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Coronary venous anatomy relevant to cardiac resynchronization therapy – an angiographic study

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SUMMARY

Cardiac resynchronization therapy (CRT) involves placing a lead through the coronary sinus to pace the left ventricle. However, technical problems arise in the procedure either due to variant anatomy or due to the presence of valves. Information on coronary venous anatomy is scarce in the South Indian population. The aim of this study was to describe the coronary sinus anatomy in patients undergoing CRT implant. Coronary sinus angiograms were used to study the following parameters: (a) Dimensions of coronary sinus (b) Number and distribution of tributaries (excluding middle and great cardiac veins) (c) Diameter of major veins at the origin (d) Angulation of tributaries with CS. Measurements were made using calipers in the dicom viewer.

Out of the 24 angiograms studied, only a single tributary of adequate size was noted in 70.8% (17/24) of the cases, which was most commonly a midlateral vein (76.5%). Two prominent tributaries were noted in 29.2% (7/24) of cases. The average diameter of the veins was 3.93 mm and 80.6% of the veins had an obtuse angle of drainage. Anatomical variations in the coronary venous system in this population suggest that the majority of patients have a single suitable tributary and this is most often the midlateral vein, which is known to have the most favorable outcome. Data obtained in this study will guide clinicians in left ventricular lead placement in the South Indian population leading to greater procedural success.

Key words: Cardiac resynchronization therapy (CRT) – Pacemaker – Coronary veins – Coronary sinus – Anatomy

INTRODUCTION

The coronary sinus (CS) is the main venous drainage of the heart. Its tributaries include the anterior interventricular vein (AIV), lateral cardiac veins (anterolateral, midlateral and posterolateral), posterior veins of the left ventricle (PVL), middle cardiac vein (MCV), small cardiac vein, and oblique vein of Marshall (Habib et al., 2009). The coronary sinus and veins play an important role as a conduit for various diagnostic and therapeutic procedures. Knowledge of their anatomy is key to perform various cardiovascular interventional procedures like cardiac resynchronization therapy (CRT), mapping of arrhythmias, radiofrequency catheter ablation and defibrillation (Loukas et al., 2009).

Cardiac resynchronization therapy (CRT) restores the synchrony of the heart's contractions in selected patients with left ventricular dysfunction and dys-synchrony, drug refractory systolic heart

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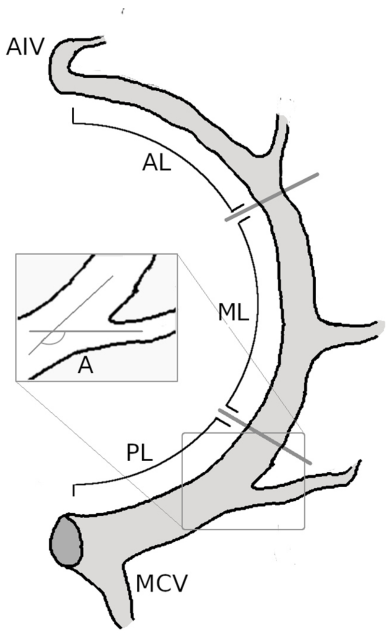

Fig 1. Schematic diagram of the anatomy of the coronary sinus and its tributaries and the definitions used in this study. AIV: anterior interventricular vein. AL: anterolateral veins. ML: midlateral veins. PL: posterolateral veins. MCV: middle cardiac vein.

failure with left bundle branch block. However, in about 10% of patients, the left ventricular lead cannot be placed and 30-40% of patients fail to respond to CRT and show no clinical improvement (Bleeker et al., 2006). The cardiac electrophysiologist places the lead for pacing the left ventricle through the coronary sinus during cardiac resynchronization therapy. There can be technical problems in the procedure either due to variant anatomy or due to the presence of valves (Noheria et al., 2013). Variations in coronary venous anatomy are one of the major anatomical barriers during LV lead implantation in CRT, and LV lead placement is dependent on the availability of a vein. Variations in the anatomy of the coronary venous system mean that there may not always be a suitable major vein for implantation of a pacing lead with acceptable pacing parameters. There have been many studies demonstrating variations in coronary venous anatomy worldwide, but information is scarce in the South Indian population. Hence this study was undertaken to describe the coronary venous anatomy using angiography in a tertiary hospital in south India.

