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Case Report

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Robotically-harvested, thoracoscopically-tunneled transdiaphragmatic omental pedicle flap for obliteration of radiated empyema cavity

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Abstract
Intra-thoracic defects continue to pose a challenge for the reconstructive surgeon. Stable soft tissue coverage and obliteration of dead space can be particularly challenging when complicated by infection or previous radiation. These cases may require a less conventional method of reconstruction. We describe a case in which vacuum-assisted closure followed by pedicled omental flap transposition was successfully used to reconstruct a complicated intra-thoracic wound following pneumonectomy, radiation therapy, and recurrent wound dehiscences secondary to chronic infection.

Keywords: Greater omental flap, pneumonectomy, radiation, empyema, thoracic defect, robotic reconstructive surgery

INTRODUCTION
Intra-thoracic defects are usually left to heal after pneumonectomy without attempting obliteration of the dead space. The space is left full of air, after which a pleural effusion gradually accumulates and the volume decreases due to shifts in the mediastinum and hemidiaphragm. A fixed, serous-filled cavity is the ultimate result under ideal conditions.

In complicated pneumonectomy wounds, the chest wall rigidity and large potential space pose a serious problem[1]. Traditional methods including Clagett[2] and Eloesser[3] procedures combine partial dead space obliteration with exteriorization of the pleural space. Adjuvant radiation therapy complicates healing after these procedures by reducing the tissue's capability to repair the open wound. Reconstructive plans for these wounds must include (A) encouraging the collapse of the pneumonectomy space; and (B) provision of tissue to both obliterate dead space and create an environment that facilitates healing and closure. Traditional methods involve the intra-thoracic transplantation of various extra-thoracic muscle flaps to control dead space[1,4-6].

When prior surgery, radiation therapy, malnutrition, and infection preempt the use of traditional reconstructive options, the wound environment should be manipulated using ideal tissue options in the least invasive manner possible. We present a case of chronically infected and previously radiated post-pneumonectomy defect that was managed with negative pressure wound therapy to reduce the volume, followed by a robotically and thoracoscopically assisted, trans-diaphragmatically-tunneled omental flap to modify the wound biology and create an ideal environment for wound healing.

CASE REPORT

A 74-year-old male presented with an open wound of the left posterior thorax. His past medical history was significant for stage IIIa non-small cell lung cancer treated 22 years previously with left pneumonectomy, resection of ribs 2-4, methyl methacrylate thoracoplasty, and adjuvant chemoradiation. His postoperative course was marked by recurrent chest wall hematomas, deep space thoracic infections, and surgical site dehiscence. As a result, the patient was routinely subject to suppressive antibiotic therapy and serial debridement. A latissimus flap had been rotated under the scapula four months previously to cover the superficial wound, but a large empyema cavity remained under it. His albumin was 2.8 g/dL with a body mass index of 21.6 kg/m^2.

On exam, there was a 1.5 × 8 cm open, radiated wound medial to the left scapula, which tracked directly to the acrylic reconstruction plate [Figure 1A]. Computed tomography demonstrated a 10.7 × 2.4 × 17 cm void in the left hemithorax with a loculated empyema [Figure 1B-D]. Due to the chronic infection and multiple prior operations, there was a paucity of local recipient vessels for free tissue transfer, and the available vessels were situated in the radiation field.

To achieve permanent resolution of the wound, a staged approach was initiated to fundamentally modify the wound biology and configuration. The methyl methacrylate plate was removed, and the empyema cavity was radically debrided. Negative pressure wound therapy and serial debridement were used over a three-week time frame to sterilize the cavity and collapse the left hemithoracic volume. Aggressive nutritional supplementation raised his albumin to 3.2 g/dL.

Once the defect volume was adequately reduced and the infection controlled [Figure 2A-C], on hospital day 29, the patient underwent definitive reconstruction of the residual intra-thoracic defect using a pedicled greater omental flap. To decrease morbidity in this frail patient, the omentum was harvested robotically using the Davinci Xi system (Intuitive Surgical, Sunnyvale, CA) and transposed into the pleural space thoracoscopically.

