Europace (2014) **16**, 1304–1308
doi:10.1093/europace/euu062

CLINICAL RESEARCH
Ablation for atrial fibrillation

Assessment of oesophageal position by direct visualization with luminal contrast compared with segmentation from pre-acquired computed tomography scan—implications for ablation strategy

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Received 27 August 2013; accepted after revision 3 March 2014; online publish-ahead-of-print 12 May 2014

Aims Atrio-oesophageal fistula is a rare but often fatal complication of catheter ablation for atrial fibrillation (AF). Various strategies are employed to evaluate the oesophageal position in relation to the posterior left atrium (LA). These include segmentation of the oesophagus from a pre-acquired computed tomography (CT) scan and direct, real-time assessment of the oesophageal position using contrast at the time of the procedure.

Methods and results One hundred and fourteen patients with drug-refractory AF underwent CT scanning prior to AF ablation. The LA and oesophagus were segmented from this scan. The oesophagus was deemed midline, ostial if it crossed directly behind any of the pulmonary vein (PV) ostia, or antral if it passed within 5 mm of a PV ostium. Under general anaesthesia at the time of ablation, the same patients were administered contrast via an oro-gastric tube to outline the oesophagus. Catheters were placed at the PV ostia and oesophageal position in relation to the PVs was established radiographically using a postero-anterior view. Oesophageal position assessed by real-time assessment correlated with the CT scan in only 59% of patients. In 34% the oesophagus was more right sided on direct visualization, while in 7% it was more left sided.

Conclusion Segmentation of the oesophagus from the CT scan did not correlate the real-time oesophageal position at the time of the procedure in over 40% of patients under general anaesthesia. Reliance on the determination of oesophageal position by previously acquired CT may be misleading at best and provide a false sense of security when ablating in the posterior LA.

Keywords Atrial fibrillation • Ablation • Oesophagus

Introduction

Catheter ablation of atrial fibrillation (AF) has become a common ablation procedure performed worldwide.[1] Placement of ablation lesions around the pulmonary vein (PV) ostia to achieve electrical isolation has become the cornerstone of the procedure. However, there is potential for these lesions to extend beyond the atrial myocardium resulting in damage to adjacent structures.[2,3]

The oesophagus lies in close proximity to the posterior left atrium (LA) with a variable amount of connective tissue in between.[4] The average retrocardiac oesophageal wall thickness is only 4 mm [5] and its position relative to the LA is variable. While it often lies behind the posterior LA between the PVs in a midline position, deviation to the left or right may place it adjacent to the right or left PV antral or ostial areas.[6] Application of radiofrequency (RF) energy to the posterior LA in contact with the oesophagus may lead to direct thermal damage to the oesophageal wall or compromise vascular supply by disruption of adventitial arterioles resulting in necrosis.[7,8]

Asymptomatic ulceration or haemorrhagic thermal lesions of varying diameter are seen in up to 15% of patients following AF

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What's new?

- Segmentation of the oesophagus from pre-acquired computed tomography (CT) scan does not correlate the real-time oesophageal position at the time of AF in over 40% of patients under general anaesthesia.
- Twenty percent of patients in whom the oesophagus is in close proximity to or passes directly behind the pulmonary vein at the time of ablation have a midline oesophagus on the pre-acquired CT scan.
- The oesophageal position tends to be more left sided on pre-acquired CT scan than at the time of ablation, regardless of the time between acquisition of CT and ablation.

ablation.[9] This can rarely lead to delayed fistula formation between the oesophagus and the LA. Although the reported worldwide incidence of atrio-oesophageal fistula formation as a result of AF ablation is low (0.03–0.2%),[10,11] it has a high mortality and morbidity rate.[11] This is at least partly related to its delayed occurrence, lack of awareness, and its complex management.[12] It remains the second commonest cause of mortality after AF ablation following tamponade, accounting for 15.6% of fatalities.[13]

