

# Integration of CT and fluoroscopy images in the ablative treatment of atrial fibrillation

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Radiofrequency pulmonary vein (PV) ablation has proved to be an effective treatment of paroxysmal and persistent atrial fibrillation [1-4]. Because of the complexity of the atrial-PV anatomy, imaging of the left atrium and pulmonary veins plays an important role in ensuring the successful outcome of the procedure. Additionally, the need to create ablation lines in three dimensions around the ostia of the pulmonary veins makes it important for imaging of this area to be integrated in the ablation procedure itself, rather than being a peripheral aid. Fluoroscopy alone shows no contrast differentiation between the pulmonary veins and the surrounding structures.

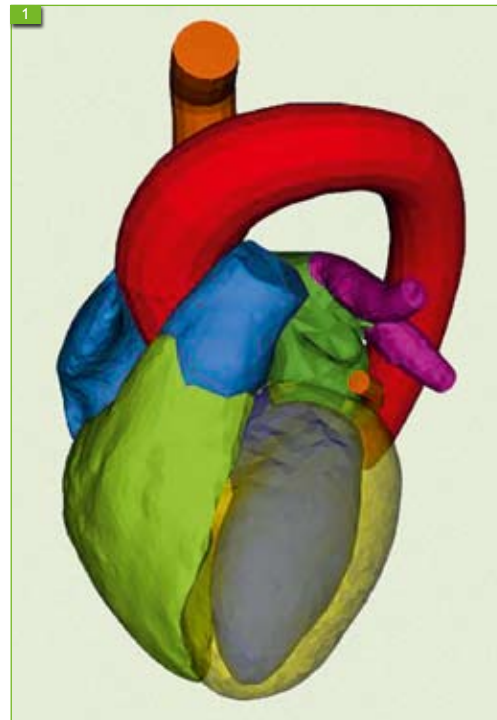
In this article we report on our experience over slightly more than a year with a CT/fluoroscopy integration system (Philips EP Navigator).

## EP Navigator

EP Navigator provides an automatically segmented 3D CT image of the heart for navigation in electrophysiology procedures. The 3D CT images can be combined with live fluoro data from a Philips Allura Xper cath lab system. The user selects the 3D anatomy (e.g. left atrium and pulmonary veins) to be combined with the live fluoroscopic images.

## Heart segmentation

Usually, the day before the procedure, all patients undergo a contrast-enhanced 64-slice CT scan of the chest. Automatic segmentation of the heart is done by matching a generic heart model to the CT images. This model has been described in detail by Ecabert et al. [5]. In brief, it is a surface model comprising the endocardial surfaces of the four chambers, the left ventricular epicardium, the pulmonary artery trunk, the aorta, the inferior and superior vena cava, the coronary sinus and four pulmonary veins (Figure 1).



## Important note:

*This article describes a study conducted outside the United States of America. At the time of publication, the U.S. Food and Drug Administration has not cleared RF ablation for the treatment of atrial fibrillation.*

