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Electrocardiographic Comparison Between Artificial Cardiac Stimulation of Apex, Septum and Right Ventricular Outflow Tract

Comparação Eletrocardiográfica entre Estimulação Cardíaca Artificial de Localização Apical, Septal e Via de Saída do Ventrículo Direito

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ABSTRACT

Background: Ventricular pacing is detrimental to cardiac function, with more deleterious effects when it is apical, widening the QRS complex, so the best cardiac pacing site is still being sought. **Objective:** To compare, by electrocardiographic measurements, the duration of QRS complexes at different cardiac stimulation sites, from the medical records of patients with pacemakers, who attended the external cardiac stimulation consultation at Monte Sinai Hospital in Cuenca-Ecuador. **Methods:** A total of 323 patients were retrospectively analyzed from January 2011 to November 2018, classifying them by electrocardiographic morphology as apical, low septal, middle septal and right ventricular outflow tract (RVOT) stimulation. The duration of stimulated QRS complexes was quantified using digital software that allows such measurement and stores all records. Subsequently, the comparison of the means of the different stimulation sites was performed using ANOVA. **Results:** The average age was 73.6 years; 56.03% corresponded to males; 49.84% had apical stimulation, 21.67% middle septal, 15.78% RVOT, 12.69% low septal. At the end of the QRS complex measurements, an average on apex of 179.94 ms, on low septum of 172.56 ms, an average on middle septum of 153.89 ms and on RVOT 171.66 ms were obtained. When comparing these values with the average ANOVA, the duration of the QRS stimulated in the middle septum was shorter than the other sites, being statistically significant ($p < 0.001$). **Conclusion:** Cardiac pacing in the middle septum is a viable alternative, which results in shorter QRS complex duration, therefore, better synchronization of myocardial contraction, also avoiding the deleterious effects of apical stimulation.

KEYWORDS: Artificial cardiac stimulation; Electrocardiography; Analysis of variance.

RESUMO

Contexto: A estimulação ventricular é prejudicial para a função cardíaca, com efeitos deletérios a longo prazo, alargando o complexo QRS, de modo que o melhor local de estimulação cardíaca ainda está sendo procurado. **Objetivo:** Comparar por medidas eletrocardiográficas a duração dos complexos QRS nos diferentes locais de estimulação cardíaca, dos prontuários de pacientes portadores de marcapasso que compareceram à consulta de Estimulação Cardíaca do Hospital Monte Sinai em Cuenca-Equador. **Métodos:** Foram analisados, retrospectivamente, 323 pacientes, no período de janeiro 2011 a novembro de 2018, classificando-os por morfologia eletrocardiográfica em estimulação apical, septal baixa, septal média e via de saída do ventrículo direito (VSVD). A duração dos complexos QRS estimulados foi quantificada usando um software digital que permite tal medição e armazena todos os registros. Subsequentemente, a comparação das médias dos diferentes locais de estimulação foi realizada utilizando ANOVA. **Resultados:** A idade média foi de 73,6 anos; 56,03% corresponderam ao sexo masculino; 49,84% tiveram estimulação apical, 21,67% septal média, 15,78% VSVD, 12,69% septal baixa. Ao final da mensuração dos complexos QRS, obteve-se média no ápice de 179,94 ms, no septo baixo de 172,56 ms, no septo médio de 153,89 ms e em VSVD de 171,66 ms. Ao comparar esses valores com a ANOVA de médias, a duração do QRS estimulado no septo médio foi menor do que os demais locais, sendo estatisticamente significante ($p < 0,001$). **Conclusão:** A estimulação cardíaca no septo médio é uma alternativa viável, o que resulta em menor duração do complexo QRS, portanto, melhor sincronização da contração miocárdica, evitando também os efeitos deletérios da estimulação apical já conhecidos.

PALAVRAS-CHAVE: Estimulação cardíaca artificial; Eletrocardiografia; Análise de variância.

