

Minimally invasive thoracoscopic surgery with laparoscopic assistance approaches in diaphragmatic eventration management

Miniinwazyjna chirurgia torakoskopowa ze wsparciem laparoskopowym w leczeniu ewentracji przepony

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Słowa kluczowe: laparoscopia, ewentracja przepony, operacja torakoskopowa.

Abstract

Introduction: Thoracoscopic plication is an effective treatment for diaphragmatic eventration, but the procedure has some disadvantages such as inadvertent abdominal organ injuries or superficial sutures that are not strong enough.

Aim of the research: In this study, we devised and tested the method of diaphragm plication through simultaneous laparoscopic- and thoracoscopic-assisted left mini-thoracotomy.

Material and methods: During the period between October 2012 and March 2014 there were four patients operated on for left-sided diaphragmatic paralysis. The average age was 52.3 ±17.8 years. The preoperative examination included a routine laboratory study, spirometry, plain chest radiograph, and computed tomographic scan of the chest. The initial part of the surgery was a two-port laparoscopy to remove the adhesions between the abdominal viscera and the abdominal segment of the diaphragm using bipolar electrocautery. After that, video-assisted thoracoscopic surgery plication of the diaphragm was performed via anterior mini thoracotomy.

Results: The mean operation time was 58 ±11 min, and the mean hospital stay was 9.0 ±2.1 days. All of the patients demonstrated good postoperative recovery. The descending distance of the diaphragm after the surgery ranged from two to four intercostal spaces, which was confirmed with plain chest X-ray. The follow-up ranged from 20 to 38 months and showed no recurrence of diaphragm elevation symptoms.

Conclusions: Simultaneous thoraco- and laparoscopic assisted mini-thoracotomy surgery for diaphragm plication is a safe procedure with strong positive clinical effect, and it can serve as an alternative to conventional thoracoscopic approaches especially in patients with high risk of inadvertent abdominal organ injuries.

Streszczenie

Wprowadzenie: Torakoskopowa plikacja jest skuteczną metodą leczenia ewentracji przepony, ale procedura ta ma pewne wady, takie jak niezamierzone urazy narządów jamy brzusznej lub niedostatecznie mocne i głębokie szwy.

Cel pracy: W badaniu opracowano i przetestowano metodę plikacji przepony za pomocą minitorakotomii wspomaganą laparotorakoskopowo.

Materiał i metody: Od października 2012 do marca 2014 r. operowano 4 pacjentów z powodu pourazowego lewostronnego paraliżu przepony. Średnia wieku pacjentów wynosiła 52,3 ±17,8 roku. Wskazaniami do zabiegu były wyniki badań radiologicznych wskazujących na nienormalnie podwyższony poziom lewej kopyty przepony od piątego do trzeciego żebra, co powoduje stałą kompresję i niedodmę dolnego płata płuca. W pierwszym etapie tej operacji posłużono się dwuportową laparoskopią w celu usunięcia zrostów pomiędzy organami jamy brzusznej i brzuszną powierzchnią przepony. Podczas wykonania piersiowego etapu operacji przez dostęp minitorakotomii odma jamy brzusznej zapobiegała uszkodzeniom narządów brzusznych.

Wyniki: Średni czas operacji wynosił 58 ±11 min, hospitalizacji 9,0 ±2,1 dnia. U wszystkich pacjentów stwierdzono dobre wyniki pooperacyjnej rekonwalescencji. Wielkość obniżenia membrany po zabiegu wynosiła od dwóch do czterech

przestrzeni międzyżebrowych. Późniejsza obserwacja od 20 do 38 miesięcy nie wykazała nawrotu objawów ewentracji przepony.

Wnioski: Minitorakotomia wspomagana laparotorakoskopowo w wykonywaniu plikacji przepony jest zabiegiem bezpiecznym, przynosi trwały pozytywny efekt kliniczny i może służyć jako alternatywa dla konwencjonalnych metod torakoskopowych, zwłaszcza u pacjentów z wysokim ryzykiem wystąpienia niezamierzonych urazów narządów jamy brzusznej.

Introduction

Acquired diaphragmatic paresis or paralysis can result from abnormalities of the neuromuscular axis between the spinal cord and the diaphragm, which may be caused by phrenic nerve trauma, including birth trauma, iatrogenic injury in surgery, infection, aortic aneurysm, neoplasms, autoimmune diseases, and neuromuscular syndromes. However, regardless of the cause, the mainstay of treatment is surgery [1]. Thoracoscopic plication, introduced by Mouroux in 1996, is an effective treatment for diaphragmatic eventration, but the procedure has some disadvantages such as inadvertent abdominal organ injuries or superficial sutures that are not strong enough [2].

