Distal end of the atrioventricular nodal artery predicts the risk of atrioventricular block during slow pathway catheter ablation of atrioventricular nodal re-entrant tachycardia


Abstract

Objective—To search for a reliable anatomical landmark within Koch’s triangle to predict the risk of atrioventricular (AV) block during radiofrequency slow pathway catheter ablation of AV nodal re-entrant tachycardia (AVNRT).

Methods—To test the hypothesis that the distal end of the AV nodal artery represents the anatomical location of the AV node and, thus could be a useful landmark for predicting the risk of AV block, 128 consecutive patients with AVNRT receiving slow pathway catheter ablation were prospectively studied in two phases. In phase I (77 patients), angiographic demonstration of the AV nodal artery and its ending was performed at the end of the ablation procedure, whereas in the subsequent phase II study (51 patients), the angiography was performed immediately before catheter ablation to assess the value of identifying this new landmark in reducing the risk of AV block. Multiple electrophysiologic and anatomical parameters were analysed. The former included the atrial activation sequence between the His bundle recording site (HBE) and the coronary sinus orifice or the catheter ablation site, either during AVNRT or during sinus rhythm. The latter included the spatial distances between the distal end of the AV nodal artery and the HBE and the final catheter ablation site, and the distance between the HBE and the tricuspid border at the coronary sinus orifice floor.

Results—In phase I, nine of the 77 patients had complications of transient (seven patients) or permanent (two patients) complete AV block during stepwise, anatomy guided slow pathway catheter ablation. These nine patients had a wider distance between the HBE and the distal end of the AV nodal artery, and a closer approximation of the catheter ablation site to the distal end of the AV nodal artery, which independently predicted the risk of AV block. In contrast, none of the available electrophysiologic parameters were shown to be reliable. When the distance between the distal end of the AV nodal artery and the ablation target site was more than 2 mm, the complication of AV block virtually never occurred. In phase II, all 51 patients had successful elimination of the slow pathways without complication when the ablation procedure was guided by preceding angiography with identification of the distal end of the AV nodal artery.

Conclusions—The distal end of the AV nodal artery shown by angiography serves as a useful landmark for the prediction of the risk of AV block during slow pathway catheter ablation of AVNRT.

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Keywords: atrioventricular nodal artery; atrioventricular nodal re-entrant tachycardia; catheter ablation; heart block.


discrete AV nodal pathways and sometimes the coronary sinus orifice floor.

It is generally believed that the dual atrioventricular (AV) nodal pathways of AV nodal re-entrant tachycardia (AVNRT) are two functionally and anatomically distinct structures, in which the fast pathway appears to be the anterior-superior atrionodal connections near the AV node and the His bundle, while the slow pathway appears to be the posterior-inferior atrionodal connections near the coronary sinus orifice. Radiofrequency (RF) catheter ablation of the slow pathway has been proved to be effective in the treatment of recurrent AVNRT. Inadvertent complication of permanent complete AV block is rare. However, the incidence of transient complete AV block during slow pathway catheter ablation remains significant, ranging from 2–24%. Unless the delivery of RF energy is immediately interrupted, the risk of permanent damage to normal AV conduction is very high. Several electrophysiological parameters harboring the potential risk of AV block during slow pathway catheter ablation of AVNRT were proposed. These warning electrical signals include the retrograde atrial activation time difference between the His bundle recording site and the coronary sinus orifice in AVNRT, the antegrade atrial activation time difference between the His bundle recording site and the catheter ablation site in sinus rhythm, junctional tachycardia cycle length during RF energy application, and junctional ectopies with retrograde ventriculoatrial (VA) block. Unfortunately, none of these signals could be used to serve as a powerful predictor to avoid the occurrence of AV block because of inadequate predictive accuracy. A reliable landmark is still lacking.

The AV nodal artery is the main artery supplying the AV node and sometimes the proximal His bundle. Selective catheterisation and application of pharmacological agents
including ethanol has been shown to damage specifically AV nodal function.16-18 Thus, we hypothesised that the distal end of the AV nodal artery visualised by angiography could be a useful landmark for the anatomical location of the AV node within Koch's triangle. The approximation of the tip of the ablation catheter to the distal end of the AV nodal artery would carry the highest risk of complete AV block in slow pathway catheter ablation.