Minimizing the risk of atrio-oesophageal fistula has become an important factor in planning an AF ablation strategy. Many advocate the use of oesophageal temperature probes and there are data to support its use coupled with reduction in power in the posterior LA.[14] There is not, however, a direct relationship between oesophageal temperature and oesophageal injury.[4] Another potential way to minimize risk is by pre-operative assessment of oesophageal position, often by segmentation of the oesophagus from pre-acquired computed tomography (CT) or magnetic resonance imaging scanning. This is subsequently overlaid on the three-dimensional (3D) LA reconstruction, and the power is reduced when ablation is performed over areas near the reconstructed oesophagus.[15] However, pre-operative imaging is usually performed at least 1 day prior to the ablation and the oesophagus is a mobile structure which may move over time.[16]

We compared the oesophageal position as determined by pre-procedural CT scanning with the position at the time of ablation as assessed by direct visualization using a simple contrast radiographic method.

Methods

One hundred and fourteen consecutive patients with drug-refractory AF underwent CT scanning prior to AF ablation. None of the patients were excluded. The LA and oesophagus were segmented from this scan using the Verisimo software (St Jude Medical, St Paul) (*Figure 1*) and a 3D geometry constructed. The LA volume and the distance in the coronal plane between the ostium of each PV and the ipsilateral oesophageal border were measured from the CT scan. The oesophagus was labelled ostial if the lateral border crossed directly behind any of the PV ostia, antral if the lateral border was within 5 mm of a PV os, or midline if lateral borders were both >5 mm from the venous ostia where it was deemed unlikely to have an effect of the ablation strategy.

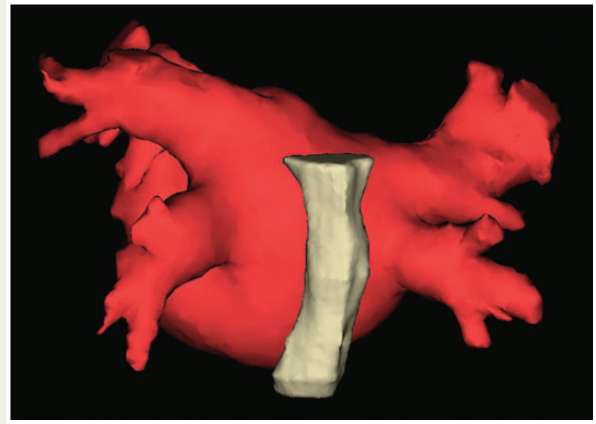

Figure 1 Three-dimensional reconstruction from CT scan (PA view) showing the LA and pulmonary veins (red) with the oesophagus (grey) lying in a midline position behind the atrium.

Under general anaesthesia with endotracheal intubation and paralytic agents at the time of ablation, the same patients were administered 10–20 mL of Visipaque contrast (GE Healthcare) via an oro-gastric tube. Using a 20 pole catheter, a 3D left atrial geometry was constructed (St Jude NavX, St Paul). Using this 3D geometry, catheters were placed at the PV ostia and the oesophageal position in relation to the PVs was established radiographically in the postero-anterior view (*Figure 2*). The oesophagus was labelled ostial if the lateral border crossed directly behind any of the PV ostia, antral if it was adjacent to, but did not cross any of the ostia, or midline. The operators were blinded to the oesophageal position on the pre-acquired CT scan.

Continuous variables are expressed as mean ± SD. Means of LA volumes between various groups were compared with the Student *t*-test. Values of $P < 0.05$ were considered significant. Comparison of the oesophageal position was performed using χ^2 analysis.