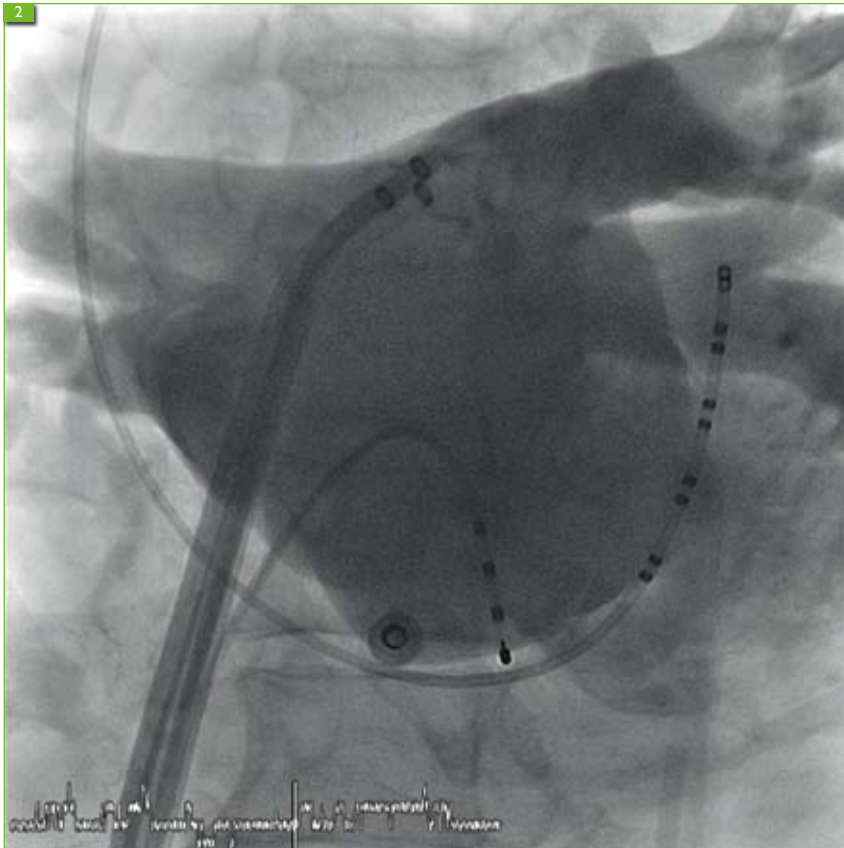
Figure 1. Generic heart model used in the EP Navigator. Heart segmentation is carried out by matching this model to the CT image.

► **The EP Navigator combines 3D CT and fluoroscopy images of the heart for accurate navigation.**

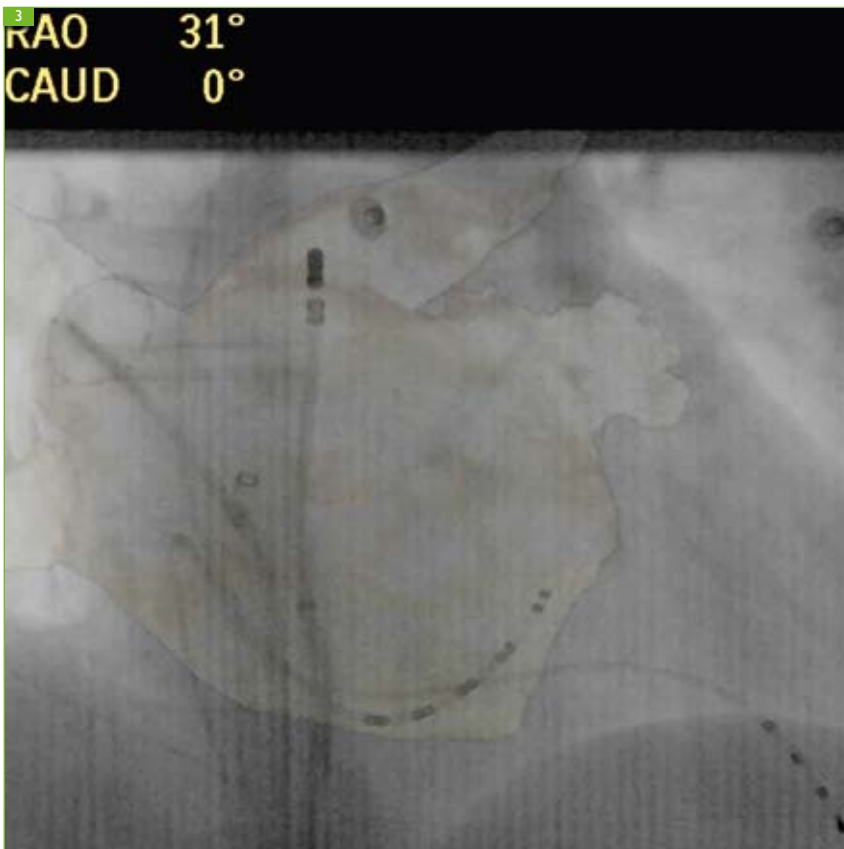
The geometry of the model is described by 8,506 surface points defining 17,324 triangles. Information on the appearance of the cardiac structures in CT images is attached to each triangle in order to support the matching process.

The model is matched to the CT images in five steps. First, the heart chambers (including the left ventricular epicardium) are detected in the image with a generalized Hough transformation and placed accordingly. Secondly, the location, orientation and scaling of the heart chambers are adjusted and, thirdly, the individual sizes of the chambers are optimized. The four chambers are then deformed to accurately represent the patient's anatomy in the CT image.

