DANISH MEDICAL JOURNAL

Brief Research Report

Video-assisted thoracoscopic plication in symptomatic adults with paralytic hemidiaphragm

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Dan Med J 2026;73(1):A05250416. doi: 10.61409/A05250416

ABSTRACT

INTRODUCTION. Flattening of a paralytic hemidiaphragm by plication may alleviate respiratory symptoms. For decades, the operation was performed through a thoracotomy that caused substantial morbidity, but now minimally invasive video-assisted thoracoscopic approaches are available. We technically modified the procedure using CO_2 insufflation and pledged sutures and aimed to investigate changes in lung function and satisfaction rates in adult patients with hemidiaphragmatic paralysis.

METHODS. We retrospectively searched the electronic patient record system for pre- and post-operative pulmonary function tests and satisfaction rates at clinical follow-up.

RESULTS. During a three-year period (2021-2023), 15 patients were operated on at a median age of 58 years. Pulmonary function tests improved significantly after diaphragmatic plication ($p < 0.01$), and nine of 12 patients with available data reported symptomatic improvement ($p = 0.02$). The median length of hospital stay was one day.

CONCLUSIONS. Minimally invasive diaphragmatic plication improves pulmonary function and respiratory symptoms in patients with hemidiaphragmatic paralysis.

FUNDING. None.

TRIAL REGISTRATION. Retrospective follow-up.

A small group of patients with dyspnoea demonstrate abnormal elevation of one hemidiaphragm on chest radiography. This may be due to simple relaxation of the muscle fibres, but more frequently results from diaphragmatic paralysis, which may arise from phrenic nerve injury or tumour compression. However, in many cases, no explanation is found [1-4].

For unknown reasons, diaphragmatic paralysis occurs more frequently in males and on the left side [5-7]. Diagnosis rests on physiological evaluation of diaphragmatic movement during fluoroscopy while breathing heavily (also named “sniff test”), where one hemidiaphragm does not move or moves paradoxically [7, 8]. Such patients typically present with progressive dyspnoea, hypoventilation, atelectasis and occasionally hypoxia [1, 4], which may severely impact their quality of life [2]. Initial management is conservative, including weight loss in obese patients to reduce their intra-abdominal pressure [4, 8]. In selected patients, diaphragmatic plication (DP) may be an option when conservative management fails [3, 8]. The procedure aims to flatten the elevated hemidiaphragm, reducing lung compression [4]. An open thoracotomy was historically preferred but caused long-lasting pain and morbidity. In recent decades, minimally invasive techniques have been introduced,

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including video-assisted thoracoscopic surgery (VATS), robotic-assisted thoracoscopic surgery and laparoscopic techniques [4, 8]. Studies have demonstrated improved lung function [2, 9], symptom relief and enhanced quality of life after DP, regardless of the surgical approach [2, 10, 11]. The benefits of minimally invasive techniques include reduced pain, shorter hospital stay and a faster recovery [9, 12].

Since 2021, we have modified the VATS technique using CO_2 insufflation and pledged stitches. This report evaluates improvements in lung function and patient satisfaction.

Methods

We retrieved electronic patient records from all patients who underwent elective VATS DP in 2021-2023 due to unilateral diaphragmatic paralysis confirmed by a positive sniff test (paradoxical movement) and who were unresponsive to conservative treatment. We compared pulmonary function tests before and after surgery and collected details about satisfaction rates from follow-up visits by phone, email or in person by the operating surgeon.

Surgical technique

Minimally invasive DP is performed at all thoracic centres in Denmark, though the approach may vary based on clinical and surgeon-related factors. All procedures were performed by one consultant with over 30 years of VATS experience, using a three-port technique under general anaesthesia with contralateral single-lung ventilation. CO_2 insufflation caused the elevated hemidiaphragm to move caudally, allowing for better overview and placement of two Prolene-1 sutures: one anchored laterally and sutured medially with felt-pledges to minimise the risk of rupture. The second was tied to the first, medially to reinforce the flattening and correct minor eventrations. We routinely applied a chest drain until the next day and used intercostal nerve blocks (bupivacaine 0.25%) in addition to oral analgesics.

Trial registration: retrospective follow-up.

Results

Fifteen patients underwent surgery. **Table 1** shows baseline and surgical characteristics. The median duration of surgery was 81 minutes (range: 61-133). The median hospital stay was one day (range: 1-7 days). Three patients had prolonged stays: two due to air leakage and one because of a splenic haematoma.

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TABLE 1 Characteristics and lung function of surgically plicated patients by the video-assisted thoracoscopic surgery technique (N = 15).

Male/female, n	14/1
Age, median (range), yrs	57 (42-74)
BMI, median (range), kg/m²	29.4 (23.3-33.2)
Smoking status, n (%)	
Current	3 (20)
Former	4 (27)
Never	8 (53)
Respiratory symptoms, n (%)[a]	15 (100)
Pulmonary function test, median (range)	
Preoperative:	
FEV1, l	2.07 (1.03-3.27)
FEV1, % of expected	56 (32-78)
FVC, l	3.32 (1.40-4.00)
FVC, % of expected	61 (36-84)
Post-operative:	
FEV1, l	2.64 (1.11-4.64)
FEV1, % of expected	69 (32-106)
FVC, l	3.79 (1.55-6.17)
FVC, % of expected	77 (36-111)
Operation side, n (%)	
Right	6 (40)
Left	9 (60)
Time of chest drain removal, median (range), days	1 (0-4)
Time of hospital discharge, median (range), days	1 (1-7)

FEV1 = forced expiratory volume in 1st sec.; FVC = forced vital capacity.
a) Preoperative.