MATERIALS AND METHODS

This was a retrospective, descriptive study conducted in the Department of Cardiology of a tertiary care hospital. Records of patients who underwent coronary resynchronization therapy were reviewed. Coronary sinus angiograms performed during the procedure by balloon occlusion method were analyzed to study anatomic variations. Coronary venography was performed in all cases using a balloon occlusion catheter placed within the proximal coronary sinus. Once the balloon is inflated to occlude the coronary sinus, contrast injection from a port distal to the balloon opacifies the coronary sinus and its branches well. This provides better images than those which can obtained by levophase images from coronary arterial injection or by coronary venous contrast injection without balloon occlusion. We have added this information in the Methods section. Cases where an angiogram was not available were excluded. Approval was obtained from the Institutional Ethics Committee.

Data Collection

The following parameters were studied in each angiogram:

a. Dimensions of coronary sinus
b. Number and distribution of tributaries
c. Diameter of major veins at the origin
d. Angulation of tributaries with CS.

All measurements were made using calipers available in the dicom viewer (RadiAnt DICOM Viewer). The diameter of the catheter was used as calibration for the other measurements. The coronary sinus diameter was measured at the os and at 1 cm distal to the os. The major tributaries were defined as those more than 2 mm in diameter at the origin, excluding the middle and great cardiac veins. We have classified the branches based on the site of origin as seen in the left anterior oblique view. All major branches apart from the middle cardiac vein and anterior interventricular vein are classified as posterolateral, lateral and anterolateral branches. Figure 1 provides a good illustration of the scheme. The left posterior or inferior veins as described in anatomy literature correspond to posterolateral or lateral veins depending on their site of origin. Similarly the left marginal vein is usually anterolateral, but may be lateral, depending on the site of origin as seen in the left anterior oblique view.

The tributaries studied were defined by their site of origin from the coronary sinus. Tributaries arising between 12 and 2 o'clock, 2 and 4 o'clock, 4 and 6 o'clock were taken as anterolateral, midlateral and posterolateral veins, respectively. Angulation of various tributaries was measured between the long axis of the proximal part of the tributary and the long axis of the adjacent CS. Figure 1 is a schematic diagram of the anatomy of the coronary sinus and its tributaries depicting the definitions used in this study

Statistical analysis

Categorical variables such as gender, acute or obtuse angle tributaries were expressed as frequency and percentages. Continuous variables such as age, angulation of tributaries, diameter of CS, number of major tributaries, diameter of major

Table 1. Frequency, diameter and angulation of coronary sinus tributaries (N=31).

Frequency of occurrence of tributaries	Diameter of vein (mean±SD mm)	Angle of drainage of vein from CS ostium (mean±SD mm)	Angle <90, n (%)	Angle >90, n (%)
Anterolateral vein n=25.8% (8/31)	4±2.1	128.4±63.6	1 (12.5%)	7 (87.5%)
Midlateral vein n=58.1% (18/31)	4.4±2.1	123.8±59.7	3 (16.7%)	15 (83.3%)
Posterolateral vein n=16.1% (5/31)	3.4±1.7	108±47.6	2 (40%)	3 (60%)

vein, ejection fraction, etc. were expressed as mean with SD or median with range.

RESULTS

In the study period, 25 coronary sinus venograms were available from patients undergoing CRT. One of these was excluded due to inadequate visualization, making it impossible to use for measurements. The remaining 24 venograms formed the material for the study.

Among the 24 patients, there were 17 males (70.8 %). The mean age of the patients was 54 ± 11 years and the mean ejection fraction was 28.58% ± 5.41%.

