

## Cryoablation-induced phrenic nerve dysfunction with preserved inspiratory function of the diaphragm

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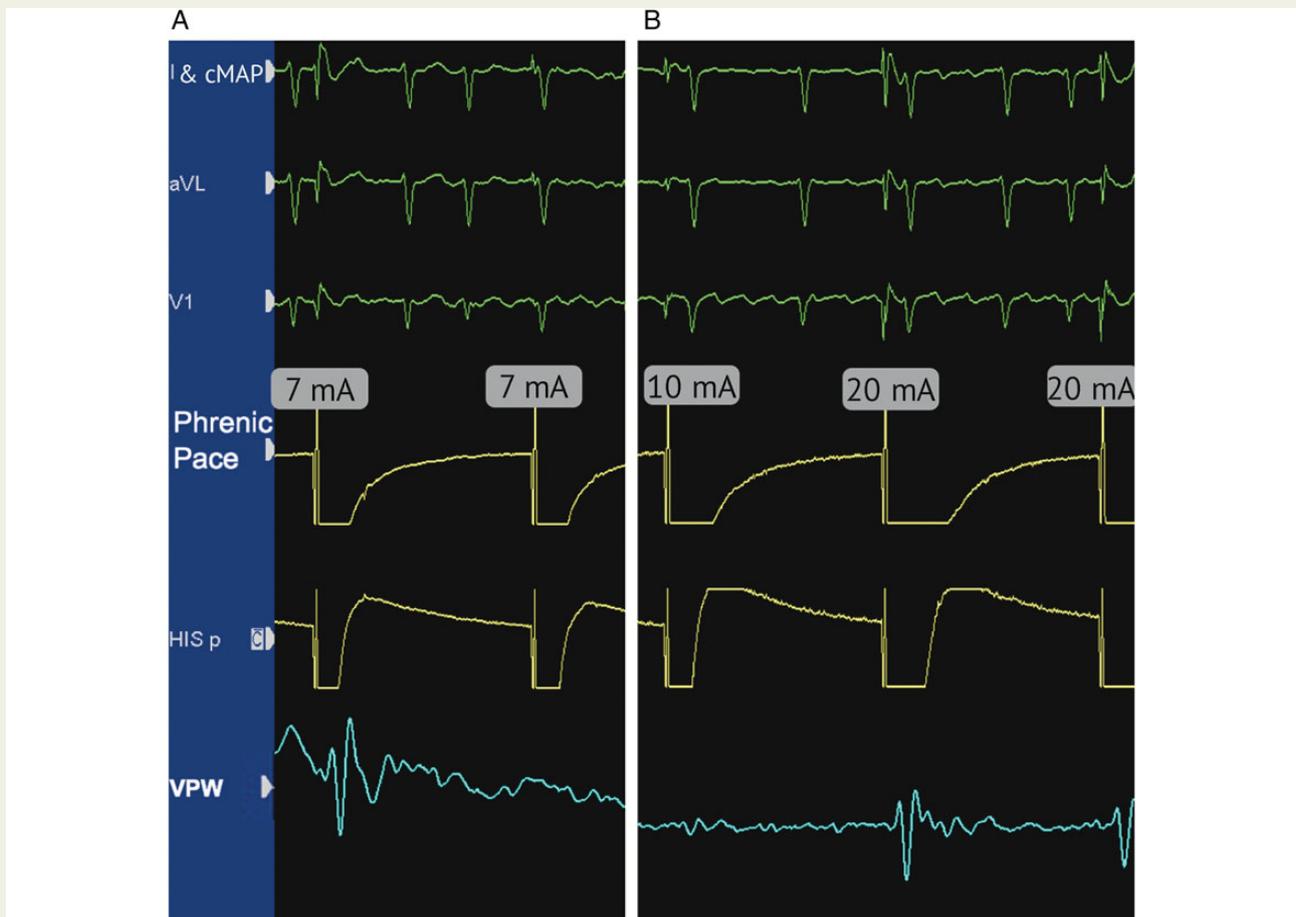
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A 49-year-old woman underwent cryoballoon pulmonary vein isolation for paroxysmal atrial fibrillation. Right phrenic nerve palsy developed during submaximal phrenic nerve stimulation. Despite the inability to stimulate the phrenic nerve with pacing, diaphragmatic excursion during inspiration was preserved. This case demonstrates that submaximal threshold stimulation allows detection of early phrenic nerve injury, with spontaneous diaphragmatic excursion still preserved.