Results

Data from a total of 114 patients with drug-refractory AF who underwent CT scanning prior to PV isolation between March 2009 and November 2011 were analysed. Of these patients, 63 underwent ablation for paroxysmal AF, 43 for persistent AF, and 8 for longstanding persistent AF as defined by current guidelines.[17]

Mean LA volume from CT was significantly larger in males (127.8cc ± 24.6) than in females (111.3cc ± 20.8) ($P = 0.05$) and between those with non-paroxysmal AF (128.9cc ± 22.8) compared with paroxysmal AF (115.9cc ± 24.1) ($P = 0.03$). This series includes 87 *de novo* and 27 repeat procedures. The average time from CT scan to ablation was 9 days in the *de novo* group and 255 days in the group undergoing the repeat procedure (these patients did not routinely undergo repeat CT scan prior to their second procedure). No patient in this series underwent a third procedure.

The oesophageal position on CT scan was midline in 67 (59%), left sided in 39 (34%), and right in 8 (7%) cases. On the left, 19 were antral and 20 ostial. Of those with an ostially located oesophagus on the left

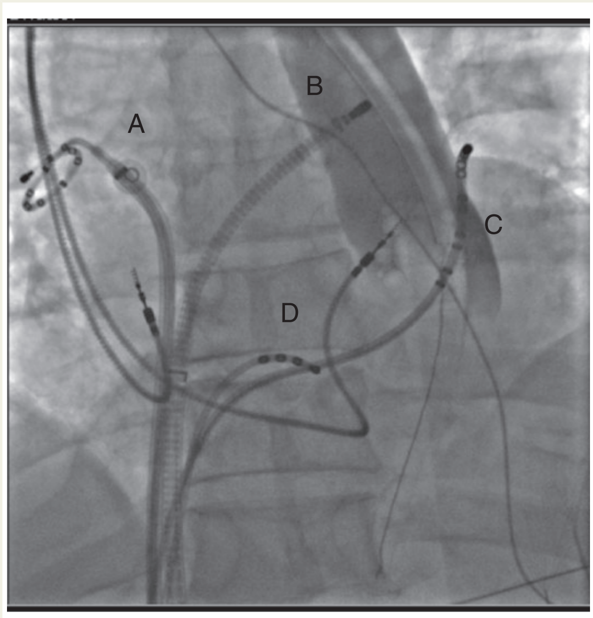

Figure 2 Direct visualization (postero-anterior view) of the same patient as *Figure 1* at the time of ablation. The ring catheter (*A*) is positioned at the os of the right PV and the ablation catheter (*B*) at the left PV os. The coronary sinus catheter (*C*) and His catheter (*D*) are also visualized and dual-chamber pacemaker leads are also seen. Contrast has been given to delineate the position of the oesophagus. In real time the left upper PV is seen lying directly over the oesophagus compared with the midline position in the pre-acquired CT (*Figure 1*). This was one of the more extreme cases of oesophageal mobility between the two imaging modalities we encountered. Dual-chamber pacemaker leads are also seen *in situ*.

side, all had the left superior PV lying directly over the oesophagus with 15 also having the left inferior PV lying over the oesophagus. Similarly all 19 individuals defined as having the oesophagus lying antrally behind the PV were located behind the superior PV with 17 also having the oesophagus overlying the inferior PV antrum. None of the patients had the oesophagus located solely ostially or antrally over the left inferior PV.

On the right side, the oesophagus was positioned ostially in three and antrally in five patients. One patient had the oesophagus lying behind both the right superior and inferior PV ostium, while in the other two it was lying behind the inferior PV ostia only. Of the five patients in whom the oesophagus was lying antrally behind the right lower PV, two were also seen to have it lying behind the upper vein antrum. None of the patients had the oesophagus lying behind the right superior PV antrum only.

On average the left upper PV was closest to the ipsilateral oesophageal border at 8.2 ($\pm$9.3 mm) on the coronal plain with the left lower 10.0 mm ($\pm$9.1) from the oesophageal border. The right upper PV was furthest from the ipsilateral oesophageal border at an average of 22.7 mm ($\pm$11.4) from the border with the right lower slightly closer at 18.6 mm ($\pm$10.5).