Coronary sinus venogram analysis

Figure 2 shows illustrative angiographic images

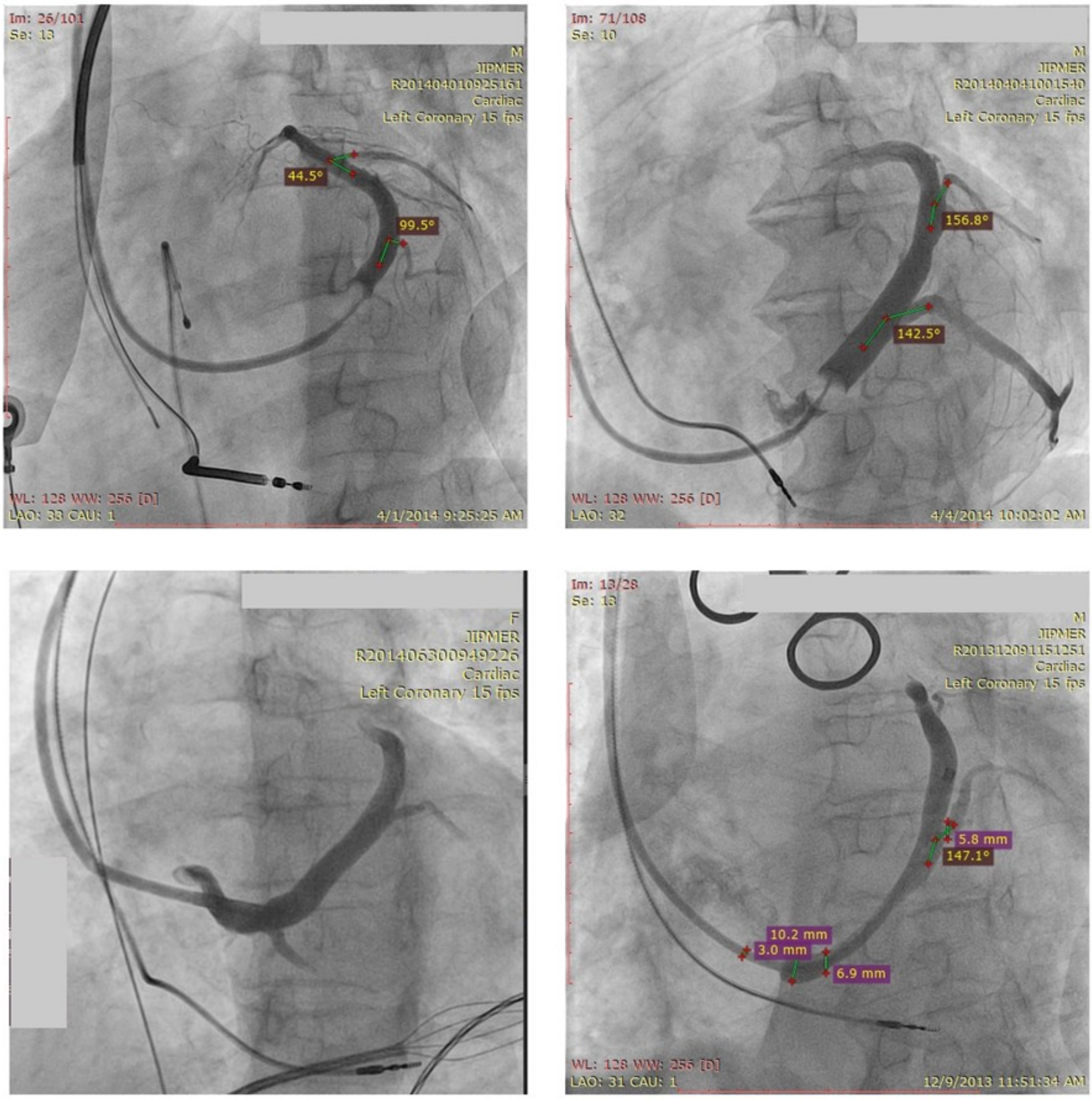

Fig 2. Illustrative angiographic images of the coronary sinus in the left anterior oblique view from four different patients. The measurements are also shown in three of the images.

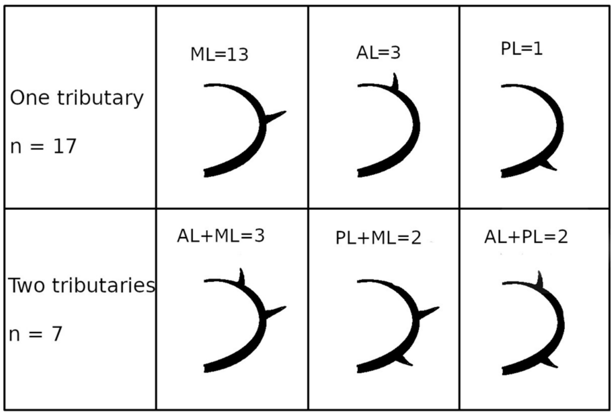

Fig 3. Schematic representation of number, names and frequencies of coronary sinus tributaries (N=24).

from four different patients. The average diameter of CS at its os was 10.9 ± 3.6 mm and at 1 cm distal to the os was 9.4 ± 3.4 mm. Only a single tributary of adequate size was noted in 70.8% (17/24) of the cases, which was most commonly a midlateral vein (76.5%). Two prominent tributaries were noted in 29.2% (7/24) of cases. These tributaries were anterolateral (AL), posterolateral (PL) and midlateral veins (ML) present in various combinations as shown in Fig. 3.

Analysis of the total 31 identified tributaries is given in Table 1. The most common tributary was midlateral vein followed by anterolateral vein and posterolateral vein in decreasing order. The average diameter of the veins was 3.93mm. Out of the 31 tributaries found, 6 (80.6%) had an angle greater than 90oand he most common vein to have an obtuse angle was the anterolateral vein followed by the lateral, then posterolateral vein.

DISCUSSION

In this retrospective analysis of coronary sinus angiograms from patients undergoing CRT implant, we found that most patients had only a single tributary of sufficient size and only around 30% of patients had two tributaries of adequate size. The midlateral vein was the most common suitable tributary, followed by the anterolateral and then posterolateral vein. The anterolateral vein more commonly had an obtuse angle of origin, while the posterolateral vein more commonly had an acute angle at its origin.

