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Reconstructive

Thoracic Duct Lymphovenous Bypass: A Preliminary Case Series, Surgical Techniques, and Expected Physiologic Outcomes

Yoshiko Toyoda, MD*
Cody Fowler, MD*
Daniel M. Mazzaferro, MD, MBA*
J. Reed McGraw, BS*
Sammy Othman, MD†
Said C. Azoury, MD*‡
Maxim Itkin, MD§
Stephen J. Kovach III, MD*

Background: In patients with recalcitrant mechanical thoracic duct obstruction, microsurgical lymphovenous bypass is an emerging therapeutic option. We herein discuss the preoperative workup, share our current operative technique, and evaluate preliminary outcomes with an emphasis on changes in physiology.

Methods: A retrospective review of adult patients who underwent thoracic duct lymphovenous bypass by a single surgeon and interventional radiologist from 2019 to 2022 was performed. Demographics, comorbidities, perioperative data, and postoperative outcomes were collected.

Results: Nine patients were included in the study. Immediate postoperative heart rate increased significantly among this heterogeneous patient population, but within 4–6 hours the change in heart rate was no longer significant. Mean arterial pressure and oxygen requirement were not significantly different before and after bypass.

Conclusions: Thoracic duct lymphovenous bypass seem to be well tolerated in the short-term even in patients with cardiopulmonary comorbidities. Further data are necessary to continue to better understand the resulting physiologic changes and to optimize patient outcomes. *(Plast Reconstr Surg Glob Open 2022; 10:e4695; doi: 10.1097/GOX.0000000000004695; Published online 12 December 2022.)*

INTRODUCTION

The lymphatic system holds several vital physiologic functions, including extracellular fluid homeostasis, lipid absorption from the gastrointestinal system, and immune trafficking. As such, lymphatic obstruction can disrupt these processes and has numerous negative consequences.[1,2] The volume of lymphatic flow is not insignificant. An estimated 1% of the intravascular fluid moves into the interstitial space with each cardiac cycle. The thoracic duct is the main conduit of lymph and typically empties into the venous system at the junction of the internal jugular and subclavian veins.[1,3] The thoracic duct may become obstructed due to trauma, iatrogenic disruption (ie, central line, lymphatic dissection), malignancy, and congenital conditions, among others.[4] Thoracic duct obstruction can lead to chyle buildup in various cavities, resulting in lymphedema, chylothorax, and chylous ascites. For patients with these conditions, first-line therapy is often conservative (ie, diet changes, oral medications) followed by minimally invasive procedures (ie, angioplasty, ligation, embolization).[5–7]

When these traditional therapies fail, we have previously demonstrated that microsurgical lymphovenous bypass is an efficacious option for mitigating lymphatic obstruction.[8–10] Although we have had successes, there is very little known about the long-term outcomes of lymphovenous bypass, and these early cases should be critically assessed. In particular, given the significant volume of lymph, which is returned to the circulation with effective bypass, there is a theoretical concern of increased preload, resulting in physiologic changes that may have adverse effects on patients with cardiopulmonary

*From the *Division of Plastic and Reconstructive Surgery, University of Pennsylvania, Philadelphia, Pa.; †Department of Plastic and Reconstructive Surgery, Northwell Health, New Hyde Park, N.Y.; ‡Division of Plastic and Reconstructive Surgery, Memorial Sloan Kettering Cancer Center, New York, N.Y.; and §Section of Interventional Radiology, Department of Radiology, University of Pennsylvania, Philadelphia, Pa.*

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comorbidities. We herein present our case series to discuss key aspects of their preoperative workup, describe our current operative technique, and evaluate preliminary outcomes with an emphasis on changes in physiology.

Takeaways

Question: Does thoracic duct lymphovenous bypass (TDLB) cause physiological changes in the acute postoperative setting?

Findings: TDLB briefly increases heart rate postoperatively, but otherwise has nonsignificant effects on cardiopulmonary physiology.

Meaning: TDLB does not seem to have detrimental effects on cardiopulmonary physiology even in comorbid patients.

METHODS

This study was approved by the University of Pennsylvania institutional review board (protocol #849429). A retrospective review of all nonsyndromic adult patients who underwent thoracic duct lymphovenous bypass by the senior author (SJK) from 2019 to 2022 was performed. Of note, all patients had evidence of thoracic duct obstruction on imaging (ie, lymphangiography) at the level of the neck above the clavicle and were referred from interventional radiology (MI) after prior interventions failed. Demographics, comorbidities, perioperative data, and postoperative outcomes were collected.

