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Technical Note

How to perform complete resection of peritoneal carcinomatosis nodules infiltrating the diaphragm without opening the pleural cavity in patients with advanced-stage ovarian cancers☆

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ABSTRACT

Patients with advanced-stage ovarian cancer frequently present with peritoneal carcinomatosis, and a diaphragmatic involvement is observed in about 40% of cases. The goal of treatment includes complete surgical cytoreduction associated with systemic chemotherapy. Complete diaphragmatic cytoreduction is a crucial step and plays a major role in the overall survival of these patients. Deep infiltrating peritoneal carcinomatosis nodules are treated with diaphragmatic full-thickness resections, but these procedures involve opening the pleural cavity and are associated with a high rate of postoperative complications, such as pleural effusion and pneumothorax. A chest drain is often required, causing significant discomfort for the patients and potentially being an additional source of complications.

In this study, we present a novel surgical technique to perform diaphragmatic resections using a linear stapler without opening the pleural cavity or needing a chest drain.

Introduction

Ovarian cancer represents the most lethal gynecological malignancy, with an overall 5-year survival rate of approximately 50% [1]. This is partially explained by its early and "silent" spread, with more than half of patients presenting with distant metastatic involvement at diagnosis [1]. Patients with advanced-stage ovarian cancer frequently present peritoneal carcinomatosis, with diaphragmatic involvement observed in about 40% of cases [2]. The goal of treatment includes complete cytoreduction associated with systemic chemotherapy [3]. Complete excision of diaphragmatic lesions is a crucial step of cytoreductive surgery, playing a major role in the overall survival of these patients [4].

Diaphragmatic cytoreduction can be performed by several approaches depending on the volume, distribution, and depth of infiltration of the metastatic lesions. Superficial lesions can be treated by coagulation or peritonectomy ("stripping"), while diaphragmatic full-thickness resection (DFTR) is indispensable to remove peritoneal carcinomatosis nodules presenting muscular infiltration [5]. When DFTRs are performed, diaphragmatic defects are closed with direct sutures or, more rarely, with a prosthetic mesh for extensive resections. DFTRs involve opening the pleural cavity and are associated with a high rate of postoperative complications, such as pleural effusion and pneumothorax [2, 6]. These procedures often require the placement of a chest drain to limit postoperative complications, causing significant discomfort for the patients and potentially being an additional source of complications.

Abbreviations: DFTR, diaphragmatic full-thickness resection

☆ **Statement of Prior presentation:** This study has never been presented or published.

☆ **Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki. Informed consent was obtained from the patient involved in the study. This study was approved by the institutional review board: project-ID 2021-02473 (24/03/2022, CER-VD, Lausanne, Switzerland).

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To reduce the morbidity associated with DFTR, in 2018, we implemented a novel surgical technique to perform diaphragmatic resections using a linear stapler without opening the pleural cavity. The current study is intended to describe how to perform this technique.

This study was approved by the institutional review board, and informed consent was obtained from the patient involved.

Surgical technique

Case presentation

A 26-year-old woman presented with a low-grade serous tubo-ovarian papillary adenocarcinoma stage FIGO IVB with single liver metastasis but no extra-abdominal involvement. Right diaphragmatic lesions were identified on the preoperative computed tomography scan (Fig. 1A). To select the proper management, we considered the tumor type (low-grade serous ovarian cancer) and its complete resectability, as well as the patient's fitness and acceptance to undergo the proposed treatment strategy [7,8]. The patient underwent complete cytoreductive surgery, including a hepatic wedge resection and a right DFTR using a linear stapler. The procedure and post-operative period were uneventful, and the patient did not need a chest drain. A computed tomography scan performed seven days after surgery showed complete resection of the diaphragmatic infiltrating lesions (Fig. 1B). The patient underwent adjuvant chemotherapy with carboplatin and taxol. Twenty-eight months after primary surgery, the patient presented a supra- and infradiaphragmatic nodal recurrence and underwent thoracoscopic and laparotomic complete secondary cytoreductive surgeries. Intraoperative inspection of both sides of the previously operated right diaphragm revealed no adhesions, muscular defects, or metastatic implants, and no pleural metastases were observed. During the 36-months following the first surgery, the patient presented no complications associated with the stapled right DFTR.

Installation, surgical approach, and inspection of the peritoneal cavity

Under general anesthesia, patients are placed in a dorsal lithotomy position. A midline xipho-pubic laparotomy is performed to access the abdominal cavity, and careful exploration is performed to assess the tumor extension. To access the right diaphragmatic dome, the table is rolled to the left, and the surgeon stands between the patient's legs or to her left. The reversed setting is prepared to access the left diaphragm.

