Value of CT localization of the fossa ovalis prior to transseptal left heart catheterization for left atrial ablation

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Aims Transseptal puncture (TP) can be a difficult procedure and is not without risk of complications. The purpose of this study was to evaluate the use of three-dimensional multi-detector row computed tomography (MDCT) to localize the fossa ovalis (FO) and facilitate TP in patients undergoing left atrial catheter ablation.

Methods and results Fourteen consecutive patients were studied. Thirteen patients underwent pulmonary vein isolation and one patient had ablation for left atrial flutter. All patients underwent cardiac MDCT imaging pre-ablation for use in conjunction with electroanatomic mapping. Prior to puncturing the interatrial septum, standard fluoroscopic views of the transseptal sheath were compared with corresponding MDCT images tagging the FO. Successful, uncomplicated TP was achieved in all 14 patients. The mean duration of TP was 15.6 ± 10.0 min. The average fluoroscopy time was 8.5 ± 7.4 min. The MDCT images were deemed helpful in facilitating TP in 13 patients (93%).

Conclusion This study demonstrates the feasibility of MDCT to localize the FO and aid TP. For patients undergoing left atrial ablation in whom MDCT imaging is undertaken pre-ablation, tagging the FO can be easily performed and is a novel tool for guiding transseptal catheterization without additional risk.

KEYWORDS Transseptal catheterization; Computed tomography; Left atrial catheter ablation

Introduction

Percutaneous puncture of the interatrial septum for left heart catheterization was first reported in 19591,2 and is an essential skill required by the modern electrophysiologist. This is particularly so in the era of left atrial catheter ablation procedures for atrial fibrillation (AF). Although the retrograde aortic approach is effective for conventional left sided accessory pathway ablation, it is not without risk of serious complications3,4 and is unsuitable for catheter ablation of AF.

Current techniques for transseptal puncture (TP) rely on fluoroscopic landmarks to define the intracardiac anatomy.1,2 In addition, some operators introduce additional anatomical markers such as a pigtail catheter into the aortic root or coronary sinus and His bundle catheters to guide successful puncture. More recently, both transoesophageal and intracardiac echocardiography have been successfully used to guide TP.5–7

Despite these advances, TP remains a difficult procedure, particularly in patients with atypical anatomy or a small fossa ovalis (FO) and is not without risk of significant complications including aortic puncture, cardiac perforation and systemic embolization.8

Current left atrial ablation strategies for AF commonly employ three-dimensional (3D) reconstructions of the left atrium and pulmonary veins using multi-detector row computed tomography (MDCT). This aids catheter navigation, and can now be integrated with electroanatomic mapping systems.9,10 Furthermore, important structures such as the oesophagus can be tagged to help avoid potentially lethal complications such as atriooesophageal fistula.11–13 However, there have been no data reporting the value of MDCT in tagging the FO to aid TP. Therefore, the purpose of this study was to prospectively evaluate the role of MDCT in localizing the FO to assist in puncture of the interatrial septum.

Methods

Patient characteristics

Fourteen consecutive patients undergoing left atrial catheter ablation were studied. The indications for ablation were pulmonary vein...
isolation (PVI) in 13 patients and ablation for left atrial tachycardia/flutter in 1 patient. Thirteen patients had no evidence of structural heart disease and one patient had a parachute mitral valve and a bicuspid aortic valve as part of the Shone syndrome. All patients were anticoagulated with warfarin for a minimum of 2 months prior to the ablation. Anticoagulation was discontinued 3 days before the procedure. None of the patients underwent transoesophageal echocardiography prior to the procedure. Patient characteristics are shown in Table 1.

Study protocol
All patients were routinely pre-assessed the day before the planned ablation and underwent a thorough history and physical examination as well as a 2D transthoracic echocardiogram. Routine blood tests for serum electrolytes and prothrombin time were taken. All patients then underwent an MDCT scan of the heart and pulmonary veins for use in conjunction with electroanatomic mapping. All patients provided written informed consent.

