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EDITORIAL

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Editorial to "Positioning an ECG electrode to the dorsal side can record higher amplitude of CMAPs during cryoballoon ablation"

Cryoballoon ablation for pulmonary vein (PV) isolation is reportedly an effective and curative therapy due to its achievement of a durable lesion, but phrenic nerve injury (PNI) remains a major complication, especially during application to the right superior PV, occurring in 3%-11% of procedures.

To prevent PNI during cryoballoon ablation, monitoring of the diaphragmatic compound motor action potential (CMAP) is useful and widely recognized to be more sensitive than palpable and visual diaphragmatic movements on fluoroscopy for detecting early changes to the diaphragmatic signal representing the function of PN.[1] The diaphragmatic CMAP can be obtained with esophageal electrodes and direct needle and body surface electrodes, with the latter being the simplest and safest approach. Several positions of electrocardiogram (ECG) electrodes for the detection of accurate diaphragmatic electromyographic signals have been previously proposed, with the best electrode position being shown to be 5 cm above the xiphoid and 16 cm along the right costal margin.[2] Using this method, Mondesert et al previously elegantly demonstrated the utility of CMAP monitoring in a human clinical study, in which a > 30% of decrease from the baseline (0.94 ± 0.61 mV) in CMAP amplitude was shown to be a reliable cutoff value for preventing PNI during cryoballoon ablation. In addition, only three of 200 (1.5%) patients showed PN palsy beyond the end of the procedure, with all cases recovering within 6 months by the interruption of application before the CMAP reduction exceeded 30%; however, that study was non-randomized analysis at a single center.[3]

The variability in the amplitude of CMAPs induced by respiration is a limitation to diaphragmatic CMAP recording on the body surface, and CMAP recordings have been unable to be obtained due to a low amplitude in some patients, especially obese subjects. Because the reduction in the CMAP amplitude is key to predicting and preventing PNI based on CMAP-guided PN monitoring, theoretically, the higher the CMAP amplitude, the easier it is to decide to stop the application at the time of >30% reduction of CMAP.

Mizukami et al reported the novel CMAP recording method using the original electrode position of 5 cm above the xiphoid on the dorsal side for the first (ie, Th7 level), with the second surface electrode positioned 16 cm along the right costal margin.[4] They retrospectively assessed and compared CMAP amplitudes between the conventional (ventral side)[2,3] and novel (dorsal side)[4] method during cryoballoon ablation, and concluded that CMAP amplitude was significantly higher with the novel method compared to the conventional method (0.80 ± 0.31 mV vs. 0.66 ± 0.29 mV, $P < .01$) and CMAP amplitude with the novel method was higher than conventional method in 85.8% of patients during pacing at right PN. In their population (n = 197), PNI persisted beyond the procedure occurred in six of 197 (3.0%), but none developed permanent PNI when using the same CMAP cutoff value (>30% reduction) of the higher amplitude in the novel or conventional method. These results suggest that measuring the CMAP amplitude with the novel method reflects a bigger summated diaphragmatic muscle potential waveform than when using the conventional method because the electrodes are positioned in the same direction as the muscle contraction.

The diaphragm is a large, complex muscle with a dome shape and several anchor points along the rib cage (sternum, thoracic, and lumbar vertebrae), in contrast to the majority of muscles studied electrophysiologically, which usually have only two anchor points and an easily identified muscle belly. The orientation of the electrical dipole of the diaphragm remains unclear, so the use of a dorsal electrode might be a good idea for detecting the diaphragmatic CMAP.

The limitations associated with their study, including the output setting (fixed 7V/2ms) for PN pacing and the study design, underscore the need for further investigation. The amplitude of the CMAP may be influenced by the threshold for PN capture, and, indeed, the baseline CMAP amplitude has been shown to vary among studies depending on the output settings for PN pacing. A previous study demonstrated a higher CMAP amplitude with PN pacing at the maximum output than at an output exceeding the pacing threshold by 10%.[5] As the pacing threshold differs according to the pacing site and contact with the pacing electrode, the use of an output with the value set around the pacing threshold is thus deemed to be effective for assessing the amplitude of CMAP. In addition, those authors elegantly demonstrated a higher CMAP amplitude with the novel method than with the conventional method; however, this result did not directly support the utility of the novel method for preventing

PNI compared to the conventional method. To assess the utility of this novel method thoroughly, a randomized study between the novel and conventional method for preventing PNI during cryoballoon ablation should be conducted.

CMAP-guided cryoballoon ablation has recently been shown to be feasible and useful, but determining the optimal PN pacing site with good stability and a low threshold for PN capture as well as applying the optimal recording method of CMAP are important for preventing PNI.

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