Liver mobilization

The round and falciform ligaments are sectioned, and a fixed retraction device is employed to expose the upper abdomen. The dissection is extended to the coronary and triangular ligaments for complete liver mobilization. The operating assistant tilts the liver to expose the diaphragm.

Diaphragmatic resection

The diaphragmatic peritoneum is initially stripped until identifying the lesions infiltrating the diaphragm. The infiltrating lesions are exposed by traction using two Kelly forceps, creating a fold of the diaphragm, which includes the metastatic nodules (Fig. 2A). The anesthesiologist performs a prolonged forced mechanical expiration, allowing the diaphragm to relax and distancing the lungs. The diaphragmatic fold is then excised at its base using one or several 45- or 60-mm linear Endo GIA black articulating reload stapler (for extra thick tissues) with tri-staple technology (Medtronic, Inc., Dublin, Ireland) (Fig. 2B). If needed, the stapled line could be reinforced with an absorbable running suture to reduce the traction on the staples. This reinforcement could be necessary in case of extensive resections with relevant traction on the diaphragmatic muscular fibers surrounding the stapled line. This technique avoids opening the pleural cavity, and no transthoracic or transdiaphragmatic drain is needed.

Postoperative care

A postoperative chest X-ray is not routinely performed in asymptomatic patients. Early mobilization is encouraged, and patients receive daily respiratory physiotherapy sessions from the first postoperative day.

Discussion

In this article, we described an innovative surgical approach to performing DFTRs in the context of advanced ovarian cancer using a linear stapler. Similar to other proposed techniques used in benign diaphragmatic surgeries [9,10], we implemented the use of a stapler device to perform diaphragmatic resections in cytoreductive procedures. From our experience, this technique allows the excision of single or multiple diaphragmatic lesions with the largest diameter up to 7-8 cm and a total area of approximately 20 cm^2. However, when the diaphragmatic tension after resection is deemed too high, a prosthetic mesh can be used to reinforce the resection site. Compared to conventional DFTR techniques, this method does not require opening the pleural cavity and appears easier and faster to perform, substantially reducing overall operating time. As it avoids iatrogenic pneumothorax, chest drains are not needed even in cases of bilateral diaphragmatic resections. Maintaining a separation between the abdominal and pleural cavities avoids contamination of the latter [11], potentially reducing the risk of pleural recurrences. In addition, the tightness conferred by stapled resections could reduce the risk of

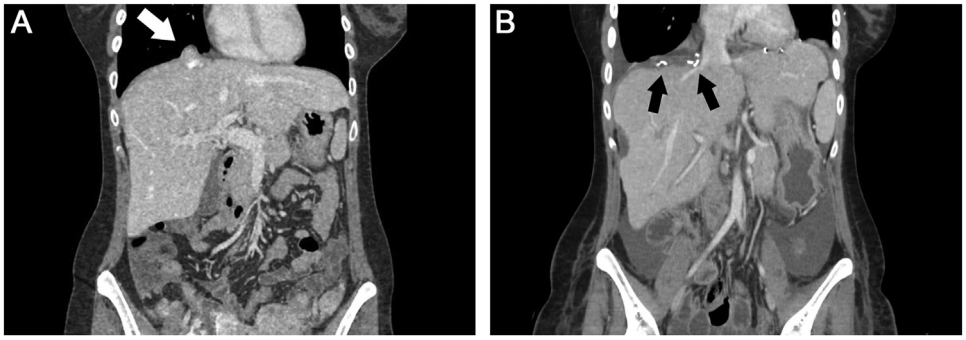

Fig. 1. (**A**) Coronal reconstruction of a thoracoabdominal computed tomography scan performed before the intervention, showing a nodule of peritoneal carcinomatosis infiltrating the right diaphragm (white arrow). (**B**) A postoperative thoracoabdominal computed tomography scan was performed seven days after surgery. This coronal reconstruction shows the operated area of the right diaphragm with the absence of the previously observed metastatic lesion and the presence of staples (black arrows).

