain-dead donor lung procurement have been held 10 in 4 years at CALNA. Herein we describe our training program for donor lung procurement using updated near-living body fixation using the Thiel method.

Preservation is one of the most crucial factors to consider when using human cadavers for surgical training. Kaliappan and colleagues[7] summarized several preservation methods, including fresh-frozen cadaver, formalin, Thiel, and saturated salt solution methods. Fresh-frozen cadavers provide a realistic model but present challenges, such as the need for freezer storage, limited working time due to rapid putrefaction, and risk of infection. Formalin is widely used because of its affordability and availability, but it is not ideal because of the adverse health effects of formaldehyde and lack of living organ qualities in 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 specifically devised to preserve the natural fresh consistency, texture, volume, shape, color, and echogenicity of organs and tissues, enabling a dissension experience. The 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, and soft tissues are as flexible as in a 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 and colleagues[8] 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 tissue quality. The Thiel-embalmed cadavers provided a more realistic model than formalin method for training in thyroid surgical skills. Kennel and colleagues[9] examined students' attitudes toward dissection with Thiel-embalmed cadavers compared with formalin/ethanol-embalmed cadavers and found significant differences between the 2 methods, indicating the advantageous learning experience offered by Thiel embalming in certain areas. Hayashi and colleagues[10] reported on the efficacy of the saturated salt solution method for cadaver preservation, emphasizing the simplicity, low infection risk, and relative low cost of this method. They 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 because of their advantages of long-term preservation and resemblance to living body characteristics. The Thiel method was used to preserve all the remains used in this study.

CST has certain limitations. 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. We also 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, sputum in the airway might not be effectively released through bronchoscopy due to degeneration. We are aware that further research is needed to address these challenges and enhance training methodologies.

The anatomy and procedures of lung procurement have been meticulously confirmed through our CST. We have had many in-depth discussions with the cardiac surgical team during the training to confirm crucial points in the procurement process, including the left atrial incision. 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 heart and lung transplantation.

References

1. Pieris D. Dissecting the dissection experience: Whither the need for humanising the cadaver. *Med Educ*. 2023;57:300-2. https://doi.org/10.1111/medu.15006
2. Chambers DC, Perch M, Zuckermann A, Cherikh WS, Harhay MO, Hayes D Jr, et al. The international thoracic organ transplant registry of the international society for heart and lung transplantation: thirty-eighth adult lung transplantation report–2021; Focus on recipient characteristics. *J Heart Lung Transplant*. 2021;40:1060-72. https://doi.org/10.1016/j.healun.2021.07.021
3. Smail H, Saxena P, Wallinder A, Lin E, Snell GI, Hobson J, et al. Donor lung procurement by surgical fellow with an expectation of high rate of lung utilisation. *Heart Lung Circ*. 2018;27:961-6. https://doi.org/10.1016/j.hlc.2017.12.007
4. Healy SE, Rai BP, Biyani CS, Eisma R, Soames RW, Nabi G. Thiel embalming method for cadaver preservation: a review of new training model for urologic skills training. *Urology*. 2015;85:499-504. https://doi.org/10.1016/j.urology.2014.11.009
5. Chen-Yoshikawa TF, Fukui T, Nakamura S, Ito T, Kadomatsu Y, Tsubouchi H, et al. Current trends in thoracic surgery. *Nagoya J Med Sci*. 2020;82:161-74. https://doi.org/10.18999/nagjms.82.2.161
6. Sundaresan S, Trachiotis GD, Aoe M, Patterson GA, Cooper JD. Donor lung procurement: assessment and operative technique. *Ann Thorac Surg*. 1993;56:1409-13. https://doi.org/10.1016/0003-4975(93)90699-i
7. Kaliappan A, Motwani R, Gupta T, Chandrupatla M. Innovative cadaver preservation techniques: a systematic review. *Maedica (Bucur)*. 2023;18:127-35. https://doi.org/10.26574/maedica.2023.18.1.127
8. Eisma R, Mahendran S, Majumdar S, Smith D, Soames RW. A comparison of Thiel and formalin embalmed cadavers for thyroid surgery training. *Surgeon*. 2011;9:142-6. https://doi.org/10.1016/j.surge.2010.09.001
9. Kennel L, Martin DMA, Shaw H, Wilkinson T. Learning anatomy through Thiel- versus formalin-embalmed cadavers: student perceptions of embalming methods and effect on functional anatomy knowledge. *Anat Sci Educ*. 2018;11:166-74. https://doi.org/10.1002/ase.1715
10. Hayashi S, Naito M, Kawata S, Qu N, Hatayama N, Hirai S, et al. History and future of human cadaver preservation for surgical training: from formalin to saturated salt solution method. *Anat Sci Int*. 2016;91:1-7. https://doi.org/10.1007/s12565-015-0299-5