Operative Technique

The patient is placed under general anesthesia with an oral endotracheal tube and laid supine in a hybrid operating suite (surgical operating table equipped with fluoroscopic abilities) with their head tilted to expose their left neck and decollete. Key anatomic landmarks are marked including the clavicle and the sternocleidomastoid (SCM) muscle. The clavicle is the inferior border of the open surgical field that can be safely accessed by the microsurgeon. The abdomen and bilateral groins are exposed and prepared in a sterile fashion.

The operation begins with identification of the thoracic duct by the interventional radiologist. Contrast is injected via bilateral groins (Fig. 1A). Once the cisterna chyli is identified on fluoroscopy, it is catheterized transcutaneously through the abdomen for direct access to the thoracic duct for real-time operative visualization via lymphangiography later in the case. Final confirmation of thoracic duct obstruction is performed before making the neck incision (Fig. 1B).

A transverse incision is made from the anterior border of the SCM and through the platysma. The SCM is either retracted or transected to visualize and expose the carotid sheath and internal jugular vein deep to SCM. The carotid sheath is entered, and the internal jugular vein is identified and followed inferiorly. Nearby venous candidates for bypass, most commonly the external jugular but sometimes also the anterior jugular, are identified and tagged. The thoracic duct, which may not be identifiable by the naked eye, can be visualized with isosulfan blue injection via the transabdominal catheter. If the location of the thoracic duct remains unclear, then the combination of catheter-directed lymphangiography, fluoroscopy, and placement of a metal surgical instrument (ie, DeBakey forceps or hemostat) for relative positioning may be used to localize the exact site of obstruction in a three-dimensional field (Fig. 1C). Once identified, the thoracic duct is cut proximal to the obstruction, which should result in egress of milky blue chyle. The size of the thoracic duct is estimated. If an appropriately sized donor vein is in the vicinity,

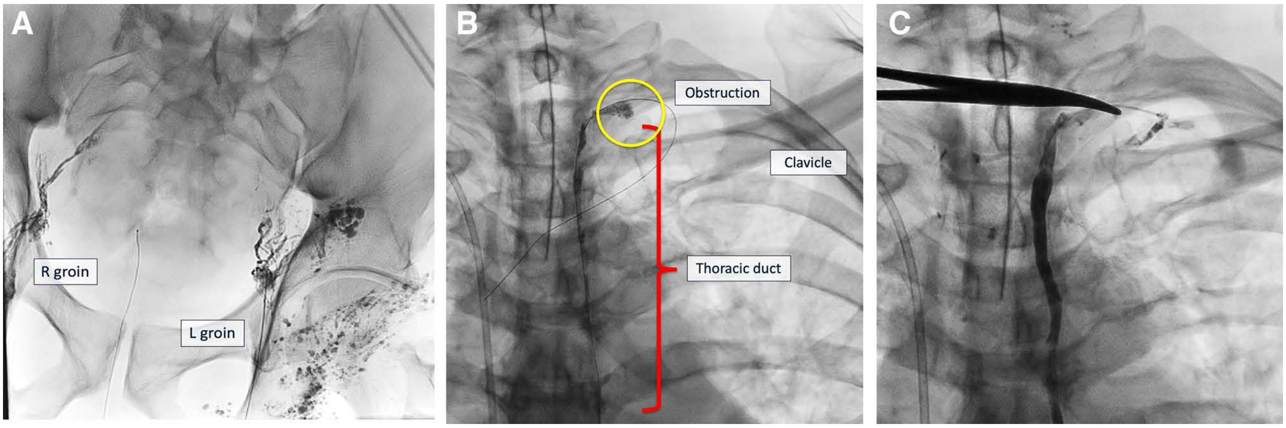


Fig. 1. Intraoperative lymphangiography confirms thoracic duct obstruction. A, Contrast is initially injected from bilateral groins and followed until they converge at the cisterna chyli. B, Thoracic duct obstruction is confirmed before making incision. The obstruction (yellow circle) is visible with cessation of contrast flow, where the thoracic duct is expected to converge into the venous system. Of note, the site is superior to the clavicle, where the microsurgeon can safely access with open surgery. C, To identify the thoracic duct within the surgical site, catheter-directed lymphangiography, fluoroscopy, and relative positioning of the obstruction was identified with a surgical instrument.

the thoracic duct and the vein can be anastomosed end-to-end with typical microsurgical venous couplers (range: 2.0–4.0 mm; GEM Microvascular Anastomotic COUPLER, TSG Medical, St. Catharines, Ontario, Canada) under loupe magnification (Fig. 2). If, due to anatomical variation or due to extensive scarring, a suitable vein is not readily present, a saphenous vein graft can be acquired and drained into the internal jugular vein via an end-to-side anastomosis. Once the microsurgery is complete, the interventional radiologist is again called back to the suite to confirm contrast flow through the anastomosis (Fig. 3). The SCM is reapproximated with sutures if it was transected at the initial exposure, the neck is closed in layers over a drain, and the patient is admitted overnight for observation.

