A 58-year-old man was referred for catheter ablation of symptomatic persistent atrial fibrillation without structural heart disease. Informed consent and local committee approval were obtained. He underwent preprocedural cardiac computed tomography (CT) angiography after administration of intravenous contrast for evaluation of left atrium and pulmonary vein (PV) anatomy. The pericardiac course of the right phrenic nerve (RPN) was delineated on the CT imaging by an experienced radiologist, either using direct RPN visualization or inferring the position of the right pericardiophrenic bundle by visualizing the right pericardiophrenic artery when RPN could not be directly seen. A new CT imaging sequence was created containing the original CT images with the path of the RPN overwritten by a 5-pixel wide 3-dimensional curved line at 900 HU value in attenuation to facilitate segmentation of the RPN in the electrophysiology laboratory. Three-dimensional reconstruction of the CT images in the new sequence was performed using the CARTO 3 software (Biosense Webster, Diamond Bar, CA). The cardiac chambers, PVs, and the RPN were segmented using the applied specific attenuation threshold.

Detailed contact electroanatomic mapping of the left atrium, PVs, right atrium, and superior vena cava was performed using the fast anatomic mapping feature of CARTO 3, and the fast anatomic mapping was then merged with the CT images using CARTOMERGE. Differential output pacing (10, 30, and 50 mA at 2-ms pulse width) was performed along the course of the RPN in right superior PV, left atrium, superior vena cava, and right atrium. RPN capture was assessed by manual palpation of the patient’s right hypochondrium for diaphragmatic contraction during pacing. Noncapture and capture points were tagged on the electroanatomic mapping using different colors depending on RPN’s threshold.

RPN capture points were marked in the cardiac chambers adjacent to the merged RPN CT image, and capture threshold correlated visually with the actual distance between capture points and the RPN (Figure). In general, capture points at 10 mA were located ≤5 to 10 mm from the RPN, whereas capture points at 50 mA were located ≤10 to 20 mm from the RPN. Noncapture points at 50 mA were distant from the RPN. Ablations surrounding the right PVs were not performed where the RPN could be captured at any output. PV isolation using circumferential antral ablation was subsequently performed without complications.

RPN injury is a highly symptomatic but uncommon complication of right superior PV isolation or superior vena cava ablation. The position of the RPN is often inferred by pacing maneuvers, and ablation is avoided where capture is obtained. There is, however, no available information about the actual distance between the anatomic site of capture at different pacing outputs and the RPN location.

We report for the first time a 3-dimensional segmentation of the pericardiac RPN in the setting of atrial fibrillation ablation, allowing an estimation of the virtual electrode size during variable output RPN pacing maneuvers. These data may provide insight into the safe anatomic distance that allows for ablation energy delivery without phrenic nerve injury. Pacing sites with no capture of the RPN at 50 mA are safe to ablate because the RPN is further than 10 mm. However, noncapture at 10 mA seems insufficient to provide safety because the RPN can still be close and may be injured by radiofrequency application. During RPN delineation using pacing maneuvers, a pacing output of 50 mA should be mandatory, and stimulators limited to 10 mA should be avoided.

Acknowledgments
We thank Heather M. Reifsnyder (Biosense Webster).

Disclosures
Dr Squara has received a research grant from Federation Francaise de Cardiologie, Sorin Group, and Endosense. The other authors report no conflicts.
References


Key Words: atrial fibrillation • catheter ablation • phrenic nerve

---

**Figure.** Localization of the right phrenic nerve (RPN) by 3-dimensional computed tomography (3D-CT) segmentation and pacing maneuvers. **A,** Three-dimensional CT reconstruction of the pericardiac RPN course. **B,** Pacing maneuvers of the RPN in superior vena cava (SVC) and right atrium (RA) and size of the virtual electrode at 50 mA. **C,** Pacing maneuvers of the RPN in left atrium (LA) and size of the virtual electrode at 10 and 50 mA. Please note that the 3 noncapture points at the inferior border of the RPN are actually further from the nerve than the capture points at 50 mA, as it can be seen in the electroanatomic mapping (EAM), or in the Movie in the Data Supplement. LAA indicates left atrial appendage; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; RAA, right atrial appendage; RIPV, right inferior pulmonary vein; and RSPV, right superior pulmonary vein.
Prospective 3-Dimensional Computed Tomography Segmentation of the Pericardial Right Phrenic Nerve in the Setting of Atrial Fibrillation Ablation
Fabien Squara, Benoit Desjardins, Francis E. Marchlinski and Gregory E. Supple

Circ Arrhythm Electrophysiol. 2014;7:561-562
doi: 10.1161/CIRCEP.113.001329

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circep.ahajournals.org/content/7/3/561

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation: Arrhythmia and Electrophysiology can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation: Arrhythmia and Electrophysiology is online at:
http://circep.ahajournals.org/subscriptions/