In order to test the hypothesis, we conducted a study in two separate phases. In phase I, selective coronary angiography to demonstrate the AV nodal artery and its ending was performed at the end of the slow pathway catheter ablation. This would allow us to find the relation between the risk of AV block and the location of the distal end of the AV nodal artery and the ablation target site. In the subsequent phase II study, the distal end of the AV nodal artery was demonstrated by angiography before slow pathway catheter ablation. Thus, the applicability and usefulness of identifying this anatomical landmark in reducing the risk of AV block can be further evaluated.

Methods

PATIENT POPULATION

Seventy-seven consecutive patients undergoing RF catheter ablation for proven AVNRT were prospectively enrolled between October 1996 and September 1997 for phase I of the study. There were 26 men and 51 women, with a mean (SD) age of 56 (12) years (range 14–78 years). All patients had recurrent clinical paroxysmal supraventricular tachycardia for a mean period of 4.2 (3.5) years (range 1–10.5 years). Few patients had organic heart disease: two patients had single vessel coronary artery disease, one patient had rheumatic heart disease status post-mitral valve replacement, and two patients had hypertensive heart disease.

For the phase II study, another 51 consecutive patients with proven AVNRT were enrolled prospectively between October 1997 and August 1998. There were 14 men and 37 women, with a mean age of 52 (18) years (range 23–78 years). One patient had two vessel coronary artery disease, one had concurrent right atrial tachycardia, and one had rheumatic heart disease status post-aortic valve replacement.

ELEPHYSIOLOGIC STUDY AND SLOW PATHWAY CATHERER ABLATION

The patients were studied in a fasting, non-sedative state after informed written consent was obtained. All antiarrhythmic drugs were discontinued for at least five half lives. During the study, standard 5 mm or 2-5-2 mm spacing quadripolar electrodes (Mansfield EP, Boston Scientific, Watertown, Massachusetts, USA) were positioned at the high right atrium, the His bundle site, and the right ventricular apex. Another decapolar catheter with a central lumen (Daig Corp, Minnetonka, Minnesota, USA) was inserted into the coronary sinus, with the proximal bipole located at the orifice. The coronary sinus catheter was used for both local electrogram recording and direct coronary sinus venography. The His bundle recording catheter was carefully adjusted to record the discrete His potential with a local amplitude ratio of atrial versus ventricular electrogram of about 0.25–0.5. Every effort was made to maintain the His bundle catheter in a stable position throughout the study.

Standard electrophysiologic study incorporating programmed electrical stimulation up to double extrastimuli at two driving cycle lengths (usually 600 or 500 ms and 400 ms) and incremental pacing was performed from both the high right atrium and the right ventricular apex to reproduce the clinical tachycardia. If necessary, isoproterenol infusion would be used to facilitate the induction. Multiple surface ECG leads and intracardiac electrograms were displayed simultaneously and recorded on a computerised oscilloscopic system (Cardiolab, Prucka Engineering Inc, Houston, Texas) with a data sampling rate of 1 kHz. Relevant intervals and amplitude measurements were calculated at a speed of 100 or 200 mm/s by the calibrated caliper of the system. Pacing stimuli were delivered by a digital stimulator (Bloom Associates, Reading, Pennsylvania, USA) at twice the diastolic threshold in strength and 2 ms in duration. The diagnosis of AVNRT was established according to the previously suggested criteria.3–5

