Editorial

Raising the bar, lowering the diaphragm: a new era in diaphragmatic plication

Savvas Lampridis^

Department of Cardiothoracic Surgery, Hammersmith Hospital, Imperial College Healthcare NHS Trust, London, UK

Correspondence to: Savvas Lampridis, MD, MSc, MRCS(Ed). Department of Cardiothoracic Surgery, Hammersmith Hospital, Imperial College Healthcare NHS Trust, 72 Du Cane Road, London W12 0HS, UK. Email: savvas.lampridis@nhs.net.

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Unilateral diaphragmatic dysfunction is a relatively rare—although likely underdiagnosed—clinical condition with variable etiology, including neurological and inflammatory diseases, compressive and infiltrative processes, iatrogenic injuries, and idiopathic causes. As the principal muscle of respiration, the diaphragm plays a crucial role in maintaining adequate pulmonary function. Consequently, diaphragmatic dysfunction can lead to dyspnea, exercise intolerance, and sleep disturbances. In more severe cases, diaphragmatic dysfunction may have a negative impact on patient survival, thereby highlighting the importance of appropriate therapeutic management (1). The mainstay of treatment of chronic, symptomatic unilateral diaphragmatic dysfunction is surgical plication, a procedure in which the weak hemidiaphragm is flattened and immobilized by folding its redundant portion. Since its first description in the early 20th century, diaphragmatic plication has largely evolved to encompass different surgical approaches and techniques. As a result, it can now be performed through a transthoracic or transabdominal approach using open or minimally invasive techniques, including thoracoscopic, laparoscopic, and robotic.

Robot-assisted diaphragmatic plication has recently garnered growing interest, as surgeons delve deeper into the advantages of robot-assisted thoracoscopic surgery (RATS). Some of the latest evidence on robot-assisted diaphragmatic plication comes from the study by Marmor *et al.* (2), which provides valuable insights into this procedure. To assess short-term outcomes, the authors conducted a retrospective review of 41 patients who underwent robot-assisted transthoracic diaphragmatic plication at their center since its first implementation in 2018. The results were generally favorable, with 36 (87.8%) patients reporting clinical improvement during their postoperative follow-up visits. To further evaluate patient-reported outcomes and experiences, which serve as essential quality measures (3), the authors developed a questionnaire consisting of modified queries from the Medical Research Council (MRC) Dyspnea Scale and the RAND 36-Item Short Form Survey, as well as original questions. Among the respondents, 88.9% reported improved breathing after surgery, and 85.7% stated that they would recommend the procedure to a friend or relative with a similar condition. Regarding surgical outcomes, the median chest-tube duration and length of hospitalization were both short at 2 and 3 days, respectively. Postoperative complications were observed in 11 (26.8%) patients, but only 4 of these cases required intervention, specifically the drainage of pneumothorax or pleural effusion. Within 30 days of surgery, 2 (4.9%) patients were readmitted due to pneumonia and acute kidney injury, respectively, but no

^ ORCID: 0000-0003-2827-5826.

mortality events were recorded. Notably, 4 (9.8%) patients experienced symptomatic recurrence of diaphragmatic elevation within 38 days post-surgery, with the earliest case occurring on the 6th postoperative day. The authors conducted a comprehensive examination of this finding, which will be discussed in greater detail in the subsequent sections of this article.

The existing literature on robot-assisted transthoracic diaphragmatic plication remains relatively scarce. A recent systematic review (4) focusing on minimally invasive diaphragmatic plication identified only 3 studies (5-7) investigating RATS since the first report of robot-assisted transthoracic diaphragmatic plication in 2012 (8). Remarkably, all 3 studies presented promising results. In the study by Bin Asaf *et al.* (5), 18 patients underwent robot-assisted diaphragmatic plication through a transthoracic (n=6) or transabdominal (n=12) approach. A comparison between pre- and post-operative pulmonary function test results revealed a significant increase in the mean forced expiratory volume in 1 second (FEV_1) by 19.9%±22.0% of predicted (P=0.002), without a significant difference between the subgroups of patients based on surgical approach. Similarly, Nardini *et al.* (6) conducted a retrospective study on minimally invasive diaphragmatic plication using RATS (n=14) or video-assisted thoracoscopic surgery (VATS; n=35). Postoperatively, the mean MRC dyspnea score decreased significantly by 2.2 (out of 5) points. Additionally, 35 (97.2%) patients reported satisfaction with the outcome, while 28 (77.8%) patients stated substantial improvements in quality-of-life indicators. It should be noted, however, that a subgroup comparison based on surgical approach was not conducted in this study. In our study (7), we retrospectively compared RATS (n=11) with thoracotomy (n=9), which is arguably the reference approach for diaphragmatic plication. Both approaches conferred good functional outcomes, with an improvement in the median MRC dyspnea score by 2 points. Nevertheless, clinical outcomes were significantly better with RATS, which achieved shorter median chest-tube duration (1 *vs.* 3 days; P=0.01) and length of hospitalization (3 *vs.* 7 days; P=0.04).