Data Acquisition

The patients' heart rate, blood pressure, and oxygen requirement in the preoperative holding area on the day of surgery were recorded as the patients' baseline. All postoperative data were compared with these values. The first set of vitals in the postanesthesia care unit was recorded as the immediate vital signs. All vital signs thereafter were recorded until time of discharge.

Statistical Analysis

Paired *t* tests were performed to compare pre- and postoperative heart rate, mean arterial pressure, and oxygen requirement using Prism 9 GraphPad (GraphPad Software, San Diego, CA). Tests were two-sided, and a value of P less than 0.05 was considered significant. All other results were descriptive in nature.

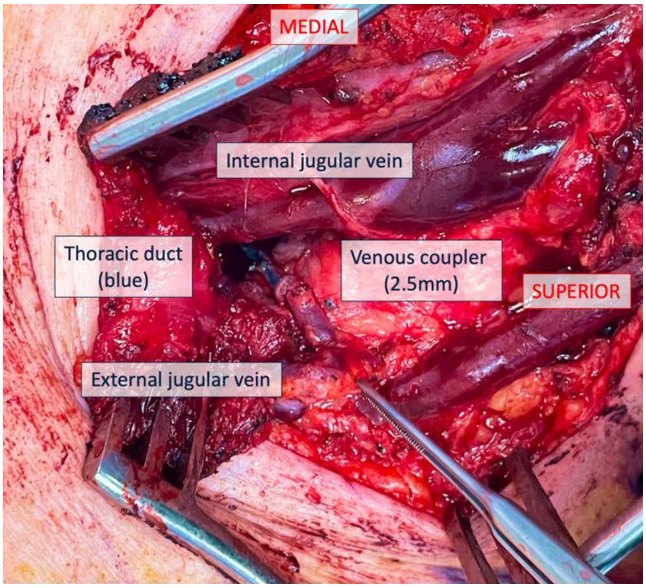


Fig. 2. The surgical field. The internal jugular vein is followed to the junction with the subclavian where the thoracic duct is typically found. The external jugular vein was identified and was appropriately sized for end-to-end anastomosis with the thoracic duct using a 2.5-mm microsurgical venous coupler.

Fig. 3. After anastomosis, lymphangiography is performed to confirm patency. Contrast is seen upon emptying from the thoracic duct into the venous system.

Table 1. Patient Demographics

Characteristic	
Women (%)	4 (44%)
Age (y)	
Mean	46.8
Range	23–66
BMI (kg/m^2)	
Mean	28.9
Range	19.3–42.4
Comorbidities	Diabetes
	HLD
	HTN
	DVT/PE
	Pulmonary hypertension
	Lung adenocarcinoma + XRT
	Liver transplantation
	Thyroid disorder

BMI, body mass index; HLD, hyperlipidemia; HTN, hypertension; DVT/PE, deep vein thrombosis/pulmonary embolism; XRT, radiation therapy.

RESULTS

The study sample consisted of nine patients (four women, five men). Mean age was 46.8 years (range: 23–66 years). Mean body mass index was 28.9 kg/m^2 (range: 19.3–42.4 kg/m^2). Comorbidities included thyroid disorder, diabetes, hyperlipidemia, hypertension, deep vein thrombosis/pulmonary embolism, pulmonary hypertension, hip replacement, liver transplantation, and metastatic lung adenocarcinoma treated with radiation (Table 1). The presenting pathology included chylous ascites, chylothorax, lower extremity edema, generalized edema, and malnutrition. Prior interventions included medical therapies such as diet change as extreme as total parenteral nutrition, compression, diuresis, octreotide, and sirolimus. As all of these patients were referred by our interventional radiology colleagues, all had prior procedural therapies, including paracentesis, thoracentesis, lymphangiogram, embolization, angioplasty, and surgical resection (Table 2).