In the phase I study, RF catheter ablation of the slow pathway was performed by dividing the tricuspid border of Koch's triangle into six areas (fig 1), labelled as A(anterior), A1, M(middle), M1, P(posterior), and P2. The RF catheter ablation site was selected by the stepwise anatomical approach suggested by Jazayeri and colleagues7 and started from the site below the floor level of the coronary sinus orifice—that is, the P2 site. The coronary sinus orifice and the tricuspid border were verified by direct coronary sinus venography (fig 2A).
Radiofrequency energy was first applied close to the tricuspid border, with an atrial to ventricular local electrogram amplitude ratio of 0.2–0.5. If ineffective, another RF pulse would be applied at a slightly more atrial site, with a nearly equal amplitude of atrial and ventricular local electrograms, before moving to the more anterior level. The slow pathway catheter ablation was undertaken in sinus rhythm with continuous monitoring of surface ECG and intracardiac local electrograms. Biplane fluoroscopic imagings were intermittently taken to check the stable positioning of the tip of the ablation catheter during RF energy application. If junctional ectopies or junctional tachycardia occurred, high right atrial overdrive pacing was delivered to monitor the integrity of AV conduction while application of RF energy continued. The pacing cycle length (usually 450–600 ms) was preselected to make sure of stable 1:1 AV conduction. If any AV block developed, the RF energy delivery was immediately interrupted and the electrode at the ablation site would be kept and imaged for record (as described below). Repeated electrophysiologic tests for the inducibility of AVNRT were conducted after each application of RF energy. Each application of RF energy was preset for a total of 60 seconds with the catheter tip temperature targeted at 60°C. Radiofrequency current (500 kHz) was delivered between the 4 mm distal electrode of the ablation catheter imbedded with a tip thermistor (Dr Osypka GmbH, Grenzach-Wyhlen, Germany or Webster-Cordis, Orlando, Florida, USA) and a large dispersive patch electrode on the back.

In the phase II study, the slow pathway catheter ablation was guided by localisation of the His bundle recording site, the coronary sinus orifice, and the distal end of the AV nodal artery demonstrated by coronary angiography before the ablation procedure. Every effort was made to keep the ablation target site posterior to and away from the distal end of the AV nodal artery. Radiofrequency energy was applied close to the tricuspid border, with smaller atrial local electrogram at the target site. At the end of the session, the final ablation site was recorded with a repeat selective coronary angiography to confirm further the anatomic spatial relation.

**ANGIOGRAPHIC STUDY**

In phase I, the final target sites of successful slow pathway catheter ablation or the sites complicated with transient or permanent complete AV block were imaged simultaneously with selective right or left coronary angiography (fig 2B). However, in phase II, selective coronary angiography for demonstration of the AV nodal artery was performed before the selection of target sites for slow pathway catheter ablation. All the angiographic images were taken in biplane left 45° and right 45° anterior oblique (LAO, RAO) views with the same magnification (9 inches (22.5 cm)) during the end expiratory breath holding period. The spatial resolution of the angiographic imaging is 0.5 mm.

For analysing the anatomical relation, the His bundle recording bipole was referred to as the apex of the Koch’s triangle at the AV junction, while the floor level of the coronary orifice was the base of the triangle. The AV nodal artery was identified as a long septal branch arising from the U loop of the posterolateral branch of the right coronary artery or from the left circumflex artery at the crux of the heart. The critical distal end of the AV nodal artery was defined as the identifiable straight ending of the AV nodal artery under 9 inch magnification films. In the event of fork shaped or double stranded arterial endings, the distal end of the AV nodal artery was taken at the midpoint.
between the two ends of the artery. Of the 128 patients with AVNRT in the phase I and phase II studies, 113 (88.3%) had a single AV nodal artery ending, 13 (10.1%) had a fork shaped ending, and two (1.6%) had a double stranded ending. The AV nodal artery originated from the right coronary artery in 118 (92.2%) patients and from the left circumflex artery in 10 (7.8%). None had double or more AV nodal arteries from the same or different coronary arteries. All of the selective coronary angiography procedures were completed smoothly without any complication.

**ELECTROPHYSIOLOGIC AND ANATOMICAL PARAMETERS PREDICTING THE RISK OF AV BLOCK**

To examine the potential predictors for the risk of AV block during slow pathway catheter ablation in the phase I study, multiple electrophysiological and anatomical parameters were independently analysed by authors from the two institutions without knowing the results of the procedures (JL Lin and LP Lai versus LJ Lin and JH Chen). If there was any controversy in the data measurement, consensus would be obtained from all four analysers to achieve resolution.