In addition to this matching process, segments of the vascular structures are subsequently added and adopted, until each structure in the heart



▲ Figure 2. Left anterior oblique 30° projection of a rotational angiogram of the left atrium during adenosine-induced asystole. Complete filling with contrast agent provides excellent visualization of the left atrium and pulmonary veins. The image also shows a 10-pole coronary sinus electrode and a 4-pole right ventricular electrode.



model is matched to the corresponding structure in the CT image.

### CT/fluoroscopy alignment

During the procedure, a 6 F 10-pole catheter (Supra-CS, Bard Electrophysiology, Lowell, USA) is placed in the coronary sinus and a 4-pole catheter is positioned at the apex of the right ventricle. After two transseptal punctures, a circular 10-pole catheter (Lasso, Biosense Webster) is placed in the left superior pulmonary vein, close to the ostium. A pigtail catheter is introduced into the left atrium, and a contrast-enhanced rotational angiography run is performed (RAO 50° to LAO 50°).

In order to achieve good filling of the left atrium and pulmonary veins with contrast agent, a short asystole (about 6 seconds) is induced by administering a bolus of 30 mg adenosine intravenously shortly before the rotational angiography (Figure 2). Alternatively, rapid ventricular pacing (200 bpm) may be used to decrease output from the left atrium to the left ventricle.

The left atrium and pulmonary veins are reconstructed from the axial slices and segmented using the image processing workstation of EP Navigator (see above: Heart segmentation).

In the next step the CT scans of the left atrium are imported into the Allura Xper system and manually aligned with the X-ray imaging projections. In order to achieve reliable alignment, three fluoroscopy projections are used: right anterior oblique 40°, anterior-posterior, and left anterior oblique 40°. In each projection, the EP Navigator enables visual adjustment of the CT image of left atrium to match the fluoroscopic image. In the CT image, the markers used for alignment are the coronary sinus and right superior pulmonary vein. In fluoroscopy, the markers are the coronary sinus catheter and a circular diagnostic catheter (Lasso) placed in the right superior pulmonary vein (Figure 3).

The present version of EP Navigator does not allow for automatic fusion of the CT image and the contour of the left atrium/PVs in rotational angiography. Nevertheless, the anatomical information gained from the angiography is of

◀ Figure 3. During alignment of the CT image of the left atrium with fluoroscopy the coronary sinus catheter and a circular mapping catheter (Lasso) placed in the right superior pulmonary vein are used as landmarks. The tip of the ablation catheter is placed at the superior segment of the ostium of the left superior pulmonary vein.

great help for the fine manual adjustment of the alignment. After fusion is completed the ablation procedure is started.

### Electrical isolation of the pulmonary veins

During the last year, 70 patients have been treated in our center by pulmonary vein isolation using the EP Navigator. In the first 50 patients we used the “double-Lasso” approach during which two Lasso catheters are placed in the right superior and inferior pulmonary veins. With the Lasso catheters in place, radiofrequency ablation is started at the superior segment of the right superior PV (about 5 - 10 mm outside the ostium) and is advanced inferiorly in order to create a ring-like ablation line that includes both PV ostia.