The patient was placed in the supine position during omental mobilization to provide the uncompromised exposure necessary for precise and complete mobilization of the entire omentum without any vascular compromise. Supine positioning combined with bed tilt movement allowed excellent visualization of all

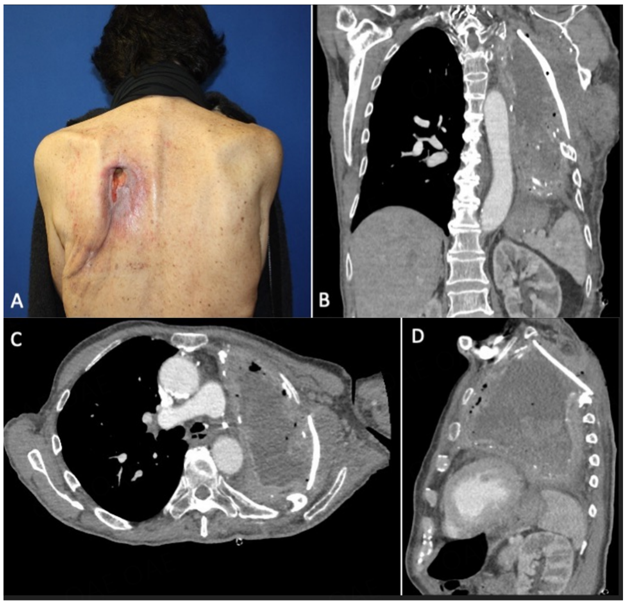

Figure 1. (A) Pre-operative left posterior thorax wound; (B-D) Coronal, axial, and sagittal sections of pre-operative CT chest demonstrating intra-thoracic defect.

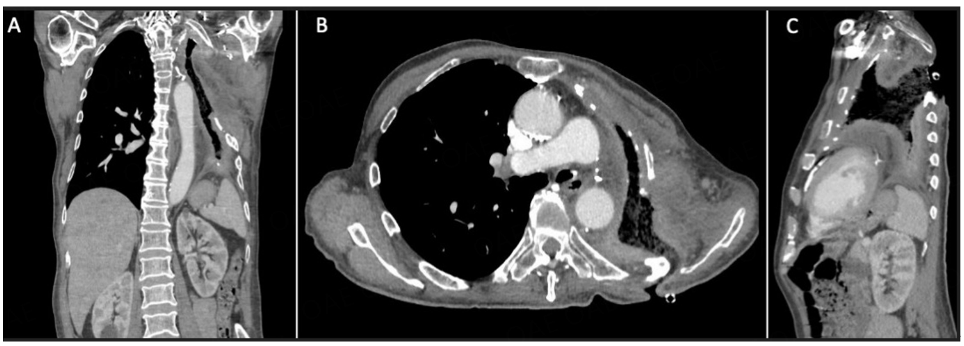

Figure 2. (A-C) Coronal, axial, and sagittal sections of CT chest imaging demonstrating decreased volume of intra-thoracic defect following radical debridement and vacuum-assisted closure.

structures involved. The robotic platform further allowed the integrated use of indocyanine green (ICG) fluorescence imaging to confirm perfusion, without loss of efficiency in comparison with conventional laparoscopy. The ports were placed in standard foregut position, with fenestrated bipolar, 30-degree camera, vessel sealer, and tip-up in arms 1 through 4, respectively. The right gastroepiploic pedicle was selected for its ability to perfuse a greater portion of the omental tissue [Figure 3A]. Once the omental harvest was completed, the patient was repositioned in the lazy right lateral decubitus position for diaphragmatic opening creation and flap inset. Adequate flap perfusion was confirmed using ICG imaging [Figure 3B]. Simultaneous thoracoscopy allowed visualization of mediastinal contours and creation of a 2 × 4 cm lateral diaphragmatic defect to the left of the heart without damage to critical structures [Figure 3C]. The omental flap was tunneled trans-diaphragmatically into the chest [Figure 3D]. The flap was then inset anteriorly, posteriorly, and apically so that it fully lined the thoracic cavity. The diaphragmatic defect was carefully re-approximated to prevent herniation of abdominal contents without compromising flap perfusion [Figure 3E]. The overlying soft tissue was closed in four layers over drains. The procedure lasted a total of 7 h and 25 mins.

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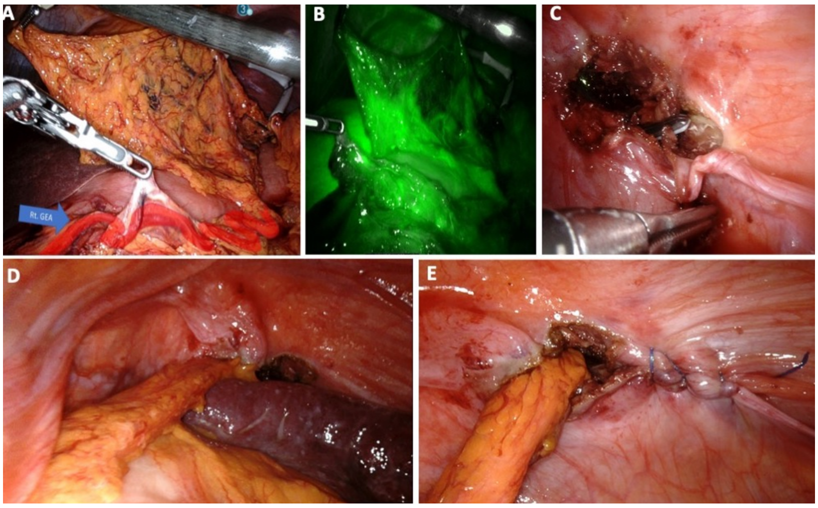