Electrophysiological parameters included the retrograde atrial activation time difference between the His bundle recording site and the coronary sinus orifice in AVNRT (A'HS-A'CSO), the antegrade atrial activation time difference between the His bundle recording site and the final catheter ablation site in sinus rhythm (A'HS-A'SCSO), and the elapsed time before the onset of junctional tachycardia during RF application. The mean cycle length of the junctional tachycardia and the occurrence of retrograde VA block with junctional ectopies were not systematically analysed because of the routine use of atrial overdrive pacing to monitor the AV conduction.

Anatomical parameters included the following spatial distances: (1) between the His bundle recording site and the coronary sinus orifice within Koch’s triangle (S-F and F-S); (2) between the His bundle recording site and the tricuspid border at the floor level of the coronary sinus orifice (that is, the tricuspid border dimension of Koch’s triangle); (3) between the His bundle recording site and the final catheter ablation site; and (4) the His bundle recording site and the distal end of the coronary sinus orifice in AVNRT (fig 2A, B).

**STATISTICS**

Continuous data were compared by unpaired Student’s t test and categoric data by χ² test with Yates’ correction. Stepwise univariate and multivariate logistic regression analysis was employed to analyse the independent predictor(s) of risk of AV block during slow pathway catheter ablation. A value of p < 0.05 was considered significant.

**RESULTS**

**SLOW PATHWAY CATHETER ABLATION OF AVNRT IN THE PHASE I STUDY**

In the phase I study, AVNRT was successfully ablated in 75 (97.4%) of the 77 patients by either slow pathway complete elimination (60 patients) or modification (15 patients). In two patients (2.6%), RF catheter ablation was complicated with irreversible complete AV block and a permanent pacemaker was implanted. In addition, in seven of the 75 patients with a successful outcome, the procedure was associated with transient high grade AV block requiring immediate interruption of RF energy application. The duration of transient AV block before full recovery of the normal AV conduction in the seven patients lasted from 5–120 seconds (mean 53.3 (38.3) seconds).

Nine patients complicated with reversible or irreversible AV block were classified as group A, while the remaining 68 patients without any complication were classified as group B. The time which elapsed before the appearance of transient or permanent complete AV block during RF energy delivery in the nine group A patients ranged from 12–90 seconds (mean 37.0 (27.9) seconds). One patient developed a period of transient complete AV block 30 seconds after completion of the preset ablation time.

The site of complete AV block was supra-Hisian in all patients. Clinical and electrophysiological characteristics including age, sex, details of induced AVNRT, distribution of the final RF catheter ablation sites within Koch’s triangle, total number of RF applications, and total procedure time were similar between groups A and B (table 1).

**ELECTROPHYSIOLOGIC PREDICTORS OF THE RISK OF AV BLOCK IN THE PHASE I STUDY**

As shown in table 2, none of the available electrophysiologic parameters either before or during RF energy application were significant in predicting the risk of AV block during slow pathway catheter ablation in the phase I study. An example of the local electrograms at the ablation target sites in a group A patient is shown in fig 3. However, the atrial activation...
time difference between the His bundle recording site and the RF catheter ablation site in sinus rhythm was shorter in group A patients (14.2 (4.6) ms in group A v 19.7 (9.2) ms in group B, p = 0.08).

ANATOMICAL PREDICTORS OF THE RISK OF AV BLOCK IN THE PHASE I STUDY

The fluoroscopic locations of the catheter ablation sites in the nine patients in group A complicated with AV block were found in the P₁ region in one patient, P₂ region in three, M₂ region in three, and M₁ region in two. In the 68 patients in group B with successful ablation, 10 sites were in the P₁ region, 43 in the P₂ region, 12 in the M₂ region and three in the M₁ region (p = 0.10 by χ², table 1). However, as shown in table 3, compared to those in group B, the anatomical parameters in group A patients characteristically had a wider distance between the His bundle recording site and the distal end of the AV nodal artery (group A v group B in RAO view: 11.3 (6.8) mm v 6.8 (3.7) mm, p ≤ 0.003; in LAO view: 11.0 (4.8) mm v 7.7 (3.9) mm, p ≤ 0.02) and a nearly overlapped approximation of the final catheter ablation site and the distal end of the AV nodal artery (group A v group B in RAO view: 0.61 (0.60) mm v 7.2 (4.0) mm, p ≤ 0.0005; in LAO view: 0.56 (0.58) mm v 6.9 (4.0) mm, p ≤ 0.00007). Examples of the anatomical landmarks for two patients in group A and one patient in group B are shown in figs 4 and 5, and fig 2B. Sequential univariate and multivariate regression analysis revealed that only the anatomical distance between the catheter ablation site and the distal end of the AV nodal artery was independently predictive of the risk of AV block during slow pathway catheter ablation of AVNRT. All of the nine patients in group A, but none of the 68 patients in group B, had a closely approximated distance of < 2 mm between the catheter ablation site and the AV nodal artery ending.

