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Original Article

Inadequacy of fluoroscopy and electrocardiogram in predicting septal position in RVOT pacing – Validation with cardiac computed tomography

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ABSTRACT

Background: Electrocardiographic (ECG) and fluoroscopic criteria, which are the only available guides to achieve a true septal position during right ventricular outflow tract (RVOT) pacing, have been infrequently validated. We sought to validate these using cardiac computed tomographic angiography (CTA) to confirm lead position within the RVOT septum.
Methods: Forty-four patients with permanent pacemaker leads in the RVOT position underwent CTA. Lead positions in RVOT were classified as anterior, free wall, or septal location. Fluoroscopic images were obtained in 4 standard views.
Results: Only 19 (43%) patients had lead in true septal position within the RVOT in CTA while 25 patients (57%) were found to have an anterior lead location. Mean QRS axis, QRS duration, negative QRS in lead I, and notching in inferior leads were not significantly different between the two groups. The standard fluoroscopic LAO view showed a rightward-directed lead not only in all 19 patients with septal location, but also in 14/25 patients in the anterior location ($p = 0.22$), and thus had a sensitivity of 100% but specificity of only 16% in predicting true septal position. The posteriorly directed lead in left lateral view was more accurate in predicting true septal position with good sensitivity (73.7%) and excellent specificity (80%).
Conclusions: This study, using validation with CTA, showed that conventional ECG criteria and fluoroscopy are inaccurate in differentiating septal from anterior RVOT pacing. The fluoroscopic lateral view, as corroborated by CTA, is more reliable than the LAO view in predicting septal lead placement.

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Abbreviations: RVA, right ventricular apex; RVO, Tright ventricular outflow tract; LV, left ventricle; RV, right ventricle; ECG, electrocardiography; CTA, computed tomographic angiography; PA, postero-anterior; RAO, right-anterior-oblique; LAO, left-anterior-oblique; LL, left lateral; ms, milliseconds.

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1. Introduction

The right ventricular apex (RVA) has been the traditional site for ventricular pacing for more than half a century, due to the relative ease of implantation, reliability, and stability. However, RVA pacing is fraught with the long-term risk of left ventricular (LV) dysfunction, heart failure, and arrhythmias, like atrial fibrillation. This led to active interest in developing alternative sites of RV pacing, which could lead to a more physiological pattern of ventricular activation.[1–3] Sites that have been studied are the low interventricular septum, mid-septum, HIS bundle,[1] and the RV outflow tract (RVOT).[2] Among these, RVOT pacing has gathered maximum interest due to its possible favorable hemodynamic and electrophysiological profiles, as compared to RVA pacing. RVOT pacing has been shown to result in narrower QRS complexes, lesser dyssynchrony, and better LV systolic function, as compared to RVA pacing.[2,3] Within the RVOT, it is the true septal position that is most desirable.[4] Acquiring a true septal location during pacemaker implantation is technically challenging, as fluoroscopy and occasionally electrocardiography (ECG) are usually the only guides available to achieve true septal pacing within the RVOT. These criteria, however, have not been widely validated against a true anatomic 'gold standard'. Cardiac computed tomographic angiography (CTA) is a technique that allows complete objective assessment of the entire geometry of the RV, including the apex and the inflow and outflow tracts.[5] We sought to validate the accuracy of ECG and fluoroscopic criteria with accurate anatomic imaging, using cardiac CTA to confirm lead position within the RVOT.

2. Methods

2.1. *Patient population*

Forty-four patients, who underwent permanent pacemaker implantation in the RVOT position in the Department of Cardiology at our institute, were enrolled in the study. Patients were subjected to standard 12-lead ECGs, fluoroscopy, and cardiac CT angiography for localization of lead tip position in the RVOT. All patients gave informed consent to participate in the study, which was approved by the Institutional Ethics Committee.

2.2. *Technique of lead implantation in RVOT*

Standard 58- or 60-cm bipolar active fixation leads with steroid-eluting electrodes were used for all implants. The single, senior operator self-shaped ventricular lead stylet to facilitate successful lead deployment onto the RVOT septum and carried out the entire procedure of pacemaker implantation. For the purpose of lead placement, RVOT was divided as defined by Mond et al.[3] into three regions: the septum, which lays posteriorly, the free wall in front, and between them, the narrow anterior wall of the RVOT.[6] Successful lead positioning was confirmed by the three fluoroscopic views: posteroanterior (PA), 40 right-anterior-oblique (RAO), and 40 left-anterior-oblique (LAO). During RVOT lead implantation, the PA view was used to position the lead in the midsection or outflow tract. The 40° RAO is then used to confirm that the lead is not in the coronary sinus or great cardiac vein. The 40° LAO was used to distinguish the three areas within these locations. In this view, free wall positioning places the lead tip anteriorly (or leftward), septal positioning places the lead posteriorly (or rightward), and anterior wall positioning places the lead pointing superiorly. The multiple fluoroscopic views were used to ensure correct lead placement. Target site was mid-septum or high septum in PA view and rightward facing lead in LAO view, but in patients where this target could not be achieved, because of difficulty to obtain stable position or failure to obtain good thresholds and sensitivity parameters, a less than optimal position was accepted.

2.3. *Electrocardiography*

Twelve-lead ECGs were obtained in all patients, acquired both at baseline, and during forced paced (at 100 beats per minute) QRS complexes. ECGs were analyzed for several parameters including QRS axis, QRS duration, amplitudes of all limb leads, limb lead polarity, and presence or absence of notching in limb leads.

2.4. *Fluoroscopy*

Fluoroscopic images were acquired in four standard views postprocedure i.e. PA, LAO-40°, RAO-40°, and left lateral (LL) views.

Fluoroscopic images were analyzed for confirmation of lead position in RVOT using PA and RAO views. The LAO and LL views were analyzed for position within the RVOT. The lead tip was designated as having either a leftward, rightward, or superior orientation in the LAO view, and an anterior, posterior or superior orientation in the LL view. Two senior radiologists and a cardiologist independently analyzed the fluoroscopic images and together they decided the final fluoroscopic lead position by consensus.

2.5. *CT angiography*

Cardiac CTA (64-slice Dual Source Siemens Definition) was performed in all 44 patients to delineate the position of the pacemaker lead tip in the RVOT. CT scans were analyzed in axial sections perpendicular to the long axis of the RVOT, and multiple orthogonal views to confirm lead tip position in the RVOT. Lead tip locations were designated as anterior, free wall, or septal in location (Fig. 1). Two radiologists who were blinded to the fluoroscopic findings of the patients analyzed the CTA for final lead position. All patients underwent routine interrogation of the pacemaker after the CTA.

2.6. *Statistical analysis*

Statistical analyses were performed using SPSS software (SPSS, Inc., Chicago, IL, USA).

Continuous data were analyzed using paired Student's *t*-test. Fisher's exact test was used for evaluating dichotomous variables. Continuous values are expressed as mean ± SD. A p-value of <0.05 was considered statistically significant.