

Radiofrequency Catheter Ablation of the Left Bundle Branch Guided by Left Bundle Potential and Three-Dimensional Electroanatomical Mapping System in Canine Models

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Abstract

Introduction: The purpose of this study was to evaluate the feasibility of left bundle ablation guided by left bundle potential (LBP) and three dimensional mapping system (EnSite NavX system) in canine models.

Methods and Results: The canines were sequentially allocated into two groups, left bundle branch ablation guided by LBP and either fluoroscopy or NavX system. An LBP (mean LBP-V 17.8 ± 2.6 ms; 13-21) was identified resulting in successful left bundle ablation in 9 dogs. The A:V electrogram ratio at the successful LBP ablation site was $<1:10$ in all 9 dogs successfully ablated. In two dogs, a similar potential (potential-V 24 or 28 ms, respectively) were identified, but radiofrequency energy application produced high degree or complete atrioventricular (AV) block. Left bundle branch ablation failed in the first three dogs. The procedure time and X-ray exposure time were significantly reduced in the group guided by LBP and NavX system compared with those by LBP and X-ray imaging (2.4 ± 0.3 Vs. 1.7 ± 0.3 hours, $P=0.015$; 0.5 ± 0.07 Vs. 0.2 ± 0.02 hours, $P0.001$, respectively).

Conclusions: Selective transcatheter left bundle ablation was successfully guided by the LBP and NavX system. Compared with the combination of LBP and fluoroscopy, NavX system can further decrease the operation time and X-ray exposure.

Keywords: Radiofrequency catheter ablation; Left bundle branch block; Three-dimensional electroanatomical mapping; Canine

Introduction

With evidence accumulated from large prospective clinical trials and clinical experience, cardiac resynchronization therapy (CRT) has become the first-line therapy for heart failure (HF) [1,2]. Updated guidelines emphasized that patients with left bundle branch block (LBBB) and QRS complexes ≥ 150 msec on 12-lead electrocardiograph (ECG) benefit more from CRT [3]. As many questions in the area of CRT for HF patients are unsolved, the construction of animal model with LBBB has become the prerequisite for future studies. Chemical ablation with alcohol or surgical ligation of the left anterior descending artery (LAD) and left circumflex (LCX) were once used to block the left bundle branches [4]. However, models constructed with these methods are not ideal because of the associated large amount of infarcted myocardium. In contrast, radiofrequency (RF) ablation of the left bundle branch and subsequent high frequency right atrial pacing are more suitable for the construction of HF model with dyssynchronized contractions [5,6]. Previous studies have elucidated the electrophysiologic and anatomic parameters for successful selective transcatheter left bundle ablation [7,8]. However, the catheter cost, complicated procedure, and large dose of X-ray exposure are the problems with conventional approach guided by fluoroscopy mentioned above [7]. Furthermore, three-dimensional (3D) mapping systems, such as NavX system or CARTO system, could provide non-

fluoroscopic localization of electrophysiological catheters in 3D space and their activation sequences with a greater precision [9]. Thus, it could reduce the x-ray exposure and increase the success rate of ablation, especially for complicated arrhythmias. In this study, we hypothesized that the procedure time and X-ray exposure time could be decreased for left bundle ablation guided by left bundle potential (LBP) and NavX system compared with the conventional method guided by LBP and X-ray imaging in canines.

Methods

Animals and apparatus

This study was conducted in 14 healthy adult mongrel canines, with average weight of 25 ± 1.8 (22-28) kg. The canines were fasted for 12 hours before the operation, anesthetized with sodium pentobarbital, and then fixed with a supine position. Images were taken by C-arm fluoroscopy (GE OEC-9800, USA) and NavX Velocity 3D mapping system (St Jude Medical, USA). 12-lead ECGs and selected intracardiac electrograms (IEGM) were continuously recorded with a multichannel physiologic recorder.

Except the first three canines that failed to create LBBB, the remained eleven canines were sequentially allocated into two groups, left bundle branch ablation guided by LBP and either fluoroscopy or NavX system. The study was approved by ethics committee of the Laboratory Animal Center at Fuwai Hospital.

