The Effects of Accumulated Experience on Radiofrequency Ablation of Accessory Pathways

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SUMMARY

Increasing experience in radiofrequency ablation for accessory pathways appears to reduce the procedure time, radiation time and radiofrequency pulse number, and results in a higher success rate. However, the effect of a learning curve on this procedure from the perspective of location and conduction direction of accessory pathways has not been reported before. The purpose of this study was to determine the effect of accumulated experience on the outcomes of radiofrequency ablation for accessory pathways and on the duration of the procedure parameters by analyzing the results of a dedicated ablation team. The first 512 patients with a single accessory pathway treated in this laboratory were included for analysis of the procedure parameters with respect to locations and conduction directions of accessory pathways. The results showed that the average procedure time, radiation time and radiofrequency pulse number differed significantly among the different subgroups (left free wall, right free wall, posteroseptal and anteromidseptal location; manifest or concealed conduction). All subgroups except the anteromidseptal pathways showed a significant improvement of the procedure parameters with increased ablation experience. Although the initial rate of improvement was similar among the different subgroups, the rate of improvement in left free wall pathways nearly reached a plateau after 120 ablation procedures. Thus it was concluded that a certain number of ablation procedures was necessary before achievement of a high success rate with shorter procedure and radiation times and a lower radiofrequency pulse number. (Jpn Heart J **36**: 729–739, 1995)

Key Words: Radiofrequency ablation Accessory pathway Experience

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RADIOFREQUENCY catheter ablation of accessory pathways has been shown to be safe and effective in patients with Wolff-Parkinson-White syndrome.[1-5] Even in experienced hands, although the ablation procedure seems to be feasible, this approach may not always be successful. Because catheter ablation requires skill in interpretation of the electrophysiologic mechanism and manipulation of the mapping/ablation catheter to map the accessory pathway location, the outcome depends on the knowledge of electrophysiology and operation technique. Although Leather et al have reported that increasing experience could reduce procedure time, radiation time, radiofrequency pulse number and achieve higher success rates, major limitations for assessing data included absence of systematic analysis and a small patient population exhibiting each pathway location.[6] To the best of our knowledge, there is no previous report of a systematic analysis, involving a large patient population, of the efficiency of a dedicated ablation team as a function of accumulated experience, and the effect of this learning curve on the success rate and procedure characteristics related to location and conduction direction of accessory pathways. The purpose of this study was to determine the effect of accumulated experience on the outcome of radiofrequency catheter ablation of accessory pathways by analyzing changes in efficacy and duration of procedure parameters as experience increased.

Methods

Patient characteristics: To prevent statistical bias, patients receiving radiofrequency ablation with a small tip-electrode and patients with multiple accessory pathways were not included. Thus this study included the first 512 patients with tachyarrhythmias mediated by a single accessory pathway; they received radiofrequency ablation using a large tip-electrode between July 1990 and July 1994. There were 313 male and 199 female patients with a mean age of 46 ± 17 years. There were 240 patients with a manifest accessory pathway and 272 patients with a concealed accessory pathway. All of these patients had frequent attacks of tachycardia and were refractory to or intolerant of antiarrhythmic drugs (mean, 2 ± 1 drugs).

Electrophysiologic study and radiofrequency ablation: As described previously, informed consent was obtained from all patients under an investigational protocol approved by the Human Research Committee of this institution.[5,7,8] In brief, an electrophysiologic study was performed while the patient was fasting and not sedated; all antiarrhythmic medications were discontinued for at least 5 half-lives before study. Three 6F multipolar electrode catheters (Mansfield, Boston Scientific, Boston MA, USA) were inserted percutaneously into the right or left femoral vein and positioned in the right atrium, the His bundle area, and the

right ventricle. One or two orthogonal electrode catheters (or other multipolar electrode catheters for recording coronary sinus electrogram) were inserted into the right internal jugular vein and placed in the coronary sinus. The diagnostic portion of the electrophysiologic study included (1) measurement of the conduction properties of the atrium, AV node, ventricle, and accessory pathways; (2) initiation of supraventricular tachycardia and atrial flutter-fibrillation; and (3) determination of the mechanism of tachycardia. If tachycardia could not be induced in the baseline state, isoproterenol (1 to 4 μg/min) or atropine (1 to 2 mg) was used to facilitate the induction of tachycardia.