In comparison, the oesophageal position determined by real-time contrast fluoroscopy was midline in 75 (66%), left sided in 20 (17%),

Table 1 Oesophageal position on direct visualization (*x* axis) vs. CT scan (*y* axis)

	Oesophageal position on direct visualization				
	R os	**R ant**	**Mid**	**L ant**	**L os**
Oesophageal position on CT scan					
R os	1 (1%)	1 (1%)	1 (1%)	0 (0%)	0 (0%)
R ant	0 (0%)	3 (3%)	2 (2%)	0 (0%)	0 (0%)
Mid	2 (2%)	9 (8%)	53 (46%)	2 (2%)	1 (1%)
L ant	0 (0%)	1 (1%)	10 (9%)	7 (6%)	1 (1%)
L os	1 (0%)	1 (1%)	9 (8%)	6 (5%)	3 (3%)

The numbers in grey indicate those patients in which the positions on CT scan and on direct visualization were correlated. Those above and/or right of the grey are those in whom the oesophagus appeared more left sided on direct visualization than on CT ($n = 8$). Those below and/or left of the grey are those in whom the oesophageal position was more right sided on direct visualization than on CT scanning ($n = 39$).

and right in 19 (17%). Of those on the left 15 were antral and 5 ostial. On the right, 15 were antral and 4 ostial.

Correlation between oesophageal positions as assessed by both CT and direct visualization occurred in only 67 (59%) of cases (*Table 1*). In over one-third of cases (34%), the oesophagus was more right sided on direct visualization compared with CT scanning ($P < 0.01$), while in only 7% did the oesophagus appear to be more left sided. In the majority of cases in whom the oesophagus appeared left ostial on CT, it was found to be either left antral or midline on direct visualization. However, in two cases it appeared to be right antral or ostial. None of those with a right ostial or antral lying oesophagus on CT were found to have a left-sided oesophagus on direct visualization.

To correct for potential confounding variable of time from CT scan to time of procedure, we performed analysis following exclusion of those with a CT scan performed remote from procedure. In those in whom the CT was performed within 2 weeks of the PVI ($n = 76$), a similar result was found with a 56% correlation between the oesophageal position on CT and on direct visualization.

There was no difference in left atrial volume between those with a midline oesophagus and those with an antral or ostial oesophagus on either CT or direct visualization ($P = 0.9$ and 0.44, respectively). There was no difference in left atrial volume between those in whom the oesophageal position on CT and real time correlated and those in whom the oesophageal position varied on the two modalities ($P = 0.62$). This was true even when the oesophagus moved by more than one predefined position ($P = 0.42$).

Of the 27 patients undergoing redo procedures, the oesophageal position on direct visualization remained unchanged from that encountered at the time of the original procedure in 21 (78%). Four (15%) had an antral position recorded at the time of their original procedure and a midline position at the time of their redo and two (7%) had an antral position originally and a midline position at the time of redo.

Discussion

We have demonstrated that the oesophageal position is not midline in around one-third of individuals undergoing AF ablation, no matter what method is used to define its position. As such, any strategy to limit or avoid RF energy delivery in close proximity to the oesophagus requires accurate information about the exact location of the oesophagus relative to the site of intended ablation in any one individual.

While some authors have previously found a good correlation between the oesophageal position on pre-acquired CT scan and at the time of ablation,[15,18] others have, like ourselves, demonstrated that there appears to be significant variation and have suggested that CT does not ensure adequate intra-procedural localization of oesophageal position.[16] A previous study comparing the pre-acquired CT-defined oesophageal position with intra-procedural contrast found concordance between the CT and direct visualization in 87%.[19] However in this study, the oesophagus was classified simply as central, left, or right and in 44% of those individuals where concordance was confirmed, the CT-defined oesophageal border was separated from that seen on direct visualization by $\geq$50% of the oesophageal diameter. In our study, the oesophageal position from the CT scan correlated with the position at the time of ablation in fewer than 60% of patients. We chose to classify those in whom the oesophagus passed within 5 mm of the PV os as having an antral oesophageal position or ostial if it crossed any of the PV os as either of these positions was deemed likely to have a potential effect on the adopted ablation strategy. The oesophagus was only deemed midline if it did not pass within 5 mm of any of the PVs. We did not differentiate between upper and lower veins on direct visualization. Given the average thickness of the oesophageal wall, we felt this was likely to the region where ablation could potentially cause oesophageal injury. If those classified as having a midline or antral position in our study were grouped into one 'central' group our results would give a concordance rate of 80%, similar to that previously published.[19] Of the 67 patients with a midline oesophagus on CT scan, 11 (16%) were found to have an antrally located oesophagus on direct visualization and 3 (4%) had an ositally positioned oesophagus at the time of ablation with a potential impact on the adopted ablation strategy.