Multi-detector row computed tomography image acquisition
All CT examinations were performed with a 64-slice LightSpeed VCT scanner (GE Healthcare, Waukesha, Wisconsin, USA). A total of 120 mL of iopromide (Ultravist; Berlex, Montville, New Jersey, USA) (300 mg/mL iodine concentration) non-ionic contrast media was administered using a power injector at a rate of 5 mL/s through an 18- or 20-gauge catheter into an antecubital vein. An initial 20 mL test bolus administered during acquisition of dynamic monitoring scans at the level of the mid-left atrium was used to determine the time to peak enhancement in the left atrium. Image acquisition was then performed during injection of 100 mL of contrast media, commencing at time to peak enhancement in the left atrium plus 6 s. Images were obtained from the thoracic inlet to the top of the left hemidiaphragm during a single breath hold using 64 × 0.625 mm collimation, 40 mm per rotation table speed, and 0.5-s rotation.

Image reconstruction
1.25 mm transverse images were reconstructed and transferred over a network connection to a workstation (Advantage Workstation, GE Healthcare). From the reconstructed transverse images, a 3D model of the left atrium was segmented using a dedicated software package (CardEP, GE Healthcare) and transferred to a volume rendering application on the same workstation [Volume Rendering (VR), GE Healthcare]. Three-dimensional volume renderings of the thoracic spine and heart were then reconstructed. The FO was identified on transverse images and marked using a 10-mm marker sphere (Figure 1), which was then converted to a volume rendering. The volume renderings of the heart, left atrium (coloured blue), thoracic spine (coloured white), and FO marker sphere (coloured yellow) were then merged to create a single 3D volume rendering. Opacity of the thoracic spine and heart volume renderings were then reduced to around 30% to make these structures semitransparent relative to the left atrium and FO marker sphere. Straight anteroposterior, 45° left anterior oblique, and 30° right anterior oblique images of the merged volume rendering were transferred along with the 1.25 mm transverse images and images of the original left atrium model, to our institutions picture archiving and communication system (Intelerad Medical Systems, Montreal, Quebec, Canada).

Transseptal puncture
Diagnostic catheters were initially placed into the coronary sinus and His-bundle region via the right femoral vein. The transseptal sheath (SL2, St Jude Medical Inc., Daig Division, Minnesota, USA or Preface sheath, Biosense Webster, California, USA) was then introduced to the superior vena cava (SVC) via a separate femoral vein puncture with the aid of a long guide wire. The transseptal sheath was loaded with a Brockenbrough needle (Cook Inc., Bloomington, Indiana, USA), which was then advanced to the tip of the dilator. Pressure monitoring was then attached to the proximal end of the needle.

The entire transseptal sheath assembly was then withdrawn from the SVC to the right atrium. The movement of the assembly from the SVC to the level of the FO was observed by fluoroscopy after the characteristic downward ‘jumps’ of the sheath. The position was then checked in three standard fluoroscopic views (anteroposterior, 45° left anterior oblique and 30° right anterior oblique), and the pressure trace was observed to ensure it appeared obstructed. The position of the sheath in the three fluoroscopic views was then compared with the corresponding 3D volume rendered MDCT images localizing the FO in relation to the heart and thoracic spine (Figures 2–4). Once satisfied that the sheath was in the FO, the interatrial septum was punctured with the needle. Successful access to the left atrium was confirmed by the observation of a left atrial pressure waveform and by free injection of contrast into the body of the left atrium. A guidewire was then placed into the left superior pulmonary vein before the sheath assembly was advanced into the left atrium. At this stage 100 IU/kg of heparin was administered intravenously and the activated clotting time was maintained >300 s throughout the procedure. The total TP time in minutes was taken as the time from when the transseptal sheath was inserted into the femoral vein to the time when successful puncture was achieved and confirmed by the above observations. The total fluoroscopy time in minutes was also recorded and the operator denoted whether the MDCT images had been helpful or not.

