Robot-assisted thoracoscopic diaphragm plication for symptomatic diaphragm paralysis after cryoballoon ablation

Adriaan Daniels, MD,* Tom Danau, MD,* Gian-Battista Chierchia, MD, PhD,† Carlo de Asmundis, MD, PhD, FHRS,† Jan Lamote, MD, PhD,* Dirk Smets, MD*

*From the *Department of Surgery, Universitair Ziekenhuis Brussel, Vrije Universiteit Brussel, Brussels, Belgium, and †Heart Rhythm Management Centre, Postgraduate Program in Cardiac Electrophysiology and Pacing, Centrum Hart-en Vaatziekten, Universitair Ziekenhuis Brussel, Vrije Universiteit Brussel, Brussels, Belgium.*

Introduction

Cryoballoon ablation is a common technique to treat atrial fibrillation. The most common complication is a phrenic nerve palsy resulting in hemidiaphragm paralysis. A recent meta-analysis estimated the overall incidence at 6.6%.[1] It usually occurs during cryothermal energy delivery on the right side because of the close relationship between the pulmonary vein and phrenic nerve. This paralysis is temporary in virtually all cases.[2] In order to minimize its risk, a pacing decapolar catheter is positioned in the superior vena cava in order to monitor diaphragmatic activity through continuous stimulation of the phrenic nerve. However, diaphragmatic palsy can persist over time in a minority of cases after cryoballoon ablation.[1] The most commonly associated symptoms are orthopnea and dyspnea. Diaphragmatic paralysis does not warrant surgical intervention unless it is symptomatic. An isolated radiographic finding should not be treated. Paralysis owing to iatrogenic phrenic nerve palsy should be observed for 1 to 2 years because function may improve with time. However, if the patient is highly symptomatic, an observation period of 6 months is considered sufficient.[3,4]

Hemidiaphragm plication has become the treatment of choice in the pediatric population for respiratory failure, but it remains rare in the adult population. This is owing to multiple reasons: the association between radiology and symptoms is often not sufficiently recognized and surgeons may be reluctant because of the perceived need for a thoracotomy or the technical difficulty in performing the procedure in a minimally invasive setting using thoracoscopy.[3,4]

KEYWORDS Complication; Cryoballoon ablation; Diaphragm paralysis; Diaphragm plication; Robot
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Case report

We present the case of a 60-year-old man who underwent a cryoballoon ablation because of symptomatic drug-resistant paroxysmal atrial fibrillation. After 85 seconds from the beginning of the freeze in the right superior pulmonary vein at a recorded temperature of −49°C, diaphragmatic capture during pacing in the superior vena cava was lost and phrenic nerve palsy was observed. Despite peremptory interruption of the freeze and immediate balloon deflation, phrenic nerve function did not recover. After the procedure, the patient started developing progressive dyspnea and orthopnea.

He was referred to our pulmonology department for these symptoms after a few months. Physical examination revealed an obese man (body mass index 34.3 kg/m^2) in rather poor physical condition, with diminished breath sounds on the right side, without peripheral edema.

Work-up showed normal N-terminal pro-brain natriuretic peptide and cardiac echography. Chest radiograph and computed tomography revealed an elevated right diaphragm, with adjacent atelectasis of the right lower lobe. A sniff test (evaluation of diaphragm movement under fluoroscopy) showed no movement of the right hemidiaphragm. Pulmonary function test showed diminished forced vital capacity (1.72 L, 45% of predicted reference value), forced expiratory volume in 1 second (1.43 L, 47% of predicted reference value), and vital capacity (1.69 L, 49% of predicted reference value).

Because the dyspnea was strongly impairing the patient's quality of life and because it was progressively getting worse, we proposed a robot-assisted thoracoscopic right hemidiaphragm plication 6 months after the nerve palsy occurred.

Procedure

General anesthesia with double lumen tube is mandatory to allow for single left lung ventilation. The patient is placed in a left lateral decubitus position, with a balloon under the thorax so that scapula and hip are on the same level. A first 8-mm

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KEY TEACHING POINTS

- Phrenic nerve injury is the most common complication after cryoballoon ablation. Especially on the right side, the risk is high owing to the close relation between the phrenic nerve and the pulmonary veins.
- Diaphragm paralysis as an isolated radiologic finding should not be treated. If symptomatic, it can be a very bothersome condition. Diaphragm plication can give good relief of symptoms.
- Minimally invasive surgery (both video-assisted and robotic thoracoscopy) gives less immediate postoperative pain and less long-term neuralgia.
- Robot-assisted thoracoscopy is a good minimally invasive alternative to classic video-assisted thoracoscopy for diaphragm plication, making it an easier procedure to perform.