Immediate postoperative basic physiologic changes were recorded for all seven patients. Heart rate increased significantly in the immediate postoperative period with a mean of differences of 11.9 ($P = 0.0042$). However, this difference decreased to 6.7 by 4–6 hours postoperatively and was no longer statistically significant ($P = 0.2656$). Mean arterial pressure increased with a mean of differences of 2.5, which did not reach statistical significance ($P = 0.6409$) (Fig. 4). All patients required a low amount of oxygen postoperatively (maximum of 3L on nasal cannula by one patient), but seven of nine returned to their baseline requirement in less than 12 hours. One patient was readmitted on postoperative day 7 with symptoms of shortness of breath and fatigue, and was noted to have grade 2 diastolic dysfunction on transthoracic echocardiogram and workup otherwise negative. However, he did not have a preoperative baseline transthoracic echocardiogram for comparison. He was restarted on his home hypertensive and diuretic medications and was discharged the following day with improvement in symptoms with follow-up with his primary care physician.

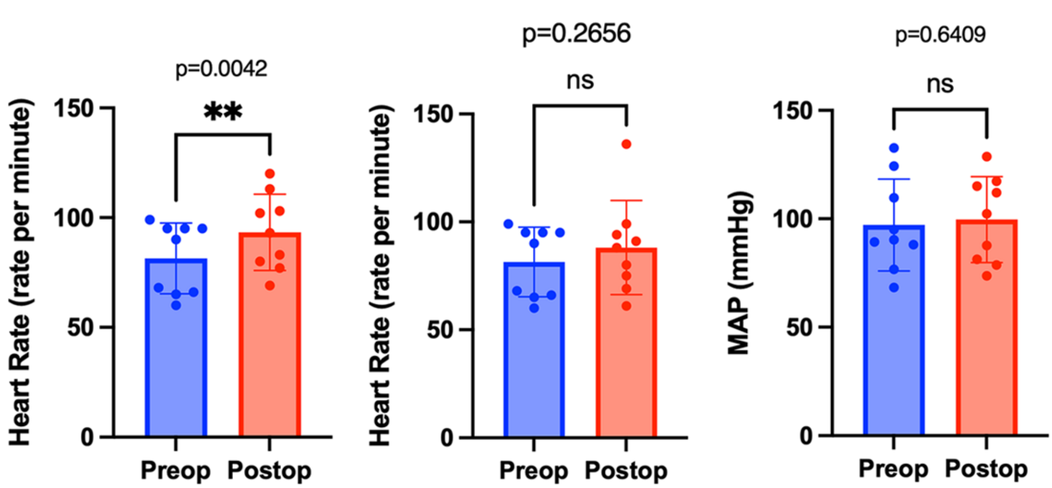
Table 2. Prior Interventions

Medical Therapies		Procedural Therapies	
Total parenteral nutrition	2	Paracentesis	4
Compression	1	Thoracentesis	2
Diuresis	1	Lymphangiogram	5
Octreotide	1	Embolization	2
Sirolimus	1	Angioplasty	4
		Surgical resection	1

DISCUSSION

Thoracic duct obstruction is a highly morbid pathology that may be challenging to manage. When traditional medical treatment and minimally invasive techniques fail, these patients are often left with only palliative options such as frequent large volume paracentesis in cases of chylous ascites or long-term chest tubes for those with chylothoraces. These options inevitably lead to infectious complications and poor quality of life. In the spirit of problem-solving and multidisciplinary collaboration (fundamental features of plastic and reconstructive surgery), the senior author developed a consistently reliable microsurgical treatment for these recalcitrant cases. Microsurgical thoracic duct lymphovenous bypass is indicated in patients with mechanical thoracic duct obstruction at the level of the neck above the clavicle on imaging whose conservative medical and procedural therapies have failed.[8,9,11] In such cases, microsurgery may alleviate symptoms or completely cure them. In collaboration with our interventional radiology colleagues and utilizing our management algorithm, we presented the largest series of thoracic duct lymphovenous bypass to date.

Open, detailed discussion of surgical techniques and honest self-critique of outcomes are key with emerging surgical treatments. Although we work to solve difficult problems in creative ways, it is critical to ensure there is no harm done to the patient in our endeavors. In communicating with covering providers and nursing staff, it is also



	Heart rate (immediate)	Heart rate (4-6hours)	MAP
Preop (avg)	81.4	81.4	97.1
Postop (avg)	93.3	88.1	99.6
Mean of differences	11.89	6.67	2.489
P-value	0.0042	0.2656	0.6409

Fig. 4. Postoperative physiologic changes. Heart rate (immediate and 4–6 hours postoperatively) and mean arterial pressure (MAP) changes pre- and postthoracic duct lymphovenous bypass.