Ablation procedure
After successful TP, PVI was performed in 13 patients and ablation for left atrial tachycardia in 1 patient. Left atrial geometry was

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<th>Table 1 Clinical characteristics</th>
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<td>Number</td>
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<td>Gender (male/female)</td>
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<td>Hypertension (%)</td>
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<td>Left atrial diameter (mm)</td>
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Data expressed as mean ± SD.
created using an electroanatomic mapping system (Ensite NavX™, St Jude Medical Endocardial Solutions, St Pauls, Minnesota, USA or CARTO, Biosense Webster, California, USA). Circumferential PVI was performed as previously described.14,15 In the patient with left atrial tachycardia, activation mapping was performed prior to successful ablation.

Statistical analysis
Continuous variables are expressed as mean ± SD.

Results
Successful uncomplicated TP was achieved in all 14 patients. The mean duration of TP was 15.6 ± 10.0 min (range 6–46 min). The average total fluoroscopy time was 8.5 ± 7.4 min (range 1.3–31.3 min). The operator deemed that the MDCT images were of additional benefit in assisting TP in 13 patients (93%), both by confirming that the fluoroscopic position of the sheath tip corresponded to the tagged position of the FO on MDCT before puncturing the interatrial septum (Figures 2–4) and also by allowing a visual assessment to be performed of the angulation of the transseptal assembly relative to the line perpendicular to the FO and the plane of the table. This could then be translated to the orientation of the Brockenbrough needle indicator and if necessary, the final angulation was adjusted or repositioning was undertaken to ensure that the puncture site was, for example, not too posterior and hence at risk of perforating the posterior right atrial wall. Refining the final position (n = 3) or repositioning (n = 2) according to
the MDCT location of the fossa was performed in five patients (36%).

In one patient undergoing PVI, the MDCT was felt not to have been helpful in assisting TP. This particular patient had undergone two previous TPs for the same indication and on that occasion, it was technically difficult to engage the FO and subsequently advance the needle across the interatrial septum. The operator felt that this could have been due to scarring around the FO. Successful puncture was however eventually achieved, although both the total TP time (46 min) and the screening time (31.3 min) were long. When these data were subsequently excluded from the analysis, the mean duration of TP was reduced to $13.2 \pm 5.1$ min and the screening time was reduced to $6.8 \pm 3.5$ min.

Figure 3  Top: Left anterior oblique (LAO) view of 3D volume rendered image of the heart, left atrium (blue), thoracic spine (white) and FO marker sphere (yellow). Bottom: corresponding fluoroscopic image of the TS at the level of the FO.

Discussion

The present investigation has demonstrated for the first time that MDCT can be successfully used to assist transseptal left heart catheterization in patients undergoing left atrial catheter ablation procedures. The FO can be reliably tagged in the majority of patients and superimposed onto the 3D volume rendered image of the heart. This allows the operator to easily compare the position of the transseptal sheath in standard fluoroscopic views with the corresponding 3D MDCT images prior to advancing the Brockenbrough needle across the interatrial septum. In our small series, knowledge of the location of the FO from the MDCT images led to either refinement of the final position or repositioning in a third of cases.
Other imaging modalities such as transoesophageal and intracardiac echocardiography have also been reported to be effective in assisting TP.\textsuperscript{5–7} Although transoesophageal echocardiography is feasible, it requires an additional invasive procedure for the patient and may prolong procedure time, requiring a longer period of intravenous sedation. In addition, there is a risk of oesophageal bleeding\textsuperscript{16} and communication with the patient during the procedure may be limited. Furthermore, cardiac perforation has been reported\textsuperscript{5} owing to inadequate localization of the FO. Intracardiac echocardiography has the advantages of providing excellent visualization of the FO\textsuperscript{7} and does not require sedation. However, this technique does require considerable operator experience and may use relatively large catheters.\textsuperscript{17,18}