The oesophagus was more left sided on the pre-acquired CT scan than at the time of ablation, regardless of the time between acquisition of CT and ablation. We are unable to account for this change in position. The oesophagus is a mobile structure.[20,21] All ablation work was performed with patients fasted and under general anaesthesia with endotracheal and nasogastric tubes *in situ* with many procedures performed later in the day, whereas CT scans were usually performed in the morning with patients awake and non-fasted. Although diurnal variation, fasting state, or changes in the autonomic tone under anaesthesia may account for part of the discrepancy between the two modalities, the fact that 22% of patients having a redo procedure were found to have a different oesophageal position on direct visualization at the time of their second procedure suggests that other factors may also play a role. No matter what the explanation, reliance on determination of the oesophageal position by previously acquired CT may be misleading at best and provide a false sense of security when ablating in the posterior LA. Conversely, it may lead the operator to reduce the power output in areas a good distance from the oesophagus, thereby potentially reducing the chances of procedural success. Indeed, the rightward shift on direct visualization moves the oesophagus further from the left superior vein, the posterior aspect of which has been shown to be in closest anatomical proximity to the oesophagus on CT scan.[22]

Real-time imaging of the oesophagus eliminates the potential for oesophageal mobility between CT scanning and the time of the ablation. Visualization can be achieved with repetitive fluoroscopic visualization of the oesophageal lumen containing contrast during the procedure. In this study, a still image X-ray was taken at the beginning of the procedure and frequent brief fluoroscopy was performed throughout the procedure to assess the oesophageal position in relation to the ablation catheter. No gross movement was detected in any case when compared with the initial reference image, though it is possible that the oesophagus could have moved to a minor degree during the procedure.

Knowledge of oesophageal position would not be critical if one could rely on other methods to prevent oesophageal injury. Luminal oesophageal temperature monitoring is used in some centres as an indicator of oesophageal injury. While widely adopted, the evidence is mixed and some investigators have demonstrated that thermal injury may occur before a rise in recorded luminal temperature with no clear direct relationship between the luminal oesophageal temperature and the occurrence of oesophageal ulceration.[8] Real-time intra-cardiac echocardiography (ICE) provides information not only on the oesophageal position but also on oesophageal wall thickness and the thickness of intervening tissue between the oesophagus and the posterior LA,[23–25] something not possible by direct visualization. However, the oesophageal wall thickness varies with peristalsis,[5] the use of ICE adds to the expense of the procedure and is not available in many centres.

Contrast imaging is a low cost, straightforward tool which is readily available and can be used to confirm or refute the findings from the pre-acquired CT scan. There is currently little evidence that direct visualization leads to a reduction in oesophageal injury.[26] This would require direct visualization of oesophageal thermal lesions post ablation and would require a large series to show a difference. However, oesophageal proximity is used by many centres in guiding ablation lesion set placement and determining RF energy delivery, thereby limiting or reducing heat transfer to, and potential thermal injury of the oesophagus when ablation is needed at the posterior LA. This study demonstrates that assessment by segmentation from pre-acquired CT scan would lead to misinformation on oesophageal position at the time of procedure in 40% of patients and should not be relied upon to guide ablation.

Conflict of interest: none declared.

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