Figure 3. (A) Greater omental flap being harvested on the right gastroepiploic vascular pedicle (arrow); (B) Indocyanine green confirmation of adequate flap perfusion; (C) Creation of diaphragmatic defect under direct thoracoscopic and robotically assisted laparoscopic visualization, viewed from abdominal cavity; (D) Abdominal view of omental flap delivered via the diaphragmatic defect; (E) Closure of excess diaphragmatic defect.

Following an uneventful hospital course, the patient was discharged home on postoperative day 6. Long-term antibiotics were discontinued 5 months postoperatively. Over one-year post intervention, the patient's incisions remained well-healed and free of infection [Figure 4A], and imaging confirmed obliteration of the space with viable omental tissue [Figure 4B-D].

DISCUSSION

Reconstruction of radiated defects poses ongoing challenges, especially when combined with fixed dead space and infection. Autologous, vascularized, non-radiated tissue coverage is advantageous to augment local perfusion and speed healing[7-9]. Free tissue transfer, although a versatile option, has higher rates of complications and failure in radiated recipient sites[10,11].

The omental flap has been well-described in the reconstruction of cardiothoracic defects[12-14]. Its physical advantages include plasticity, a long pedicle, and the ability to be harvested using minimally invasive techniques without a resulting functional deficit[15-18]. More importantly, its rich vascular supply, abundance of immune tissue, and robust healing capacity allow it to modify hostile wound environments[16-19]. While augmenting the local blood supply, the omentum rapidly adheres to inflamed tissue and recruits immune cells. While the flap could not initially obliterate the dead space completely, it was able to alter the wound biology and eventually completely heal the wound.

One prior report on robotic harvest of the pedicled omental flap described exteriorization of the flap via a sub-xiphoid fasciotomy for coverage of an anterior chest wall defect[20]. However, the combination of transdiaphragmatic tunneling[5] to the robotic harvest for coverage of an intra-thoracic defect has not been previously described. The addition of simultaneous thoracoscopy avoided injury to mediastinal structures while tunneling without the need to enlarge the thoracic wound. Without rendezvous guided by the transthoracic laparoscope light as seen from the abdomen, an ideal location for omental transfer would have required trial and error.

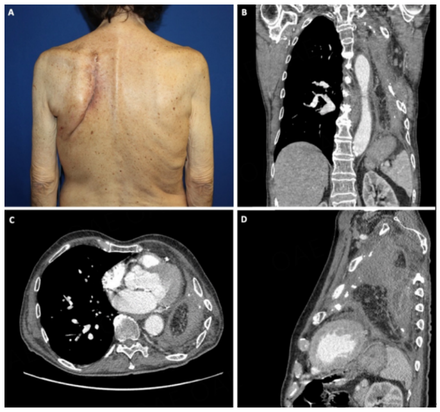

Figure 4. (A) Postoperative left posterior thorax wound, completely healed and with patient off antibiotics; (B-D) Coronal, axial, and sagittal views of CT chest demonstrating intra-thoracic pedicled omental flap with resolution of intra-thoracic defect.

The robotic platform allowed for three-dimensional visualization and included augmented visualization with near infra-red spectroscopy using ICG, all of which facilitated rapid assessments of graft function with each step of the procedure. Laparoscopic techniques for omental flap harvest have been well-described but may be limited by imprecise instrumentation and reduced visualization[21,22]. Robotic harvest has emerged as an alternative to laparoscopy, allowing for more precise visualization of the omentum and ensuring fine dissection and minimal risk to adjacent tissues[21,23]. Robotic assistance has been linked to shorter hospital stays and postoperative complications, compared with laparoscopic techniques[21], and can be performed in some cases through a single-port approach[22]. However, robotic procedures are associated with significantly greater costs, limiting their accessibility and adoption[24].

The omental flap possesses unique biological properties that make it exceptionally effective in the reconstruction of hostile intrathoracic wounds. Newer, minimally-invasive methods can be employed to reduce morbidity in frail patients via safe transdiaphragmatic tunneling.

DECLARATIONS

Authors' Contributions:

Made substantial contributions to drafting and revisions, as well as performed data acquisition, analysis, and interpretation: Mitchell B, Samaha Y

Made substantial contributions to the manuscript revisions and the procedure described herein: Imai T, Burch M, Brazio P

Availability of data and materials

Not applicable.

Financial support and sponsorship

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Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable. All participants provided written consent for their information to be used in this study.

Consent for publication

Written informed consent for publication was obtained.

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