In the present study, MDCT was routinely performed in all patients primarily to provide 3D spatial information of the left atrium and pulmonary veins for use in conjunction with electroanatomic mapping. No additional imaging was therefore required periprocedure, and the only additional requirement to the operator was to compare the fluoroscopic views of the transseptal assembly with the corresponding 3D MDCT images. This facilitated the TP being performed in a timely fashion without the need for an additional procedure or risk to the patient. However, although 3D MDCT may be the preferred imaging modality to visualize the pulmonary vein ostia prior to ablation, radiation exposure to the patient is a limitation.\textsuperscript{19} Magnetic resonance (MR) imaging has also been widely used to assess pulmonary vein anatomy\textsuperscript{10,21} and like MDCT, images can be

**Figure 4**  
Top: Right anterior oblique (RAO) view of 3D volume rendered image of the heart, left atrium (blue), thoracic spine (white) and FO marker sphere (yellow). Bottom: corresponding fluoroscopic image of the TS at the level of the FO.
integrated into electroanatomic mapping systems.\textsuperscript{9} We speculate therefore that localization of the FO could also potentially be performed with MR and hence avoid exposure to ionizing radiation, although imaging could not be performed in patients with pacemakers, metallic objects, or claustrophobia.

The FO was difficult to tag in one patient in the study. This was due to the introduction of movement artefact during the scanning protocol. However, the FO was subsequently tagged on a 'best guess' basis after review by the attending cardiologist and this was taken into account during the TP. Despite this limitation, the operator still felt that the MDCT images were helpful in localizing the transseptal sheath.

There were no complications from TP observed in this small consecutive series of patients. When performed by experienced operators, the technique is associated with low morbidity and mortality, although when complications do occur, they are often serious and may be life threatening. A retrospective review of 1279 transseptal catheterizations from a single centre over a 10-year period found a 90% overall success rate with a 1.3% incidence of serious complications, including cardiac tamponade, systemic embolii and death secondary to aortic perforation.\textsuperscript{22} In the contemporary era of TP for catheter ablation, a recent series of 184 transseptal procedures reported a higher 3.8% overall incidence of acute complications including cardiac perforation, embolic stroke and bradyarrhythmia.\textsuperscript{23} However, a significant number of subjects had structural heart disease and the report included patients undergoing mitral valvuloplasty. Most commonly, complications arise from failure to locate the FO correctly, which may result in perforation of the posterior right atrial wall or aorta. Although it is not possible to comment from this small series whether the routine use of pre-procedure MDCT would help to further reduce this risk, we speculate that 3D imaging to tag the fossa could potentially be beneficial in this regard. However, other complications such as perforation of the lateral left atrial wall due to over advancement of the transseptal assembly, thromboembolism or air embolism are independent of locating the FO correctly and would not be prevented by pre-procedure 3D imaging.

Study limitations

The major limitation of the present study was the small number of cases reported. In addition, the majority of subjects did not have important structural heart disease, which may be expected to make TP more challenging. A larger series including subjects with structural heart disease would be beneficial in further defining a potential role for pre-procedure 3D imaging of the FO.

The MDCT images for all patients in the study were acquired the day prior to ablation. It is possible therefore that on the day of the procedure, the intracardiac volumes may not have been identical, rendering the 3D images only as an approximation of the live fluoroscopic image. This may have been further complicated if the cardiac rhythm on the day of image acquisition was different to that at the time of TP. However, allowing for this, we found a good visual correlation between the marker localizing the FO and the tip of the transseptal sheath, and in our opinion, changes in intracardiac volume would not have significantly affected the identification of the FO on the transverse images. Furthermore, cardiac rhythm at the time of imaging has been reported to have no significant effect on the accuracy of surface registration during image integration into an electroanatomic mapping system.\textsuperscript{24}

Conclusion

This study demonstrates the feasibility of using 3D MDCT to localize the FO to aid TP. For patients undergoing left atrial catheter ablation in whom MDCT imaging is routinely performed for left atrial geometry, additional tagging of the FO can be easily performed and is a useful tool for guiding transseptal catheterization without additional risk.

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References