All patients underwent post-operative pulmonary function tests after a median of 119 days (range: 66-165 days). Mean forced vital capacity (FVC) increased from 63.1% ± 13.7% (mean ± standard deviation) preoperatively to 75.1% ± 18.6% post-operatively ($p < 0.01$). Mean forced expiratory volume in the first sec. (FEV1) increased from 56.1% ± 12.8% to 69.1% ± 17.3% ($p < 0.01$).

Nine of 12 patients with available data reported symptomatic improvement post-operatively ($p = 0.02$). Two patients reported no changes. One patient reported an initial improvement but experienced recurrence of symptoms 1.5 years after surgery, although his pulmonary function test remained better than at baseline.

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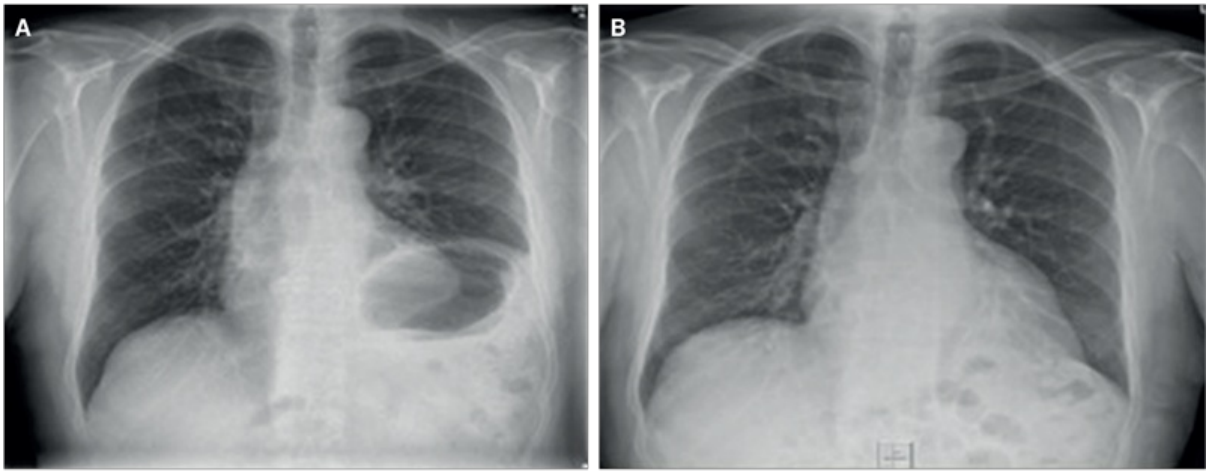
Discussion

This small case series demonstrates significant improvement in pulmonary function (FVC and FEV1) and respiratory symptoms following VATS-based DP (**Figure 1**). This is consistent with the existing literature [3, 5, 9, 11, 13], which mainly includes case reports or small case series. Freeman et al. compared VATS, open surgery and conservative treatment in a cohort study, reporting improved dyspnoea and pulmonary function at a six-month follow-up [6], with sustained increases in FVC and FEV1 of 19% and 23%, respectively, after 57 months [11].

FIGURE 1 Example of pre- (**A**) and post-operative (**B**) imaging of a patient undergoing diaphragm plication by video-assisted thoracoscopic surgery for left-sided hemidiaphragmatic paralysis.



We used VATS only but modified the previously described methods by applying CO_2 insufflation to improve visualisation of the elevated hemidiaphragm, as we believe that this technique may improve suture placement. Additionally, we used pledged felt reinforcement of every stitch to reduce the risk of diaphragmatic tears, rupture and recurrence.

Most patients were discharged on the first post-operative day; three had longer stays due to complications. Two had self-limiting air leaks, which are common after thoracic surgery [2]. The last patient suffered a conservatively managed splenic haematoma. We now encourage more careful suturing to avoid abdominal organ injury.

Three patients experienced no symptomatic improvement, which is consistent with the literature suggesting that DP may not benefit all [14, 15]. Predictors for success remain unclear, but obesity may play a role due to elevated intra-abdominal pressure, making flattening of the diaphragm more difficult. We now limit DP to patients with a BMI < 30 kg/m^2. Following Deng et al., we recommend at least six months of observation before surgery to allow for possible spontaneous phrenic nerve recovery [15]. However, in our cohort, most were followed for up to one year, and we have never observed spontaneous recovery.

Our study has obvious limitations: First, the retrospective design and reliance on unstructured patient reports introduce the risk of recall and observer bias. Furthermore, the sample size was small, and symptom data were collected from clinical notes without predefined questionnaires. Therefore, subjective outcomes should be interpreted with caution. Symptom data were missing for three patients who did not respond to follow-up contact, despite having completed lung function testing. Second, all procedures were performed by a single

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surgeon, which enhances consistency but limits generalisability. Lastly, the absence of a control group limits causal explanation of surgical efficacy.

Nevertheless, the prospectively collected pulmonary function tests showed marked improvement, and most patients reported symptomatic improvement. The follow-up duration was relatively short, so long-term outcomes remain uncertain. However, previous studies indicate that benefits persist [7, 11].

Conclusions

Modified VATS DP appears effective for selected patients with symptomatic unilateral diaphragm paralysis. All patients improved in pulmonary function, and most patients reported symptom relief.

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Accepted 14 August 2025

Published 10 December 2025

Conflicts of interest none. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. These are available together with the article at ugeskriftet.dk/dmj

References can be found with the article at ugeskriftet.dk/dmj

Cite this as Dan Med J 2026;73(1):A05250416

doi 10.61409/A05250416

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