### Case report

A 49-year-old woman underwent cryoballoon pulmonary vein isolation for paroxysmal atrial fibrillation using the second-generation 28 mm cryoballoon (Arctic Front Advance, Medtronic). During ablation of the right inferior pulmonary vein, the phrenic nerve was paced at the subclavian vein,<sup>1</sup> using a stimulation current of 10 mA, 1500 ms cycle length. This resulted in forceful diaphragmatic contraction, reported as moderately uncomfortable by the patient. The pacing output was reduced to 7 mA resulting in a less vigorous, less uncomfortable, and highly reproducible diaphragmatic contraction. Diaphragmatic output was monitored by observation of the venous pressure waveform.<sup>1</sup> Compound motor action potentials (CMAPs) were also recorded.<sup>2</sup> At 50 s of ablation, diaphragmatic motion during pacing abruptly stopped (*Panel A*). Ablation was terminated, and the balloon was immediately deflated.<sup>3</sup> Fluoroscopy of the pacing catheter showed an unaltered position. Despite extensive efforts to capture the phrenic nerve at 7 or 10 mA, diaphragmatic stimulation could not be achieved. Pacing at 20 mA resulted in forceful diaphragmatic motion (*Panel B*). Fluoroscopy of spontaneous respiration demonstrated normal excursion of the right hemi-diaphragm, but the absence of phrenic pacing (see Supplementary material online, *Video*).



Over the following 10 min, stimulation of the right phrenic nerve using 10 mA was not possible. The inferior pulmonary vein remained isolated despite the short freeze duration. At this point, due to the subclinical nature of the phrenic nerve injury, we decided to proceed with right superior vein ablation despite the theoretical risk of worsening right phrenic nerve function further. The right superior vein underwent uneventful cryoablation using a 20 mA stimulus to monitor phrenic nerve function. Following isolation of the right superior pulmonary vein, retesting the phrenic showed that normal function had returned with detectable diaphragmatic motion to a threshold of 4 mA. We have observed the same phenomenon in a subsequent case.

### Discussion

This case highlights the benefit of submaximal stimulation to identify early phrenic nerve palsy, at a subclinical level, i.e. inability to stimulate the phrenic nerve using a given output, but at the same time voluntary diaphragmatic movement being preserved. The likely mechanism for this finding is that submaximal pacing preferentially captures peripheral nerve bundles, whilst central fibres remain inactive. Cooling of the phrenic nerve initially affects the peripheral nerve bundles,<sup>4</sup> resulting in an early loss of function, allowing ablation to be ceased prior to central fibre cooling. It is unlikely that micro-displacement of the pacing catheter accounted for these findings because (i) stimulation at the right subclavian vein position is highly resistant to catheter displacement,<sup>1</sup> (ii) extensive efforts to recapture the phrenic nerve using a higher-output stimulus were unsuccessful, and (iii) during ablation of the right superior pulmonary vein, the phrenic nerve capture threshold fell from 20 to 4 mA, without repositioning of the pacing catheter. Techniques such as forming a more proximal occlusion may also assist in the prevention of phrenic nerve injury.<sup>5</sup> It is unknown if the likelihood of phrenic nerve injury at the superior vein is associated with the risk of injury at the inferior vein. Furthermore, it is unclear if the effect of a second lesion would be additive to or independent of the first lesion. However, in this case, due to the subclinical nature of the initial lesion, and the effectiveness of the Immediate Balloon Deflation technique, we elected to proceed with ablation cautiously at the superior vein.

This case demonstrates that stimulating the phrenic nerve with a submaximal pacing stimulus leads to early detection of phrenic nerve palsy, and normal inspiratory diaphragmatic motion can be present despite 'apparent' phrenic nerve palsy.

### Supplementary material

Supplementary material is available at *Europace* online.

**Conflict of Interest:** J.G. has received honoraria for lectures relating to cryoablation.

## References

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