Aim of the research

In this study, we devised and tested the method of diaphragm plication through simultaneous laparoscopic- and thoracoscopic-assisted left mini-thoracotomy.

Material and methods

During the period between October 2012 and March 2014 there were four patients operated on for left-sided diaphragmatic paralysis. The number of male and female patients was equal. The average age was 52.3 ± 17.8 years old (within the range between 30 and 72 years old).

The preoperative examination included a routine laboratory study, spirometry, plain chest radiograph, and computed tomographic scan of the chest (Figure 1) to exclude other causes of abnormal diaphragm elevation such as diaphragm herniation or rupture. The indications for surgery included radiological findings of abnormally elevated left hemi-diaphragm to the level from the fifth to the third rib, thus causing persistent compression atelectasis of the lower lobe, with recurrent pneumonias in 2 cases, and increasing lung function disorders with symptoms of effort and/or positional dyspnoea in all cases.

All the patients had preoperative spirometry, which showed the reduction of lung volumes with a restrictive pattern. The mean forced vital capacity (FVC) was $67 \pm 5\%$ of predicted values, and forced expiratory volume in 1 s (FEV_1) amounted to $68 \pm 4\%$.

All the patients had general anaesthesia with intubation of the right bronchus and were placed in the head-up position with carbon dioxide (CO_2) insufflated into the abdominal cavity with intra-abdominal pressure (IAP) limited to below 8 mm Hg during the surgery.

The initial part of the surgery was a two-port laparoscopy to remove the adhesions between the abdominal viscera (the spleen in 3 cases and the colon for 1 patient) and the abdominal segment of the diaphragm using the bipolar electrocautery.

Before the beginning of the video-assisted thoracoscopic surgery (VATS) the surgical table was rotated

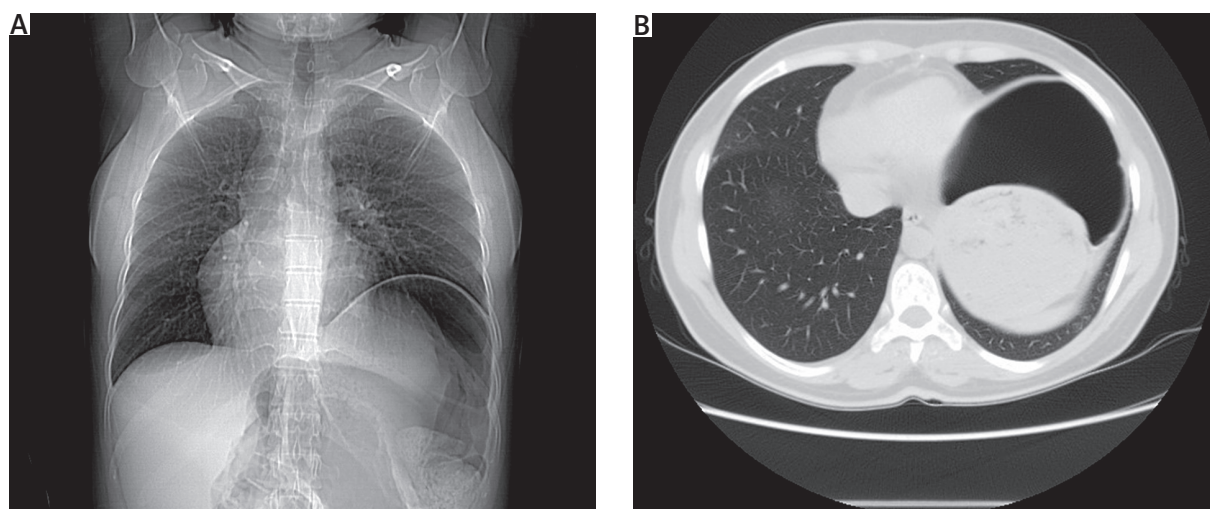


Figure 1. Thoracic computed tomography (CT) scans of a 48-year-old female showed an abnormally elevated diaphragm on the left side at the level of 5 ICS (A); lower lobe atelectasis, relocation, and retraction of the colon loops, the stomach and the spleen towards diaphragm (B)

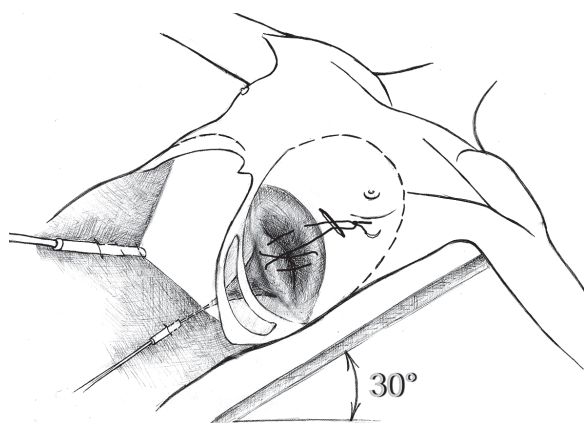


Figure 2. The first figure-of-eight suture passed through the bottom of the diaphragm keel inverted towards the abdomen

thirty degrees to the right and patients were placed in the slight lateral position.