More recently, due to the growing interest in the field, robot-assisted transthoracic diaphragmatic plication has been investigated in other controlled studies. Le *et al.* (9) retrospectively compared patients who underwent diaphragmatic plication via RATS (n=31) or VATS (n=12). Intraoperative outcomes, postoperative morbidity, and length of hospitalization were similar between the groups; however, RATS was associated with significantly shorter median chest-tube duration (1 *vs.* 2 days; P=0.008). Moreover, patients in the RATS group experienced a significant postoperative increase in mean FEV_1 and vital capacity by 7% and 9%, respectively (P<0.001 for both values). Stuart *et al.* (10) conducted a multicenter, retrospective study comparing short-term outcomes following diaphragmatic plication via RATS (n=39) or thoracotomy (n=61). Although patients undergoing RATS were older (median age of 64 *vs.* 55 years; P=0.01) and had a higher burden of comorbidities (median Charlson Comorbidity Index of 2 *vs.* 1; P=0.02), the RATS group exhibited shorter median length of hospitalization (3 *vs.* 6 days; P<0.01) compared to the thoracotomy group. The rates of postoperative complications and 30-day readmissions were similar between the groups.

As previously mentioned, Marmor *et al.* (2) observed a relatively high incidence of symptomatic recurrences within a brief period post-surgery. Following data analysis, the authors identified that these cases had been performed with the use of an extracorporeal knot-tying device only, as opposed to those who underwent diaphragmatic plication with the use of intracorporeal instrument knot tying (alone or supplemented by extracorporeal knot tying). Of the 17 patients who underwent plication with extracorporeal knot tying alone, 4 (23.5%) patients developed recurrence. The rate of recurrences in this group was significantly higher than that recorded in the group of patients who underwent intracorporeal knot tying (23.5% *vs.* 0%; P=0.016). While there may be contributing factors at play, it is conceivable that the sole reliance on extracorporeal knot tying could be the primary culprit behind the recurrences. Should this hypothesis hold true, the recurrent incidents might be attributed to the inherent characteristics of the device or the way it was employed. Crucially, the authors effectively addressed these concerns by employing the additional use of intracorporeal knot tying, as well as enhancing bedside-assistant training and supervision.

Drawing from the previous observations, the study by Marmor *et al.* (2) underscores the imperative of prudently introducing emerging technologies and novel techniques not only in the realm of thoracic surgery but across the broader surgical field. While often promising improved patient outcomes and reduced risks, new technologies and techniques may initially be accompanied by uncertainty regarding their effectiveness and potential hazards due to limited data (11). This necessitates further implementation to accumulate knowledge and real-world evidence (12).

Pioneering practitioners, tasked with establishing the foundation of clinical experience, ought to provide comprehensive accounts of their encounters with an innovative procedure to facilitate its safe dissemination for broader application (13,14). During this phase of exploration and early dispersion, methodical data collection for each patient undergoing the procedure is critical, especially for documenting adverse outcomes (15). Surgeon-led assessments aimed at uncovering underlying challenges, in tandem with comprehensive education of the entire surgical team, are also pivotal for the safe introduction of a novel procedure into surgical practice (16). Although challenging, the rigorous evaluation of new surgical interventions is achievable through carefully designed studies and meticulously reported evidence, which informs surgical practice (17). The study by Marmor *et al.* (2) serves as an excellent example of this.

In conclusion, the available evidence demonstrates that robot-assisted transthoracic diaphragmatic plication is a promising approach for the treatment of unilateral diaphragmatic dysfunction. The procedure has shown favorable short-term outcomes and patient-reported experiences, as well as comparability to other approaches. As the literature on robot-assisted diaphragmatic plication remains limited, further research is warranted to corroborate these findings. Future studies should focus on long-term outcomes, cost-effectiveness, and potential learning curve implications of this technique. Furthermore, large prospective trials comparing robot-assisted diaphragmatic plication with other minimally invasive and open approaches would provide more robust evidence to inform surgical decision making. Most importantly, the safe and effective implementation of novel technologies and techniques in surgery depends on the diligent reporting of outcomes and experiences by early adopters, which guides subsequent practice and ensures optimal patient care.

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