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INTRODUCTION

It is known that ventricular pacing is harmful to global cardiac function, with long-term clinical consequences, so that the best cardiac pacing site is still being investigated without conclusive results. Apical stimulation of the right ventricle is associated with deleterious effects on cardiac function. In general, the narrower the QRS complex, the better the left ventricular function[1]. The right ventricle stimulation promotes reversal of the natural sequence of cardiac electrical activation, generating an artificial blockade of the left branch, with enlarged QRS complex, predictor of heart failure in patients with definitive pacemakers, because when most of the cells are contracted, another part is still relaxed hindering the work of cardiac contraction, which causes loss of systolic efficiency[2,3]. It can develop or aggravate mitral regurgitation[4,5], increase the risk of atrial fibrillation (AF), heart failure (HF), and increase mortality[6,7] in patients with systolic dysfunction.

The need for more physiological artificial cardiac stimulation is indisputable. For almost 40 years, since the use of artificial cardiac stimulation, the apex of the right ventricle was considered as the preferred site for the implantation of ventricular electrodes[8]. The concern with the assessment of the damage caused by the stimulation of this site is relatively recent.

At the moment, an alternative stimulation site is being investigated to avoid the harmful effects of the apex and make it as physiological as possible. The studies published so far are few and many of them inconclusive. Because there is no registry in Ecuador, which does not allow us to contrast the currently available information, we propose a retrospective study that compares electrocardiographically the duration of QRS complexes with artificial cardiac pacing in the apical, low-septal, mid-septal pathways and the right ventricular outflow tract (RVOT). Also, the duration of the pre- and post-stimulation QRS complexes are compared to verify the difference between them.

METHODS

A retrospective comparative study was performed. The sample contains a total of 338 patients with ventricular electrode pacemakers (regardless of the pathology), but 11 patients were excluded for not presenting the necessary electrocardiographic records and four patients under 16 years of age. Thus, the final sample was 323 patients assisted in the cardiac pacing consultation at Hospital Monte Sinai da Cidade de Cuenca-Ecuador, from January 2011 to November 2018, who were classified according to the following electrocardiographic morphological parameters: apical (negative QRS complex in D2, D3, and aVF, basically QS complex), low-septal (upper electrical axis, however, with initial positivity in D2, D3, and aVF but with R/S ratio < 1), mid-septal (isodiphasic QRS complexes or with clear tendency to isodiphasism in D2, D3, and aVF derivations) and septum of the RV outflow tract (obviously lower electrical axis, with R/S ratio > 1). Regarding stimulation, 161 patients presented apical (49.84%), 70 mid-septal (21.67%), 51 RVOT (15.78%), and 41 low-septal (12.69%) (Fig. 1).

Once classified by the location of ventricular pacing, the duration of the QRS complexes pre-stimulation (of patients who were not dependent on the pacemaker or who had a previous record with their rhythm) and post-stimulation was measured using a digital electrocardiographic acquisition module for computer (ECG PC, TEB®), which keeps records of all patients. Once the data were collected, they were first compared with the t-test of two samples between apical and septal stimulation (low and median septum). Subsequently, all sites were compared by analysis of the variance of ANOVA means to know which is the most physiological stimulation site. Besides, it was compared using the paired t-test between the duration of the previous and subsequent QRS of each location to assess its difference. An analysis of the atypical data was made according to the distribution of the samples to corroborate that there were no measurement errors so that these data

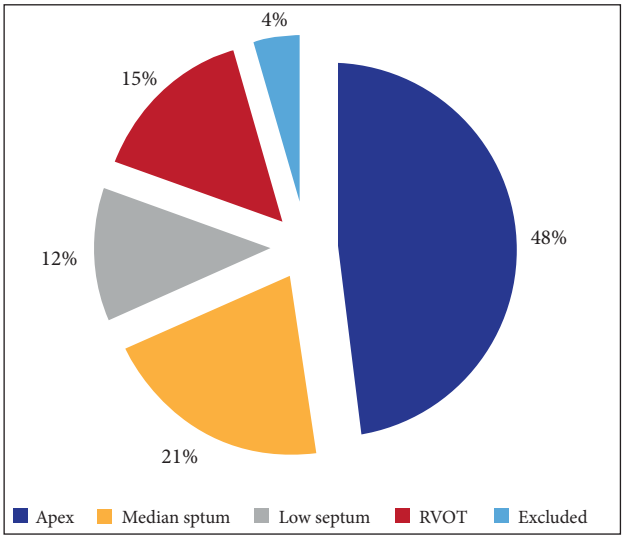

Figure 1. Sample distribution.

were submitted to a second measurement, which coincided with the first (Fig. 2). A database was designed in Microsoft Excel software and later exported to Minitab, with which the statistical analysis was performed.