The success site without AV block was 7.2 (4.0) mm (RAO view) and 6.9 (4.0) mm (LAO view) away from the distal end of the AV nodal artery, and 14.1 (4.3) mm (RAO view) and 14.4 (3.5) mm (LAO view) from the His bundle recording site (table 3).

SUCCESS, COMPLICATION, AND ANATOMICAL LOCATIONS OF SLOW PATHWAY CATHETER ABLATION OF AVNRT IN THE PHASE II STUDY

Of 51 patients with AVNRT in the phase II study, the slow-fast type was found in 47 patients, fast-slow type in two, and both slow-fast and fast-slow type in two. The mean cycle length of the induced AVNRT was 360 (42) ms (range 242–510 ms). Slow pathway catheter ablation guided by the three anatomical landmarks in Koch’s triangle—that is, the His bundle recording site, the coronary sinus orifice, and the distal end of the AV nodal artery—successfully eliminated all forms of AVNRT without AV block. The slow pathway conduction of the AV node was eliminated in 35 patients and modified in 16. None of the 51 patients had inadvertent fast pathway damage or modification.

### Table 2

Comparison of warning electrophysiologic predictors noted during slow pathway catheter ablation in nine patients with (group A) and 68 patients without (group B) AV block during slow pathway catheter ablation of AVNRT in the phase I study

<table>
<thead>
<tr>
<th></th>
<th>A’HB-A’CSO</th>
<th>AHB-AMAP</th>
<th>AV</th>
<th>JT/JE</th>
<th>JT onset</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>9.6 (8.3)</td>
<td>14.2 (4.6)</td>
<td>0.4 (0.6)</td>
<td>9.9</td>
<td>9.4 (12.8)</td>
<td>0.25</td>
</tr>
<tr>
<td>Group B</td>
<td>13.0 (8.2)</td>
<td>19.7 (9.2)</td>
<td>0.7 (0.6)</td>
<td>59.88</td>
<td>10.0 (18.1)</td>
<td>0.08</td>
</tr>
</tbody>
</table>

### Table 3

Comparison of anatomical parameters demonstrated by angiography in nine patients with (group A) and 68 patients without (group B) AV block during slow pathway catheter ablation of AVNRT in the phase I study

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>p₁</th>
<th>p₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAO 45° view</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D₁₁₀-HB-CSSF</td>
<td>18.8 (4.2)</td>
<td>20.1 (5.3)</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>D₁₁₀-HB-NGSS</td>
<td>11.3 (6.8)</td>
<td>6.8 (3.7)</td>
<td>0.003</td>
<td>0.11</td>
</tr>
<tr>
<td>D₁₁₀-HB</td>
<td>11.7 (6.8)</td>
<td>14.1 (4.3)</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>D₁₁₀-RAO-REF</td>
<td>0.61 (0.60)</td>
<td>7.2 (4.0)</td>
<td>0.00005</td>
<td>0.001</td>
</tr>
<tr>
<td>LAO 45° view</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D₁₁₀-HB-CSSF</td>
<td>20.6 (5.9)</td>
<td>23.6 (4.6)</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>D₁₁₀-HB-NGSS</td>
<td>11.0 (4.7)</td>
<td>7.7 (3.9)</td>
<td>0.02</td>
<td>0.43</td>
</tr>
<tr>
<td>D₁₁₀-HB</td>
<td>12.8 (5.2)</td>
<td>14.4 (3.5)</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>D₁₁₀-RAO-REF</td>
<td>0.56 (0.58)</td>
<td>6.9 (4.0)</td>
<td>0.00007</td>
<td>0.001</td>
</tr>
</tbody>
</table>