robotic port was placed in the fourth intercostal space for the camera (30-degree angle down scope). Three more robotic ports were placed on 1 line (1 to the anterior side, 2 to the posterior side) at least 8 cm apart, after CO_2 was insufflated up to 5 mm Hg. One classic 12-mm thoracoscopic assistant port was placed anteriorly just above the diaphragm. A da Vinci Xi Robot (Intuitive Surgical, Sunnyvale, CA) was docked in pelvic mode and targeted toward the bulging diaphragm. On the medial side a fold of the diaphragm was grasped and sutured to a lateral fold using Ethibond 2-0 horizontal mattress suture (Johnson & Johnson Medical, Diegem, Belgium) reinforced with pledgets. This process was repeated 10 times until the whole diaphragm was plicated and was no longer bulging (Figure 1). A chest tube was placed and normal lung ventilation was recommenced. The patient was extubated without any problems. Subsequently, he was brought to the postoperative recovery room, where he was observed uneventfully until the next morning. He was then transferred to the general surgery ward. A postoperative chest radiograph showed marked radiologic improvement (Figure 2). He was discharged 3 days postoperatively.

Follow-up

The patient was reassessed 3 weeks postoperatively. He noted marked improvement of dyspnea but complained of right-sided chest pain. His chest radiograph revealed the presence of a minor amount of pleural fluid. Two and 6 months after the operation his pain was still present and his chest radiograph remained stable. Dyspnea and orthopnea remained much better than preoperatively. However, pulmonary function test showed only minor improvements (Table 1). The patient gained another 3 kg and was advised to lose weight and start physiotherapy, but unfortunately he refused this.

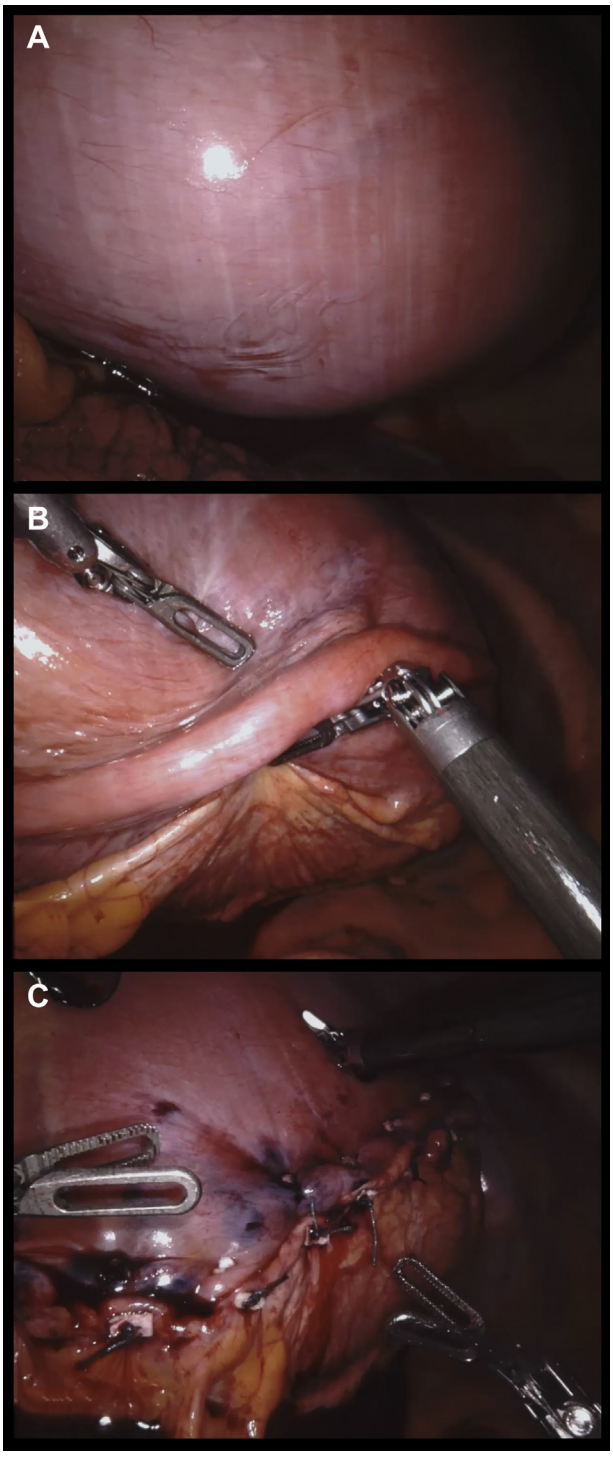

Figure 1 **A:** Bulging diaphragm. **B:** Medial and lateral fold grasped and brought together. **C:** Diaphragm after plication.