There was anterior mini thoracotomy from 5 to 6 cm without rib spreading performed in the 7th, 6th, or 5th intercostal space (ICS), depending on the severity of diaphragmatic elevation and the patient's body habitus.

Pneumoperitoneum in the course of the thoracic stage of the operation allowed creation of a CO₂ gap between the stretched diaphragm and intra-abdominal organs, which served as a means to prevent their damage until the full thickness diaphragm suture was performed via mini thoracotomy access.

The first suture was localised by means of laparoscopic downward traction of the diaphragm dome apex, with non-absorbable figure-of-eight stitches performed on its thoracic surface through the bottom sectors of the diaphragm keel inverted towards the abdomen (Figure 2). Subsequent figure-of-eight sutures were performed on the same principle, i.e. after preliminary abdominal traction and inversion of the apical part of the "next CO₂-inflated dome" in the most flaccid segment of the diaphragm. The procedure (suture) was repeated from five to seven times to secure adequate diaphragmatic tension for complete expansion of the lung into the increased hemithorax volume. Intercostal novocaine-alcohol block anaesthesia was used at the end of operation in all of the treated patients.

The cut muscle edges in the mini-thoracotomy wound were approximated, leaving a 28 Fr tube as an intercostal drain to remove reactionary fluid in the 24 h after surgery. All of the patients had a first postoperative day chest radiograph taken to confirm the adequacy of the plication and to exclude pneumothorax or early onset pneumonia.

Statistical analysis

Results were expressed as mean \pm standard error. Statistical analyses were performed with Statistic ver-

sion 7. Dependent Samples *t*-test was used for comparison of the pre- and postoperative spirometry variable. $P \leq 0.05$ was considered to be significant.

Results

The mean operation time was 58 ± 11 min. There was no mortality. The intraoperative haemorrhage was 100 ± 28 ml. All the patients demonstrated good postoperative recovery, except for one patient with left lower lobar post-atelectasis pneumonias discovered radiographically, which were not problematic for treatment. The mean hospital stay was 9.0 ± 2.1 days. The descending distance of the diaphragm after the surgery ranged from two to four intercostal spaces (mean distance: 3.0 ± 0.8 ICS), which was confirmed with plain chest X-ray (Figure 3). The follow-up ranged from 20 to 38 months and showed no recurrence of diaphragm elevation symptoms. Postoperative pulmonary functions improved significantly at first year follow-up, and mean postoperative FVC was $81 \pm 4\%$ ($p = 0.036$) and FEV₁ $77 \pm 7\%$ ($p = 0.05$).

Discussion

Fluoroscopy, ultrasound evaluation with using motion mode [3], or brightness mode ultrasonography [4] may be used preoperatively to confirm diaphragmatic paralysis, but we prefer to use thoracic computed tomography for differential diagnosis of herniation or subphrenic tumours.

Diaphragmatic plication is a surgery indicated for symptomatic diaphragmatic paresis in adults. Various approaches to diaphragmatic plication have been employed, including open thoracotomies, sternotomy, hemi clam shell and transabdominal incision, minimally invasive thoracotomies, thoracoscopic, and thoracoscopically assisted or laparoscopic approaches [5].

Our experience demonstrates the need to determine the minimum effective thoracotomy depending on the overall size of the surgical instruments on the one hand and easing the manipulation with them in the thoracic cage on the other hand, which usually results in an incision smaller than 5 cm in the anterior segment of the ICS because it is always wider than the posterior one.