Ablation of LBBB

Animal preparation

Following sterile skin preparation, the right femoral vein and artery were isolated. Then a 7F and a 6F polyethylene catheter were inserted to provide routes for arterial and venous access, respectively. A quadripolar or steerable catheter introduced via the right femoral vein was positioned across the tricuspid valve to record His-bundle electrograms from the right side of the septum. Bard B-curved catheter (Bard Electrophysiology, New York, USA) or Celsius A-type curve ablation catheter (Biosense Webster Inc., California, USA) was retrogradely introduced into the left ventricle across the aortal valves via the right femoral artery to map the left-sided His-bundle potential and LBP guided by fluoroscopy and/or NavX system.

Mapping and ablation

LBP mapping and left bundle ablation: 12-lead ECGs and selected IEGMs were recorded simultaneously with a multichannel physiologic recorder. Guided with the fluoroscopy and EnSite NavX system (Figure 1), the ablation catheter was advanced to the left ventricular apex with the tip deflected toward the septum. The ablation catheter was retracted carefully until a LBP was founded (Figure 2). When mapping the LBP, turning the catheter clockwise or taking the U-shaped configuration (Figure 1A) could enhance the attachment to the septum and improve ablation success rate. The ablation energy was limited by temperature with an upper limit of 60, 30-40W. The impedance was continuously monitored during the energy application. Appropriate attachment and adequate heating was denoted by a drop in impedance. If no change in the QRS complex morphology was observed after 10 seconds, energy delivery was suspended and the catheter was retracted until a new LBP was founded. After the LBBB QRS morphology developed on the 12-lead ECG, the energy application was continued for 60-90 seconds or discontinued with a sudden increase in impedance. A 30 minutes waiting period was allowed to confirm permanent LBBB. The energy delivery was stopped instantly on the appearance of accelerated junctional rhythm or complete atrioventricular block (AVB). PR intervals, QRS morphologies and durations on the surface ECGs, AH intervals, HV intervals, and A:V ratios on IEGMs were compared before and after ablation. The LBBB is defined that leads V1 and V2 showed rS complexes and leads V5 and V6 showed single broad, notched R deflections as in previous article [10].

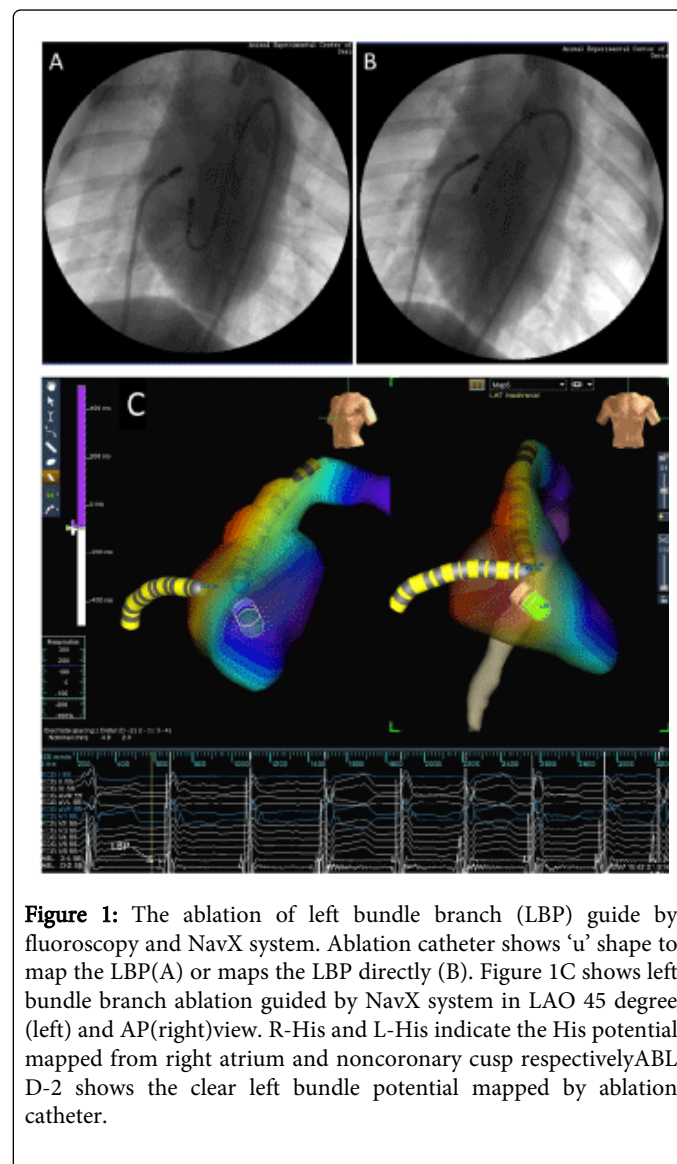
The procedure of left bundle ablation guided by NavX system was as follow: firstly map the right-side His potential and made a mark in the geometry. Then left ventricular geometry was constructed and left-side His potential mapped from noncoronary cusp. All the procedures of LBP ablation were guided by NavX system.