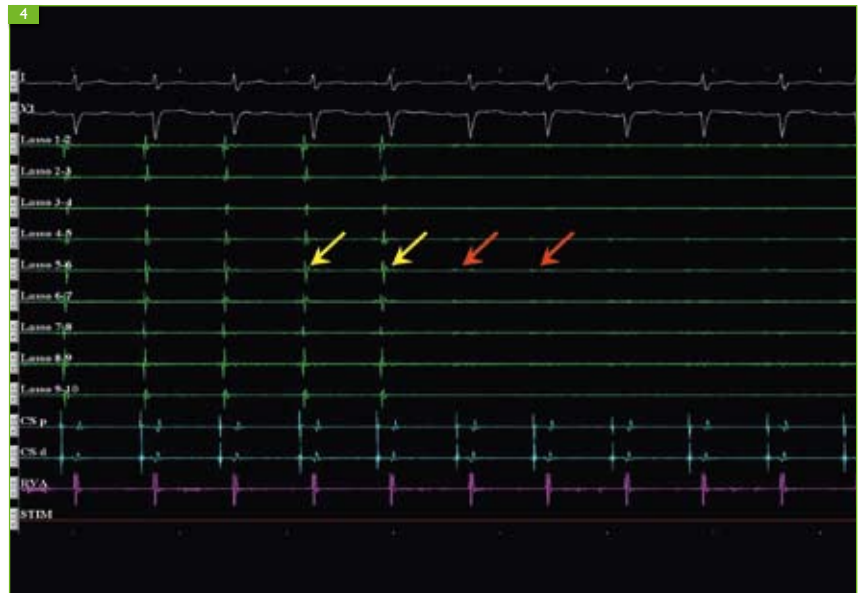
After electrical isolation of the right PVs (Figure 4) there is a waiting time of 30 minutes. During this time, reconnection of the PV occurs in about 30% of the patients. If this is the case the “gap” in the ablation line is again targeted with RF energy to achieve re-isolation.

The same procedure is then followed for the left PVs, with special attention being paid to the anterior ridge of the left superior PV immediately adjacent to the left atrial appendage. The end point of the procedure is the complete electrical isolation of all pulmonary veins.

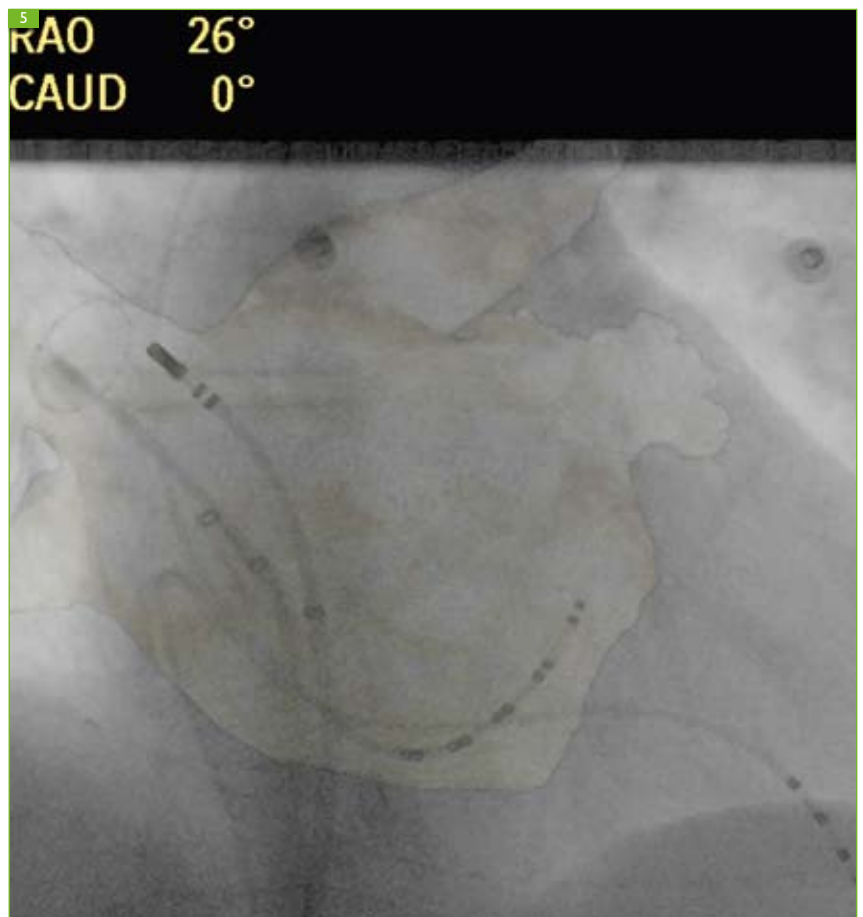
In the second group of 20 patients, in order to reduce the length of the procedure, we used a single Lasso catheter placed sequentially in all four pulmonary veins. If the patient was in atrial fibrillation at the end of the procedure, electrical cardioversion to sinus rhythm was performed.