D₁₁₀-HB-CSSF, D₁₁₀-HB-NGSS, D₁₁₀-HB, D₁₁₀-RAO-REF, AVNRT: distance between AVNRT and RF; p₁, p value between group A and group B, by Student’s t test; p₂, p value by multivariate regression analysis; p ≤ 0.05 is significant. The number in the parenthesis represents the standard deviation of the mean value.
The fluoroscopic locations of the successful ablation sites were found in the P, region in seven patients, P, region in 28, M, region in 14, and M, region in two. The distal ends of the AV nodal artery were located in the A, region in 13, A, region in 10, M, region in 13, M, region in 10, P, region in four, and P, region in one. Final angiographic reconfirmation showed that the spatial distance between the catheter ablation site and the distal end of the AV nodal artery was 8.8 (4.2) mm (v = 7.2 (4.0) mm for group B in phase I, p = 0.03) in RAO view and 9.2 (5.1) mm (v = 6.9 (4.0) mm in phase I, p = 0.007) in LAO view, while that between the ablation site and the His bundle recording site was 15.8 (4.7) mm (v = 14.1 (4.3) mm for group B in phase I, p = 0.04) in RAO view and 16.0 (3.8) mm (v = 14.4 (3.5) mm in phase I, p = 0.02) in LAO view. The distances from the His bundle recording site to the distal end of the AV nodal artery and the floor level of the coronary sinus orifice were similar to those in the phase I study (table 4).

**Discussion**

**MAIN FINDINGS**

This study showed that the anatomical approximation of the ablation target site to the distal end of the AV nodal artery is highly and independently predictive of the risk of AV block during slow pathway catheter ablation for the treatment of AVNRT. A spatial distance < 2 mm between the ablation target site and the distal end of the AV nodal artery almost always resulted in supra-Hisian AV block. Thus, the distal end of the AV nodal artery apparently serves as a useful landmark for angiographic localisation of the AV node within Koch’s triangle. In addition, patients complicated with transient or permanent complete AV block characteristically had a more posteriorly located AV node. In contrast, none of the electrophysiologic signals either before or during RF energy application were predictive of the occurrence of AV block.

**AV NODAL ARTERY AND AV NODE**

The AV nodal artery which supplies the AV node usually originates as a septal branch from the distal right coronary artery proper (or uncommonly from the left circumflex artery proper) at the crux of the heart in humans. The artery penetrates toward the interatrial septum and tapers to < 0.4 mm in internal diameter before entering the compact AV node. Inside the compact node, the AV nodal artery directly transforms into minute plexiform arterioles and communicates with the vascular network around the His bundle. Previous experimental and clinical studies have shown that selective catheterisation of the AV nodal artery and direct infusion of contrast medium, acetylcholine, alcohol concentrate or collagen emboli consistently results in complete AV block in the node, not at or below the His bundle. The selectivity of the anatomical site of injury leads to our hypothesis that the distal end of the AV nodal artery could serve as the anatomical landmark for localisation of the AV node within Koch’s triangle.

**ELECTROPHYSIOLOGIC PARAMETERS VERSUS ANATOMICAL LANDMARKS FOR PREDICTING THE RISK OF AV BLOCK**

Current practice for prevention of inadvertent AV block relies primarily on the analysis and continuous monitoring of local electrophysiological parameters either before or during slow pathway catheter ablation. Jazayeri and colleagues first found that the retrograde atrial activation time difference between the His bundle site and the coronary sinus orifice (A’_HB - A’_CSO ≤ 15 ms) during AVNRT or...
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studies, which show a low specificity (for example, junctional ectopies with retrograde VA block). During RF application cannot be evaluated and cannot be compared with that of our proposed anatomical landmark. Furthermore, it might be too late to avoid AV block at the time when VA block occurs during junctional tachycardia. Third, the subtle details of the distal end of the AV nodal artery—for example, the plexiform connections with the posterior His bundle vascular networks—could not be demonstrated on standard angiography and fluoroscopic magnification. Nevertheless, our phase II study supported the finding that the distal end of the AV nodal artery shown by the standard technique would be sufficient enough to serve as a useful landmark to avoid the risk of AV block. Fourth, only the angiographic locations of the successful ablation sites and the sites complicated with AV block were recorded for analysis. The cumulative effect from previous RF applications at the failed ablation sites could not be verified.