The procedure time of the left bundle branch ablation were recorded from the beginning of the mapping procedure to the end of LBBB completion. The fluoroscopy time was recorded the same as the measurement of the procedure time for each canine.

Pathology examinations: Reconfirmation of LBBB was conducted 1 week after ablation with 12-lead ECG. The location and measurement of the ablation sites were determined by postmortem autopsy.

Statistical analysis

Descriptive statistics are described as mean±SD. Paired t-test and Chi-square were used for statistical comparisons. P<0.05 was considered statistically significant.



Results

There are 14 canines were enrolled in this study. In the first 3 cases, we were unable to map the LBP with merely the fluoroscopy guidance and failed to create the LBBB. The remained 11 canines were sequentially allocated into two groups, left bundle branch ablation guided by LBP and either fluoroscopy (5 cases) or NavX system (6 cases). LBBB was accomplished in 9 of the remained 11 canines and failed in the other 2 canines. Among 2 failed canines, complete AVB was obtained in one canine of X-ray group and high degree AVB in another case of NavX group respectively.

The energy delivered to achieve successful ablation was 30-40W, with the temperature of 48-53°C and 5 ± 2 lesions (3-8) created. All the successful ablated canines were examined 1 week later with 12-lead

ECG to confirm the LBBB. The averaged interval between LBP to the earliest ventricular electrograms (LBP-V) at successful ablation sites measured 17.8 ± 2.6 ms (1321), significantly shorter than the baseline HV interval (333 ms, $P < 0.05$).

In the 9 canines with successful left bundle ablation, no significant changes were observed in PR interval (105 ± 10 Vs. 104 ± 12 ms), AH interval (69 ± 12 Vs. 72 ± 10 m) or HV interval (33 ± 3 Vs. 35 ± 3 ms) after ablation (Table 1). The QRS complexes increased from 52 ± 3 ms to 101 ± 5 ms ($P < 0.001$). The A:V ratio on IEGM at the ablation site was $< 1:10$ in all the 9 canines. 2 canines experienced ventricular fibrillation (VF) during ablation, and were converted to sinus rhythm with 200J direct-current nonsynchronized defibrillation therapy. The prophylactic intravenous injection of amiodarone could reduce the recurrence of VF during ablation at the site of LBP and Purkinje system.

	PR	QRS	AH	HV	LBP-V
	(msec)	(msec)	(msec)	(msec)	(msec)
Baseline	105 ± 10	52 ± 3	69 ± 12	33 ± 3	17.8 ± 2.6
Post-LBP ablation	104 ± 12	101 ± 5	72 ± 10	35 ± 3	
P Value	NS	0.001	NS	NS	

Table 1: Baseline and Post Left Bundle Ablation ECG and Intracardiac Electrogram Intervals

During the initial period of experiments, neither was LBP clearly mapped, nor were left bundles successfully ablated with the guidance of X-ray images in the first 3 canines. In addition, the ECG returned to normal 30 minutes after achieving LBBB QRS morphology in one canine, and subsequent ablation resulted in complete AVB. Another canine was confirmed with high degree AVB during 1-week follow-up. The ablation site potential to earliest ventricular potential was 24 and 28msec respectively, and rapid AV junctional rhythm response during ablation suggested that the ablation site was very close to His-bundle area.



Figure 2: A typical recording of the left bundle potential (arrow) at a successful ablation site and creation of LBBB after ablation at this site. The LBP-V interval is 20 ms, H-V interval is 35 ms, and the A:V ratio $< 1:10$.