Intraoperative hemodynamic studies suggest that placement of a pacing electrode along the lateral wall of LV results in the greatest benefit (Singh et al., 2005) and the vein in which LV lead is placed during CRT influences the outcome (Putnik et al., 2011). Therefore, the knowledge of number of optimal tributaries draining the free wall of the left ventricle is important, because the fewer the number of tributaries, the less will be the scope of optimal site selection of catheter insertion.

The diameter CS ostium usually ranges from 5-15 mm (Habib et al., 2009). A study on cadaveric hearts in the Indian population noted that the average vertical and transverse diameter of the ostium with Thebesian valve were 5.66 ± 1.27 mm and 3.41 ± 1.11 mm, respectively and in the CS ostium without Thebesian valve, the same diameters were 5.86 ± 1.28 mm and 3.57 ± 0.84 mm (Randhawa et al., 2013). Another such autopsy study on Indian hearts demonstrated the mean coronary sinus os diameter to be 11.75 ±2.66 mm (Mehra et al., 2016). In our study, the mean diameter of the coronary sinus at its os was slightly larger, at 10.91 ± 3.62 mm. We believe that this is likely to be more accurate than cadaver-based studies.

CS tributaries between anterior interventricular and middle cardiac veins are the final pathway of lead placement, but the number of tributaries of adequate size for LV lead placement varies. An angiographic study reported the number of visible tributaries to range from 0 to 3, with no single visible tributary in 1% of patients (Gilard et al., 1998). In our study, it was either 1 or 2 tributaries visible per case studied. In terms of number of suitable tribularies, one UK-based study showed more than one suitable tributary was seen in 42.2% of cases (Khan et al., 2009). Another report in Indian hearts noted that 72% had more than one adequate tributary (Randha et al., 2013). Our study population showed comparatively fewer suitable tributaries, with only 29.2% having more than one adequate vein.

Among the many tributaries, the posterior and lateral tributaries are usually the first choices for lead placement. However, their presence, position and size are variable (Kawashima et al., 2003; Bales, 2004). The choice of tributary can affect the outcome, with the lateral veins having the best response rate to CRT (Putnik et al., 2011). Our study demonstrated that the most common suitable tributary was the midlateral vein (18/24) and the most common combination, in hearts with more than one adequate vein, was the midlateral with anterolateral vein (3/7).

The choice of LV lead depends on the diameter of the first-degree tributary of CS. The LV dislodgement rates are approximately 5-10% (Singh et al., 2005), and the veins with larger diameter present a greater risk of lead dislodgement. Prior knowledge of these parameters might help in selecting the lead of appropriate catheter size, improving the ease of implant, and understanding the likelihood of lead dislodgement after initial implantation.

The angle formed by the branching vessel with the main axis of CS is an important factor for successful cannulation. Obtuse angulations (>90) between the first-degree CS tributary and main CS make cannulation easier (Randhawa et al., 2013). In another Indian study, obtuse angulations were most commonly found in the posterolateral vein, followed by the anterolateral and then midlateral vein. This is slightly different from our study, wherein percentage of obtuse angulations was more for anterolateral vein (87.5%) followed by midlateral vein (83.3%) and posterolateral vein (60%), suggesting the success is more with the anterolateral vein.

Implication: Coronary venous anatomy is essential for cardiac resynchronization therapy, but is also useful for various other cardiovascular interventional procedures like radiofrequency catheter ablation, mapping of arrhythmias, and defibrillation. This study will improve knowledge of coronary venous variations and measurements of the anatomic structures and the common patterns of venous arrangements with respect to the possible approaches to LV epicardial CRT in the South Indian population.

CONCLUSION

In the era of modern medicine and prevalent usage of CRT, the anatomy of the coronary venous system should be well studied and analyzed for better success of the procedure. In this study, the majority (70.8%) of coronary sinuses had only one tributary of adequate size. This was most commonly the midlateral vein, which has been shown to have the most favorable outcome. In addition, most (80.6%) of the veins drained into the CS at an angle >90, out of which the anterolateral vein had the highest percentage of obtuse angulations. We present this study describing the anatomical variations in the coronary venous system in a small population which will provide data for future studies and aid in effective LV lead placement for a more favorable outcome.

Author contributions

Ramanathan P: Project development, data collection, data analysis, manuscript writing.

Veeramani R: Project development, data analysis, manuscript writing.

Selvaraj R: Project development, data analysis, manuscript writing.

Agarwal G: Data analysis, manuscript writing.

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