For ablation of the right superior PV (RSPV) we usually use a projection in fluoroscopy and the EP Navigator that clearly shows the transition of the PV ostium to the PV antrum. In the majority of the patients this is RAO between 30° and 10° (Figure 5). In this projection, the EP Navigator enables accurate positioning of the ablation catheter at the antral site of the PV ostium, thus avoiding RF application within the PV.

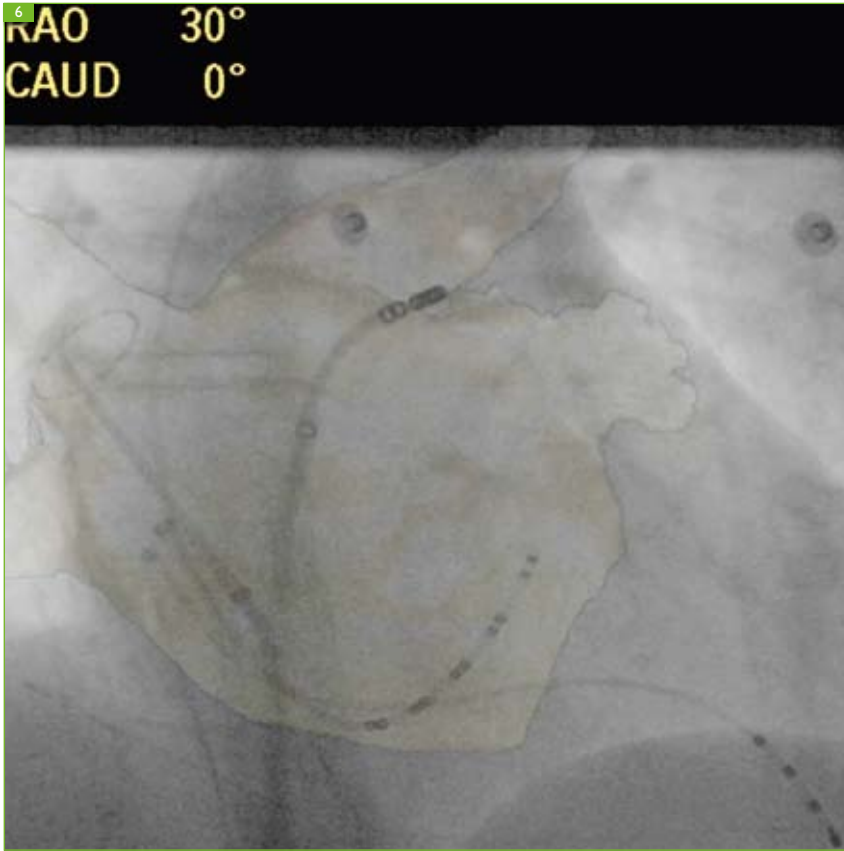
Turning the ablation catheter clockwise or counter-clockwise allows the anterior and posterior segments of the PV ostium to be reached, respectively. The anterior or posterior position is verified in the EP Navigator in the left anterior oblique (LAO) projection (usually about 40° - 50°). For ablation at the ostium of the right inferior PV (RIPV), the EP Navigator is rotated to the LAO 40° - 50° projection.



▲ Figure 4. Electrical isolation of the right superior pulmonary vein (RSPV). The 10-pole Lasso catheter is placed at the ostium of the RSPV and registers the characteristic PV potentials (Lasso 1 - 10, yellow arrows). Upon completion of the isolation line around the PV ostium, PV potentials abruptly disappear (red arrows).



▲ Figure 5. Radiofrequency ablation of the right superior pulmonary vein seen in the right anterior oblique 26° projection. The tip of the ablation catheter is placed in the superior segment of the vein ostium. In this projection the transition of the pulmonary ostium to the adjacent left atrium can be clearly identified.



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 Figure 6. Radiofrequency ablation of the left superior pulmonary vein in the right anterior oblique 30° projection. In this projection EP Navigator clearly shows the “ridge” between the left superior pulmonary vein and the left atrial appendage.

If necessary, the distance of the tip of the ablation catheter from the RIPV ostium is reassessed in an RAO projection (usually RAO 50° - 30°). During ablation, special attention is paid to the inspiration-dependent inferior displacement of the RIPV. This can be up to 18 mm [6]. The present version of EP Navigator does not align the CT image of the left atrium/PV to the respiration-dependent movements of these structures.