In the first 3 failed cases, the average operation time was 3.5 ± 0.5 hours, and the X-ray exposure time was 0.7 ± 0.17 hour. The following

successful 9 canines were allocated into two groups. In the first group of 4 canines with LBP and fluoroscopy, the mean operation time decreased to 2.4 ± 0.3 hours with the X-ray exposure time decreased to 0.5 ± 0.07 hours. In the second group of 5 canines with LBP and NavX system, the operation time was further shorted to 1.7 ± 0.3 hours ($P = 0.015$), and the X-ray exposure time was limited to 0.2 ± 0.02 hours ($P < 0.001$) (Figure 3).

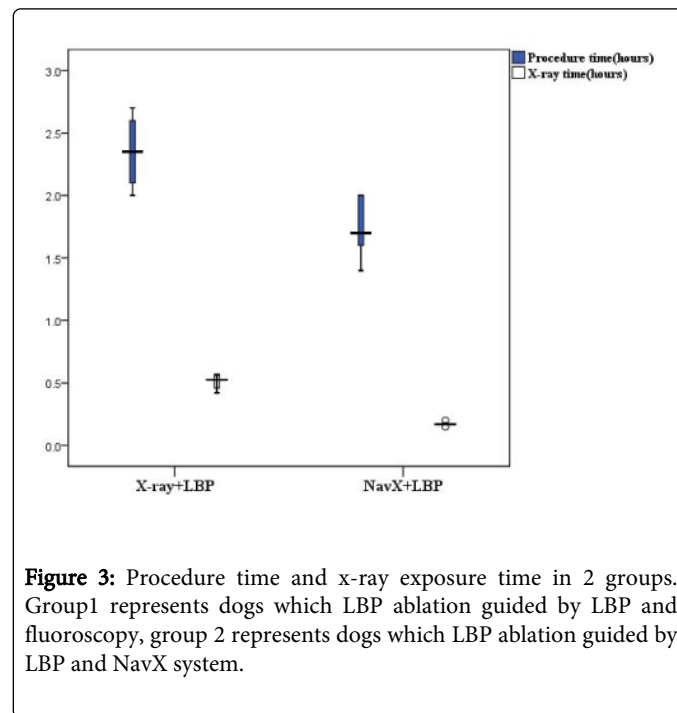


Figure 3: Procedure time and x-ray exposure time in 2 groups. Group1 represents dogs which LBP ablation guided by LBP and fluoroscopy, group 2 represents dogs which LBP ablation guided by LBP and NavX system.

Postmortem autopsy located the ablation site inferior to the junction of the right coronary sinus and the noncoronary sinus, with a mean lesion size of 7 ± 2 mm in length and 6 ± 2 mm in width (Figure 4).

Confirmation of LBBB was further achieved with activation mapping under the guidance of NavX system, revealing an earliest activation from the His-bundle, then interventricular septum, and finally reaching the basal part of the lateral-inferior wall. The activation sequence is in accordance with LBBB pattern.

Discussion

This study demonstrates the feasibility of selective left bundle ablation guided by LBP and NavX system in canine models. Compared with fluoroscopy, the NavX system can further decrease the operation time and X-ray exposure.

Accurate recognition of LBP and restrictive limitation of the A:V ratio $< 1:10$ are critically important for ablation success and avoiding complete AVB. LBP denotes electrical activation in the left bundle branch, just between His potential and Purkinje potential (P), so the LBP-V interval should be shorter than the H-V interval and longer than the P-V interval. In the study by Helguera et al. [7], LBP-V interval < 20 ms and A:V ratio $< 1:10$ are two useful criteria to avoid complete AVB in left bundle ablations guided by LBP. Our results are in accordance with those of Helguera et al's, with a mean LBP-V interval of 17.8 ± 2.6 ms (13~21). Complete AVB or high degree AVB was induced in two canines with an accelerated junctional rhythm

during energy application. In these two cases, the potential to V interval was longer than in the successful LBP-V group (26 ± 2.8 ms vs 17.8 ± 2.6 ms; $P=0.003$). It is suggested that the ablation site was proximate to the distal part of His bundle and the “potential” was not the true LBP but distal His-bundle potential. In addition, our study did not confirm the feasibility to accomplish left bundle ablation with the help of X-ray image alone as previously reported [11]. Various variations in the conduction system and unfamiliarity with the anatomical features of the canines made it nearly impossible to guide precise ablation merely by X-ray images. Although a potential <20 ms ahead of V on the IEGM could effectively differentiate LBP from the His bundle potential, it is too short to indicate the potential of Purkinje fiber and failure of complete block of left bundle branch. Besides, we observed a higher chance of VF when ablating at the site of LBP or Purkinje fiber. Therefore, defibrillators should be prepared to terminate VF promptly. Additionally, prophylactic administration of antiarrhythmic drugs could help reduce the VF rate.