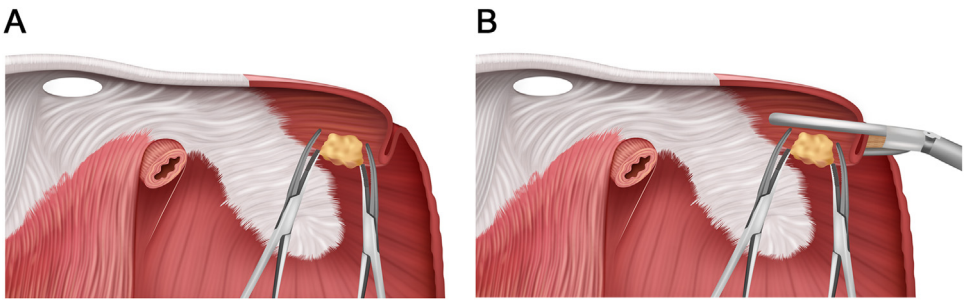

Fig. 2. Graphic reconstruction of the diaphragm showing a nodule of peritoneal carcinomatosis infiltrating the left dome, exposed by traction on two Kelly forceps. (**B**) The diaphragmatic fold formed by this traction, including the nodule, is resected at its base using an articulating linear stapler.

postoperative pneumothorax and decrease the amount of pleural effusion resulting from the transfer of ascites to the pleural cavity or from inflammatory processes associated with pleural cavity opening. A stapled resection could also be helpful to avoid inadvertent diaphragmatic tearing and pleural cavity opening when performing superficial peritoneal dissection on very thin and fragile diaphragmatic portions such as its central tendon. In addition, stapled resections appear safe to ensure long-term diaphragmatic integrity, as suggested by the secondary surgical diaphragmatic inspection and the uncomplicated 3-year follow-up in our patient.

Potential limitations of this procedure include the impossibility of performing an intraoperative inspection of the pleural cavities and the potential risk of diaphragmatic paralysis due to iatrogenic injuries of the diaphragmatic nerve. In the case of conventional DFTR, transdiaphragmatic thoracic exploration can be performed [12], but its role could be limited in the case of small diaphragmatic resections because of difficulty accessing the upper part of the pleural cavity and the impossibility of inspecting the contralateral cavity. In addition, this inspection increases the risk of thoracic contamination with microscopic peritoneal metastases [11]. Alternatively, the thoracic inspection can be performed via thoracoscopy in selected patients (e.g., presenting pleural effusion or radiologic findings suggesting thoracic metastases) [13, 14]. However, the roles of intrathoracic evaluation and cytoreductive surgery remain controversial and not fully understood, and more evidence is needed to establish the indications of these procedures [14]. Hemidiaphragm paralysis due to iatrogenic injury of the diaphragmatic nerve is a rare but potentially severe complication of diaphragmatic resections. As for other diaphragmatic surgical techniques, particular attention should be paid to the anatomical course of this nerve when performing a stapled DFTR.

A recent study demonstrated that, compared to conventional techniques used to perform DFTRs, this surgical approach could reduce the risk of postoperative complications such as the need for a chest drain, the development of pneumonia, or the presentation of a severe respiratory complication requiring re-intubation and/or prolonged mechanical ventilation [15]. The risk of malignant pleural recurrence also seems to be reduced, although a significant difference has not been demonstrated [15].

The optimal timing of debulking surgery for patients with advanced ovarian cancer is still an open debate [16], but primary surgeries are considered the management of choice when complete cytoreduction appears feasible. Primary cytoreductions are frequently associated with radical and ultraradical upper abdominal procedures, and diaphragmatic resections are often needed. These interventions are associated with a high rate of postoperative complications [5, 6]. Reducing these complications is crucial to improving postoperative recovery and preventing adjuvant treatment delay [17]. Our novel technique represents a promising option for reducing postoperative morbidity and improving the management of advanced-stage ovarian cancer patients requiring a DFTR. In addition, this surgical approach can be used even by laparoscopy, representing an interesting option to perform safe and rapid resections in other fields of gynecologic surgery. Although never reported to date, this approach could be implemented in the treatment of deep diaphragmatic endometriosis.

In conclusion, this surgical technique appears to be a fast and easy method to perform diaphragmatic resections. This approach allows for complete diaphragmatic cytoreduction and can reduce the risk of postoperative complications.

Contributors

DH, MC, and IF conceptualized the surgical technique and performed the intervention. DH and YH conceptualized and designed the study. DH and VB collected data. DH and YH analyzed data and drafted the article. MC, IF, SS, and VB revised the article critically for important intellectual content. All authors gave final approval of the version to be submitted.

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Patient consent for publication

The patient gave written consent.

Data availability statement

Data are available on request from the authors.

Declaration of Competing Interest

None declared.

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None.

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