RF ablation of the left superior PV (LSPV) is performed in the LAO 40° - 50° projection in the posterior ostial segments and in the RAO 40° - 30° in the anterior segments. In the EP Navigator this projection enables a clear identification of the ridge between the RSPV and the left atrial appendage (Figure 6). Application of RF energy proximal to the ostium of the left inferior PV (LIPV) is performed in the LAO 40° - 50° projection. Turning the ablation catheter clockwise or counter-clockwise moves its tip to the posterior or anterior segments of the ostium.

In the majority of the patients we do not perform additional ablation lines after isolation of the pulmonary veins. If this is considered to be necessary we perform two additional lines: a roof line (Figure 7) and an ablation line at the mitral isthmus (between the left inferior PV and mitral annulus) under guidance of the EP Navigator.

### Limitations

Because of the lack of clear anatomic points for the fusion of fluoroscopy and computer tomographic images of the left atrium, the fusion process is performed using the fluoroscopic position of catheters placed in anatomic structures such as the coronary sinus and left superior PV, while the same structures are seen in CT. This imposes a significant limitation on the alignment process, as it does not rely on real anatomical reference marks.

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 Figure 7. Performance of a roof line ablation using EP Navigator.

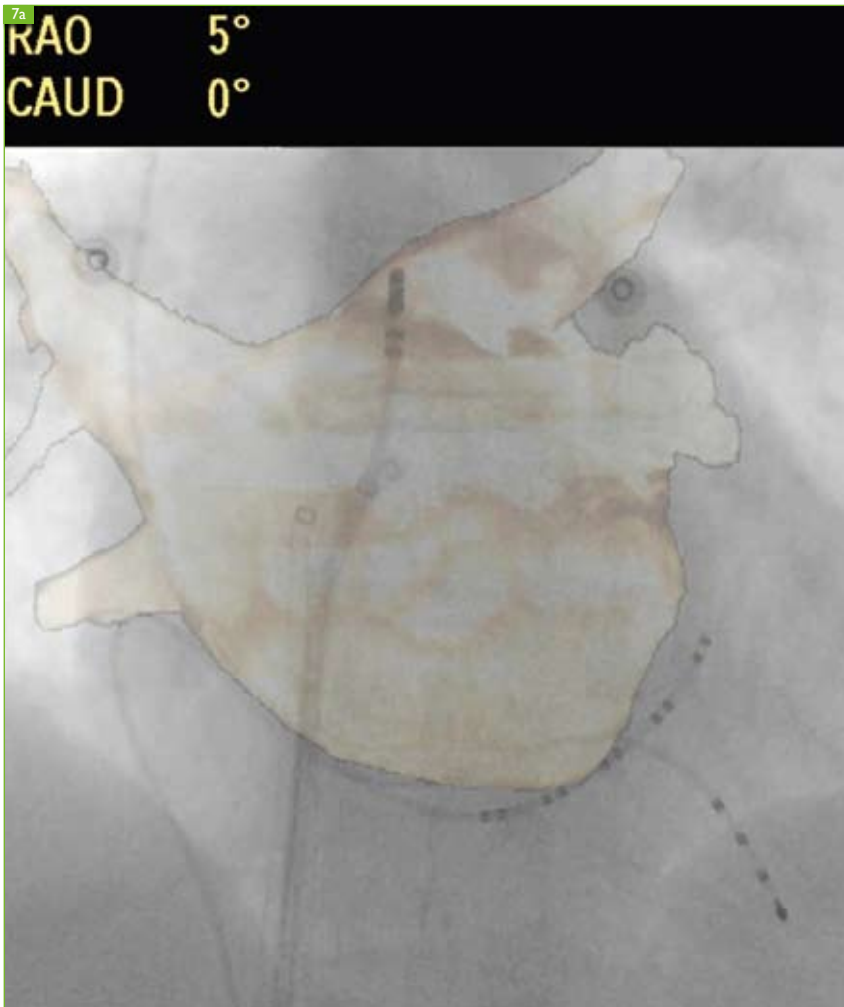


Figure 7a. The ablation catheter is placed against the roof segment of the left superior pulmonary vein.