**CONCLUSIONS**

The identification of the distal end of the AV nodal artery by selective coronary angiography is useful for the prediction of AV block during slow pathway catheter ablation of AVNRT. Prior angiographic demonstration of this anatomical landmark before application of RF energy may be an important step for assisting the selection of an appropriate target site for ablation in order to minimise the risk of AV block.

This study is supported in part by grants from the National Science Council (NSC 87-2314-B-002-193) and the National Health Research Institute (DOH 87-HR-711) in Taiwan. The authors appreciate the technical support from Mr. Ming-Lung Liu and Mr. Shin-Jee Ho in angiographic studies and the secretarial assistance of Ms. Yeh-Ju Luo and Ms. Jen-Yu Huang in preparation of the manuscript. This paper was presented in part at the 47th annual scientific session of the American College of Cardiology in Atlanta, March, 1998.


LIMITATIONS

First, the clinical applicability of this anatomical landmark—that is, the distal end of the AV nodal artery—in the slow pathway RF catheter ablation of AVNRT could be limited by the increased cost and potential risk associated with the additional coronary angiography. However, our study at least showed the feasibility and reliability of using such a new landmark in identification of the site at high risk of AV block during RF ablation of AVNRT by the posterior approach. It might be helpful in patients with an unusual functional anatomy of Koch’s triangle—for example, the posteriorly deviated AV node or fast pathway. Second, because of the use of atrial overdrive pacing to monitor the integrity of AV conduction in the present study, the usefulness of junctional ectopies with retrograde VA block during RF application cannot be evaluated and cannot be compared with that of our proposed anatomical landmark. Furthermore, it might be too late to avoid AV block at the time when VA block occurs during junctional tachycardia. Third, the subtle details of the distal end of the AV nodal artery—for example, the plexiform connections with the posterior His bundle vascular networks—could not be demonstrated on standard angiography and fluoroscopic magnification. Nevertheless, our phase II study supported the finding that the distal end of the AV nodal artery shown by the standard technique would be sufficient enough to serve as a useful landmark to avoid the risk of AV block. Fourth, only the angiographic locations of the successful ablation sites and the sites complicated with AV block were recorded for analysis. The cumulative effect from previous RF applications at the failed ablation sites could not be verified.

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Strangulated gastric volvulus: an unusual cause of cardiac compression resulting in electromechanical dissociation

A 50 year old man was admitted with severe epigastric pain. He had previously had an open Heller's cardiomyotomy for achalasia. Subsequent investigations for persisting dyspepsia had demonstrated a rolling hiatus hernia. He was tachycardic and hypotensive, with a raised jugular venous pressure. His chest radiograph showed bowel loops within the left hemithorax and a left pleural reaction.

An urgent transthoracic echocardiogram revealed that the atria were obscured by an extracardiac mass. A diagnosis of extrinsic cardiac compression secondary to a gastric volvulus was made. While awaiting emergency surgery his condition deteriorated culminating in electromechanical dissociation (EMD). Following successful resuscitation there was an immediate improvement in his blood pressure. At surgery he had a tight, scarred hiatus below which only the pylorus was visible. The stomach was brought down into the abdomen, and an anterior gastropexy performed. He was discharged 12 days later and is well at six month follow-up.

There are few reported cases of gastrointestinal causes of extrapericardial cardiac compression producing haemodynamic compromise. We believe this is the second report involving a gastric volvulus. The echocardiographic features of diaphragmatic herniae have been previously characterised, with the hiatus hernia usually being visualised as an amorphous solid mass compressing the atria. We postulate that, in our case, there was significant compression of both atria causing tamponade. Although the patient suffered an EMD cardiac arrest, the physical act of cardiac massage may have resulted in partial decompression of the volvulus, since the haemodynamic parameters were much improved immediately postarrest.
Distal end of the atrioventricular nodal artery predicts the risk of atrioventricular block during slow pathway catheter ablation of atrioventricular nodal re-entrant tachycardia


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