Although similar to human conduction system in anatomy [12], canines have a relatively longer His bundle with more left side oriented penetrating portion and main left bundle, which may account for the high ablation success rate. Besides, with a width of 0.3-0.5 cm, the main left bundle may need more than one time ablation for complete blockage.

Our experimental model offers several new features and advantages to the previous experimental studies.

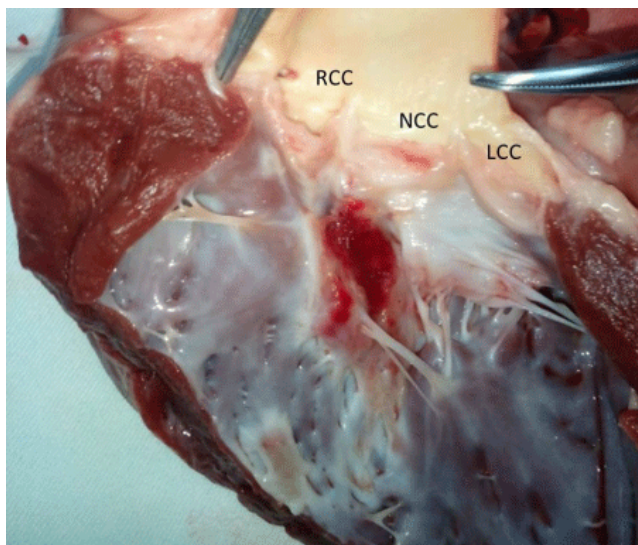


Figure 4: Left ventricular septal lesions was 5 mm below the junction of right coronary cusp and noncoronary cusp (10*8mm). RCC=right coronary cusp, NCC=noncoronary cusp, LCC=left coronary cusp.

Firstly, introducing catheters via the femoral artery, in combination with NavX system, further reduces X-ray exposure as it increases distance and allows adoption of lead board between researchers and the X-ray emitter. Although Helgura et al preferred a more direct approach and more appropriate attachment to the left ventricle septum via carotid artery for left bundle ablation [7], our study didn't find any difference in the success rate of model construction. Compared with X-ray imaging, NavX system could significantly

reduce the operation time and X-ray exposure, correspondingly reduce the side effects of X-ray to researchers [9]. Besides, as NavX system can be reused, the new method reduces catheter use and cost. We highly recommend using the NavX system to carry out this procedure.

Secondly, only 2 catheters are needed to accomplish the whole process of common left bundle ablation. The complexity and the cost of the procedure is significantly reduced. Helguera et al. used 5 catheters, locating in right ventricle apex, coronary sinus, right side of His bundle, noncoronary sinus, and left ventricle [7]. Sheng et al. reduced the number of catheter use to 3, which includes His bundle catheter on the right side of junctional region and mapping catheters at the base of right coronary sinus and the left ventricle [11]. In our approach, one mapping catheter was used to map the His bundle potential from right atrium and one ablation catheter was used to map and ablate LBP in the left ventricle. Although increasing the number of catheters provides more anatomical markers along the conduction system for improved precision, it also leads to increased cost, prolonged operation time, and higher amount of X-ray exposure, especially for researchers unfamiliar with the anatomy and X-ray images of a canine heart.

Last but not least, the supine position used in our approach not only presents the appropriate attachment of the ablation catheter, but also requires the least amount of X-ray exposure.

Limitation

The main limitation of this study is a relatively small number of animals enrolled in two groups. It is possible that the procedure and fluoroscopic time may have been lower in both groups if a larger number of animals were practiced. However, several studies have confirmed the advantages of NavX system, with reduced fluoroscopy time, radiation dose, and procedure time, compared with conventional, fluoroscopic guided approaches. In addition, the NavX system also has its weakness and the chosen must depend upon the operator's familiarity with NavX system.

In conclusion, combining the 3D mapping system (Ensite NavX) with the LBP is safe and effective for complete ablation of the left bundle branch. Guiding with the 3D mapping system also reduces the procedure time and X-ray exposure compared with fluoroscopy alone.

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