Discussion

Video-assisted thoracoscopic diaphragm plication has proven to improve outcomes of patients with symptomatic unilateral diaphragm paralysis.[3] However, owing to perceived technical difficulty this procedure is often not offered in many institutions, including our own. Robotic surgery is starting to gain some ground in thoracic surgery

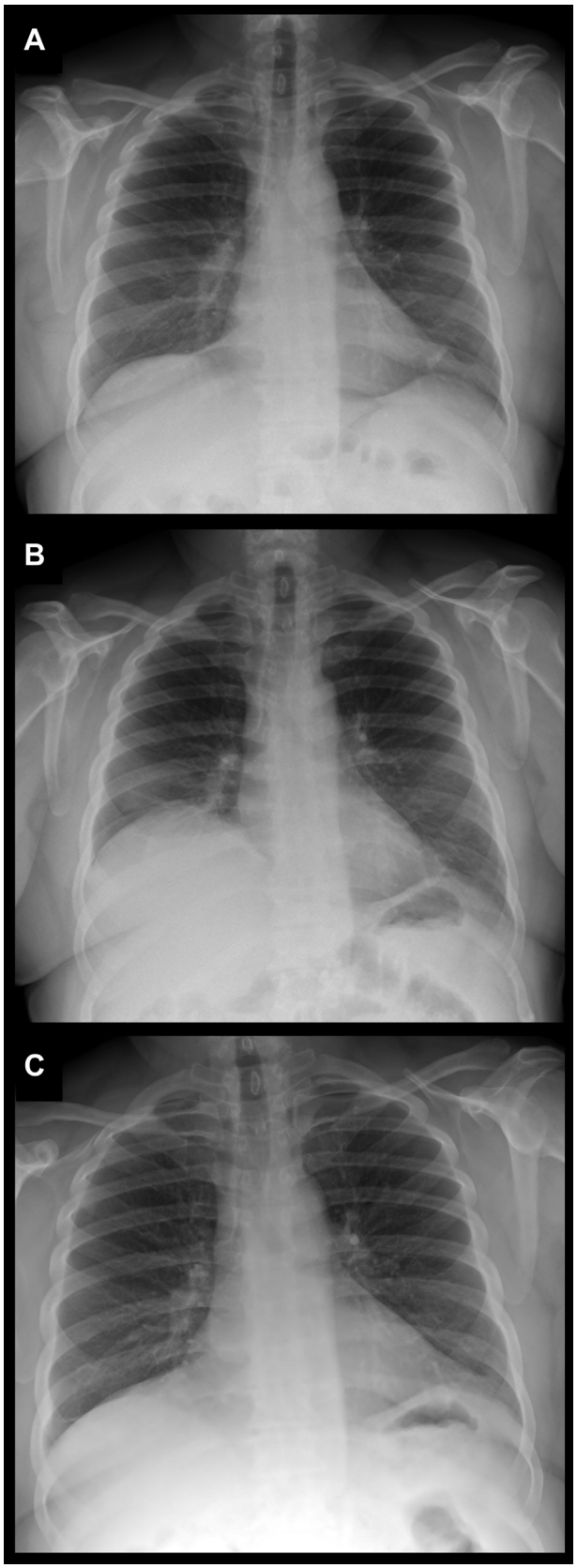

Figure 2 **A:** Chest radiograph before ablation. **B:** Chest radiograph after ablation. **C:** Chest radiograph 6 months postoperatively; note the changing position of the right hemidiaphragm.

Table 1 Pulmonary function test

	FVC (L)	VC (L)	FEV_1 (L)
Before surgery	1.72	1.43	1.69
After surgery	1.95	1.58	1.70

FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; VC = vital capacity.

and has proven to be a good alternative for many other procedures (eg, lobectomy) with a shorter learning curve than classic video-assisted thoracic surgery.[5] Some institutions prefer a hybrid approach that combines classic thoracoscopy with mini-thoracotomy,[6] but in our experience a robotic procedure is a feasible and relatively easy procedure for a thoracic surgeon with robotic experience. It might convince surgeons to approach this procedure in a minimally invasive way. Although we cannot show a marked objective improvement in this case report, we strongly believe that a robotic approach should be considered at least as good as a classic thoracoscopic procedure. Moreover, this approach provides more ease and comfort to the surgeon, thanks to the improved visualization with the 3D camera and the added degree of mobility that the robotic platform offers.[7] However, the higher cost is an obvious disadvantage. We should also note that our patient developed a postoperative neuralgia. Minimally invasive surgery has proven to result in less immediate postoperative pain and long-term neuralgia than thoracotomy, although neuralgia remains an important problem (up to 18%). There is no difference in neuralgia between robotic and classic thoracoscopy.[8,9]

Conclusion

We believe that robotic diaphragm plication can be a good minimally invasive alternative for patients with symptomatic diaphragm paralysis. Physicians performing cryoballoon ablation for symptomatic drug-resistant paroxysmal atrial fibrillation should be made aware of this minimally invasive surgical option.

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