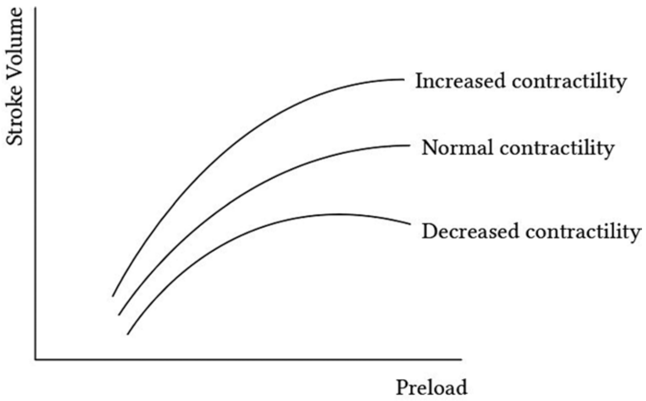


Fig. 5. Frank-Starling curve.

important to be aware of general expected outcomes after the surgery, especially as they relate to hemodynamics.

Given the theoretical concern that lymphovenous bypass could result in fluid overload, we examined physiologic changes as a result of thoracic duct lymphovenous bypass. Depending on where along the Frank-Starling curve the patient's cardiac physiology lies, should there be an increase in preload, the stroke volume may increase (normal baseline cardiac function) or decrease (decreased baseline cardiac function) (Fig. 5). Assuming patients were euvolemic before the procedure, an increase in preload would not be expected to significantly decrease their heart rate. Rather, with the total increase in cardiac output (with the addition of previously obstructed lymphatic volume), the heart rate may remain relatively stable for those with normal cardiac function, but may increase in those farther along the Frank-Starling curve who are unable to increase stroke volume effectively. In these patients, persistent tachycardia is not a favorable postoperative outcome due to the risk of heart failure, and they should be monitored closely. In such patients, respiratory distress with increasing oxygen requirement would be a red flag indicative of cardiogenic pulmonary edema. With regard to blood pressure, assuming stable systemic venous resistance pre- and postoperatively, with the increase in stroke volume, it is conceivable that patients may develop higher systolic blood pressures.[10]

In this study, given our small patient cohort, we analyzed them en bloc, and they ranged significantly in age, severity and quality of symptoms, and comorbidities. Although there was a temporary significant increase in heart rate after the bypass compared with preoperative values, by 4–6 hours postoperatively, the difference was not statistically significant. Some patients required a low level of supplemental oxygen (the maximum was 3L of nasal cannula), but these were all weaned to preoperative levels within a few hours. Mean arterial pressures also increased postoperatively, but not significantly. These findings suggest that in patients with similar cardiopulmonary function as our patients preoperatively, thoracic duct lymphovenous bypass is safe from a physiological standpoint despite the theoretical increase in preload. In patients with significant cardiopulmonary comorbidities such as known heart failure or severe pulmonary hypertension, preoperative echocardiograms and other risk stratification tests may be prudent.

Our study is not without limitations. Firstly, when studying the increase in preload from lymphatic return, the outflow from the new anastomosis must be considered. Depending on the patient's anatomy, couplers of sizes ranging from 2.0 to 4.0 mm were used, resulting in up to a 16 times difference in outflow based on Pouiseuille's law. Secondly, in addition to the theorized increase in preload from lymphatic return, there are numerous perioperative effects on changes in vital signs, most notably pain, anesthesia/medication effects, extent of volume resuscitation, and patient comorbidities. These confounders were unable to be thoroughly assessed in our small case series. Thoracic duct mechanical obstruction is treated by medical and minimally invasive techniques first, and only recalcitrant cases are referred to the microsurgeon, reducing case volume. Furthermore, given the relatively new surgical technique and collaboration, there is more work to be done to develop the infrastructure in our health system. We are in the process of building a center for multidisciplinary care for these patients. Finally, heart rate, oxygen requirement, and mean arterial pressures are easily acquirable, but composite measurements that are affected by numerous autoregulation loops (ie, volume management, catecholamine responses).[10] In the search for more quantitative and less dependent surrogates for preload, we are currently working with cardiac anesthesia collaborators to use Doppler ultrasound technology to better understand the effects of return of lymphatic fluid to the circulatory system.

CONCLUSIONS

Lymphatic obstruction can be a highly morbid problem, and in the appropriate patient population, microsurgeons have a role in the multidisciplinary treatment of thoracic duct outlet obstruction via lymphovenous bypass. We have demonstrated that our surgical techniques do not seem to have detrimental effects on cardiopulmonary physiology even in comorbid patients. Continued clinical investigation with greater patient numbers and longer follow-up are needed to continue to optimize care for this difficult patient population.

Stephen J Kovach III, MD
3400 Civic Center Boulevard
Philadelphia, PA 19104
E-mail: stephen.kovach@pennmedicine.upenn.edu

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