Several variations in the technique of thoracoscopic and laparoscopic plication of diaphragmatic eventration and paralysis/paresis have been described. In the first report of thoracoscopic plication, Mouroux *et al.* [2] used insufflation to keep the diaphragm down. Since then, many reasonably successful attempts have been made to improve and simplify diaphragmatic plication using video-assisted thoracic surgery [6–9], which allows comfortably and quickly to place figure-of-eight, full thickness, interrupted diaphragmatic sutures with extracorporeal knotting, thus essentially reducing the operation time. Our

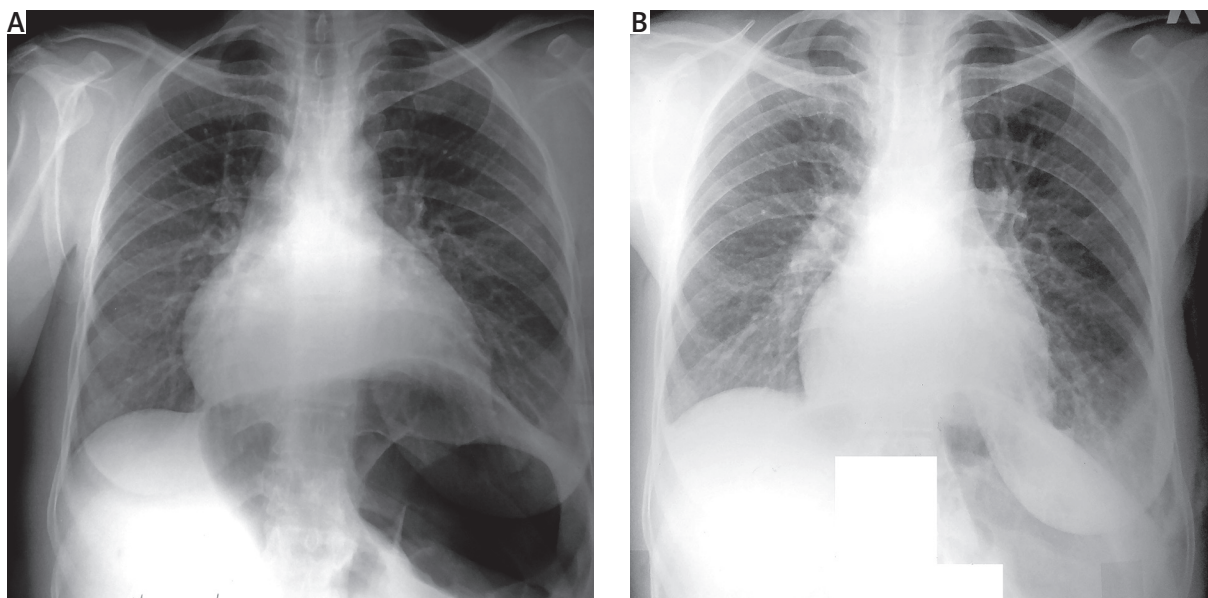


Figure 3. Posteroanterior chest X-ray of a 48-year-old female before (A) and on the first postoperative day after placcation (B). The X-ray shows descending left hemidiaphragm and lung re-expansion after the surgery

method of simultaneous assistance does not require incising the diaphragm to aid suture placement and prevent inadvertent damage to the adjacent abdominal organs as other researchers suggest [8]. Moreover, when the diaphragm is laparoscopically pulled down, the CO₂ gap between the diaphragm and the abdominal organs does not allow any increase in the contact surface, which reduces the risk of inadvertent abdominal injuries [10]. Increased by CO₂ insufflations, intraabdominal pressure (≤ 8 mm H₂O) is a factor that helps to continually identify the most flaccid parts of the diaphragm, inverting and invaginating them underneath by successively (“one by one”) applied interrupted sutures, and allows determination of the placement and optimal number of sutures. Intraperitoneal carbon dioxide insufflation has never caused hypercapnia during the operation but has allowed examination of whether unreinforced and unbuttressed sutures are strong enough to sustain the potential force of intra-abdominal pressure in the post-operation period.

We believe the number of suture layers is not critical because it is more important that the degree of plication or “diaphragm tautness” should be not as tight as possible or tense when palpated [1, 11] or form a flattened dome (Leo *et al.* [12]), but should be sufficient for complete intra-operation re-expansion of the left pulmonary artery.

We also achieved a postoperative increase in pulmonary function in our patients, and this improvement, as is well known, ensures symptomatic relief and reflects directly on the patients’ clinic [13]. Therefore, we recommend our modification of diaphragm plication to make this procedure safer, easier, more

reliable, and time-efficient, especially in surgeries of patients with expected adhesions of the diaphragm to subdiaphragmatic viscera.

Conclusions

Simultaneous thoraco- and laparoscopic assisted mini-thoracotomy surgery for diaphragm plication is a safe procedure with strong positive clinical effects.

The method can serve as an alternative to conventional thoracoscopic approaches, especially in patients with diaphragmatic elevation and with a high risk of inadvertent abdominal organ injuries in the course of operation.

Conflict of interest

The authors declare no conflict of interest.

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