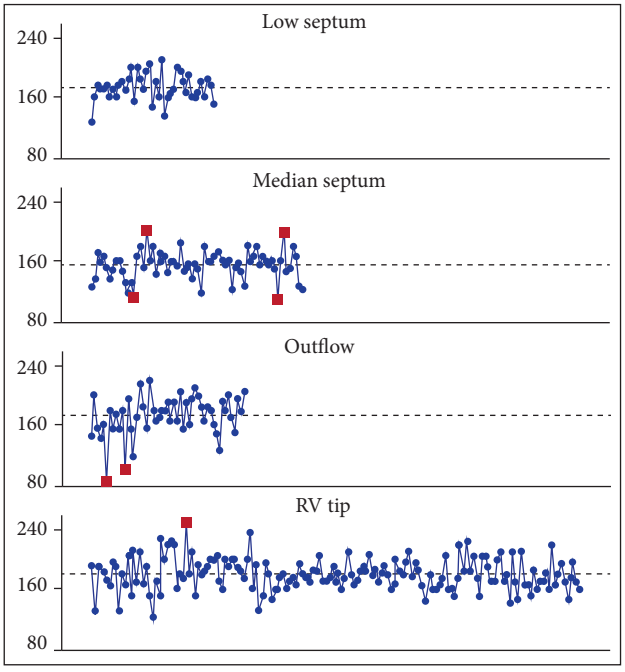

Figure 2. Distribution of data by location, duration of QRS complexes, and location of atypical data (red).

RESULTS

The mean age was 73.6 years; 56.03% were male. At the end of QRS complex measurement, a mean apex of 179.94 ms was obtained with a 95% confidence interval (CI) of 3.36 ms (176.55-183.32 ms), in the low septum 172.56 ms, CI 5,79 ms (166,77-178,35 ms), in the median septum 153,89 ms CI 4,70 ms (149,18-158.59 ms), and RVOT 171.66 ms CI 7.71 ms (163.96-179.38 ms). When comparing apical and septal pacing (low and median septum), apical pacing is higher ($p < 0.001$).

Comparing the means of all locations by ANOVA, it was obtained that the stimulation of the median septum differs from the others, giving a shorter duration of the statistically significant QRS complex ($p < 0.001$) (Table 1, Fig. 3).

When comparing the duration of the QRS complexes before and after stimulation, 69 patients dependent on the pacemaker and for whom there was no record before pacemaker implantation were excluded. The application of the paired t-test for each of the sites showed a statistically significant difference in all ($p < 0.001$), indicating that after stimulation, the means of all sites increased in duration (Fig. 4). When obtaining this result, the authors wondered how much the QRS complexes increase after ventricular pacing. Thus, the mean pre-stimulation was 133.40 ms, and the post-stimulation was 167.30 ms, resulting in a range of 33.80 ms.

Table 1. Comparison of the mean duration of QRS complexes by apical, septal, and RVOT location.