Fine adjustment of alignment is done by using the anatomical information derived from rotational angiography. In the EP Navigator rotational angiography cannot be directly used as a template for adjusting the CT image of the left atrium.

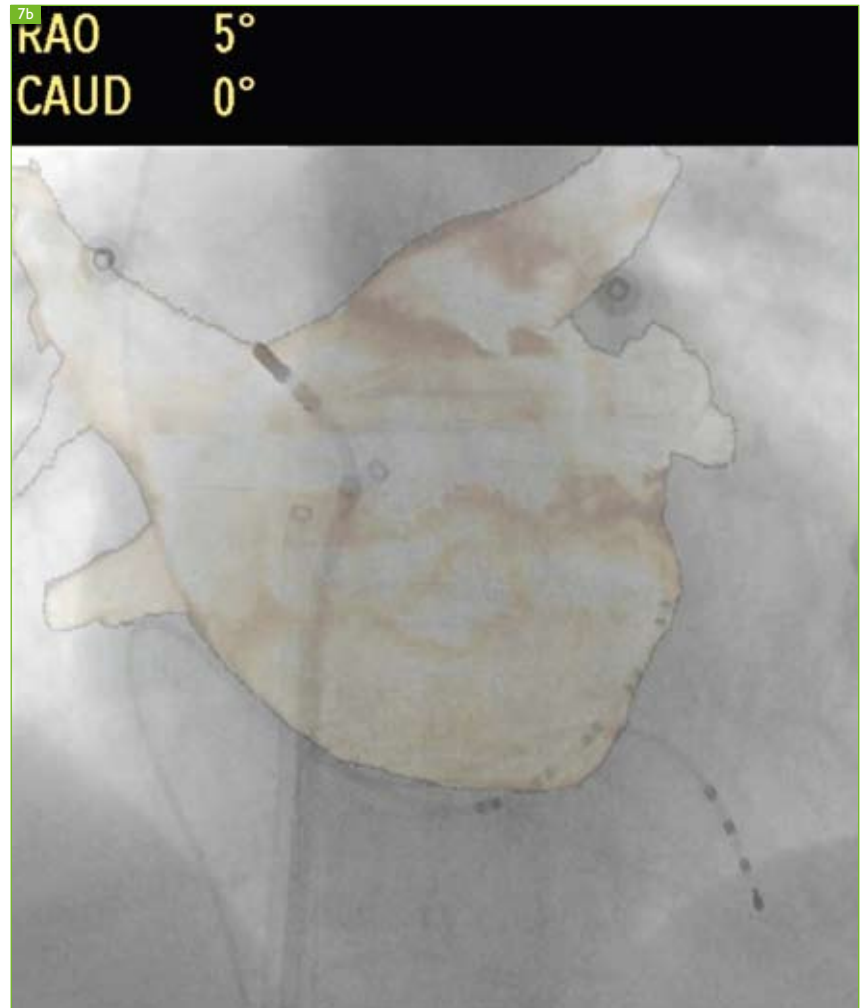
Another limitation is that the present version of EP Navigator does not allow marking of the ablation points. For that reason the use of other mapping and annotation systems (like CARTO in our EP laboratory) is still mandatory.

### Future developments

In order to enhance accuracy, future versions of EP Navigator should be able to trigger CT/fluoroscopy alignment from the respiratory movements of the patient. Additionally, the software should allow positional corrections in the event of involuntary patient movements. Automatic fusion based on the anatomical information from rotational angiography of the left atrium would markedly increase accuracy and probably decrease the time needed to perform the alignment. Finally, marking of the ablation points would enable the operator to track the ablation lines as they are created.

### Conclusion

EP Navigator is very helpful in demonstrating all relevant structures during interventional treatment of atrial fibrillation. The ability to match the 3D CT image to the different fluoroscopic projections enables accurate positioning of the ablation catheter and helps to ensure safe ablation around the ostia of the pulmonary veins ■



▲ Figure 7. Performance of a roof line ablation using EP Navigator.

Figure 7b. During radiofrequency application the ablation catheter is drawn slowly along the roof of the left atrium towards the right superior pulmonary vein.

### References

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