	Stimulation site			
Variable	Apex	Low septum	Median septum	RVOT
n	161	41	70	51
QRS mean (ms)	179.94	172.56	153.88	171.66
CI 95%	176.58 – 183.30	166.77 – 178.35	149.18 – 158.59	163.96 – 179.38
Statistical significance	$p < 0.001$			

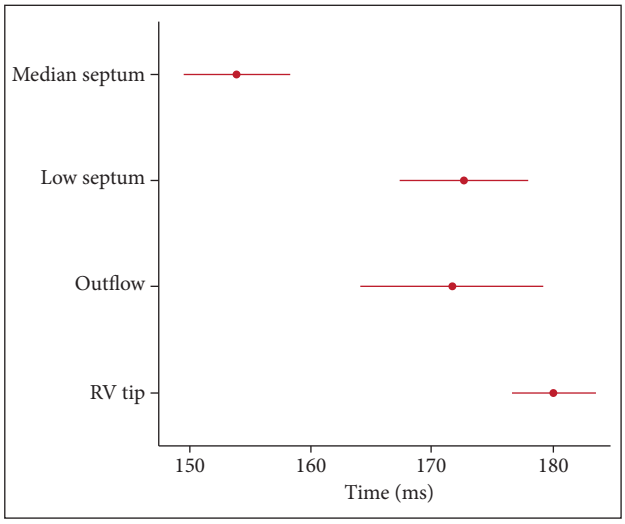

Figure 3. ANOVA comparison of the means of the QRS complexes with their respective confidence intervals.

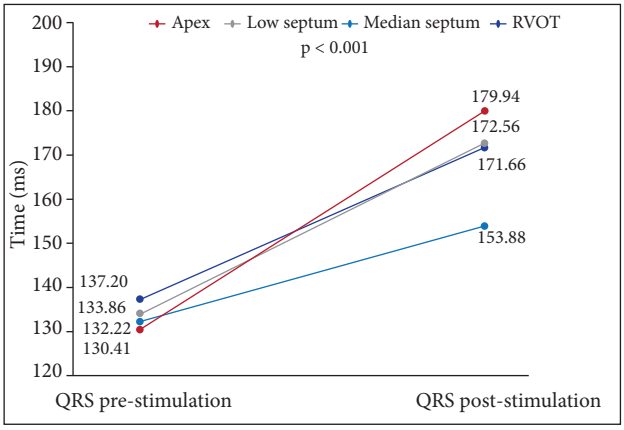

Figure 4. Comparison of the duration in milliseconds of the QRS complexes before and after stimulation of the different locations.

DISCUSSION

The most physiological site of ventricular pacing is still a challenge for the area of cardiac pacing. There are few published comparative studies to contrast the information with. Based on the results obtained, it is recommended to avoid (whenever possible) the apical stimulation of the RV and to prefer the stimulation at the level of the middle interventricular septum, cataloged for years as more laborious and long-lasting. However, in the experience of the authors of this study, with the appropriate technique and with the aid of oblique projections, no difference was observed with the apical implant but rather a lower rate of complications at the septal level, especially perforations. It is known that there are still many issues to be resolved, so the authors recommend prospective studies in which not only electrocardiographic parameters are measured but also clinical, echocardiographic, and laboratory parameters.

CONCLUSIONS

Valuable information has been received about the population. It has been statistically demonstrated that artificial cardiac pacing, in general, increases the duration of the QRS complex with a range of 33.8 ms. Apical stimulation prolongs the duration of the QRS longer than the septal. The median septum according to electrocardiographic parameters in the sample of patients used is the best site of ventricular pacing, because it has a significantly shorter duration of QRS complexes than the other sites. Therefore, it can be extrapolated that there is a better synchronization of myocardial contraction, closer to physiological, besides avoiding the deleterious effects already known from apical stimulation.

For all these reasons, the authors consider the middle interventricular septum a viable alternative that should be tried whenever possible. In contrast, the apex is the place where the QRS complex is most prolonged and, due to the evidence currently available, one of the worst sites of stimulation.

AUTHOR'S CONTRIBUTION

Conceptualization, Alvarez Coello RC and Serrano Piedra DP; Methodology, Alvarez Coello RC and Serrano Piedra DP; Investigation, Alvarez Coello RC; Statistical Analysis, Alvarez Coello RC; Writing – Original Draft, Alvarez Coello RC and Serrano Piedra DP; Writing – Review and Editing, Alvarez Coello RC and Serrano Piedra DP; Resources, Alvarez Coello RC and Serrano Piedra DP.

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