Target sites for ablation were identified by the presence of discrete atrial and ventricular electrograms, earliest ventricular activation relative to the onset of the delta wave on the surface electrocardiogram during antegrade (manifest) accessory pathway conduction in sinus rhythm or earliest atrial activation during retrograde accessory pathway conduction in orthodromic tachycardia or ventricular pacing, and/or a possible accessory pathway potential between the atrial and ventricular electrograms. Radiofrequency energy (from a Radionic-3C generator) was delivered during sinus rhythm in patients with manifest accessory pathways and during ventricular pacing in patients with concealed accessory pathways when electrograms at the presumed ablation sites were stable (the amplitudes of five consecutive electrograms differed less than 10%). Eight subgroups were classified according to the electrophysiologic study, endocardial mapping, location (left free wall, right free wall, posteroseptal and anteromidseptal areas) and conduction direction (manifest or concealed) of accessory pathways. These diagnostic and ablation techniques have been described previously, and were well established in this laboratory.[5,7,8]

Procedure analysis: The electrophysiologic study and catheter ablation procedures were performed by a team of 4 staff electrophysiologists and 6 electrophysiology fellows. The 4 electrophysiologists were continuously involved in the program; the 6 fellows participated in the program for 12 to 24 months each. Inserting and positioning the electrode catheters was done by the electrophysiology fellows; manipulation of the mapping/ablation catheter for endocardial mapping and approaching the presumed ablation sites was performed primarily by an electrophysiology fellow and a junior staff; electrogram analysis and identification of appropriate ablation sites was performed by a senior staff. The equipment and electrode catheter used for the electrophysiologic study, endocardial mapping and ablation remained constant for all 512 patients. Duration of the ablation procedure included the time needed for inserting and positioning catheters, the diagnostic electrophysiologic study and the catheter ablation procedure. Radiation exposure time, number of radiofrequency pulses, and success and complication rates were analyzed. All procedure parameters including procedure time,

radiation time and radiofrequency pulse number were used for comparison between different pathway location groups and were further analyzed as a function of accumulating experience, i.e. the total number of procedures previously performed.

Statistical analysis: Data are presented as mean ± SD or median as appropriate. Fisher's exact test was used to compare the success rate between different subgroups. Two-way analysis of variance was used to test for the effect on the performance parameters of the different accessory pathway locations and conduction directions.

Regarding the learning effect, linear regressions were used to test the performance parameters against procedure number. The procedure number used was a single series of integers, increased by one for each procedure, irrespective of the type of pathway. Regression slope was used to estimate the improvement of procedure characteristics. Differences between regression slopes for all eight subgroups defined by different location and conduction direction were tested by multiple regression with procedure number, procedure time, radiation time and radiofrequency pulse number as covariants.

Results

Out of 512 ablation procedures, 497 (97%) accessory pathways were ablated successfully in the primary ablation session. Five left free wall, five right free wall and five posteroseptal pathways were not ablated. Thus, the failure rate was 1.8%, 5.5%, 4.8% and 0% for left free wall, right free wall, posteroseptal and anteromidseptal pathways, respectively; these differences were not statistically significant. Furthermore, there were 5 (5%), 4 (4%), 3 (3%), 2 (2%) and 1 (0.9%) failures in the first, second, third and fourth 100 patients and last 112 patients, respectively; these differences did not show statistical significance.

Regression analysis of the parameters as a function of the number of patients previously treated showed a clear overall improvement with accumulating experience in procedure time, radiation time and radiofrequency pulse numbers for accessory pathways located in the left free wall, right free wall and posteroseptal areas (Figures 1 and 2 and Table). Because the analysis in patients with left free wall pathways showed that the procedure parameters reached a nearly constant value, a cut off point (120 procedures) was chosen to compare these parameters between the first and second halves of the total group of patients treated. The improvement in procedure and radiation times in the second half was still significant but this improvement was less than in the first half; however, improvement in the radiofrequency pulse number in the second half was not significant (Figure 1, Table). As the slopes (i.e. regression coefficients)

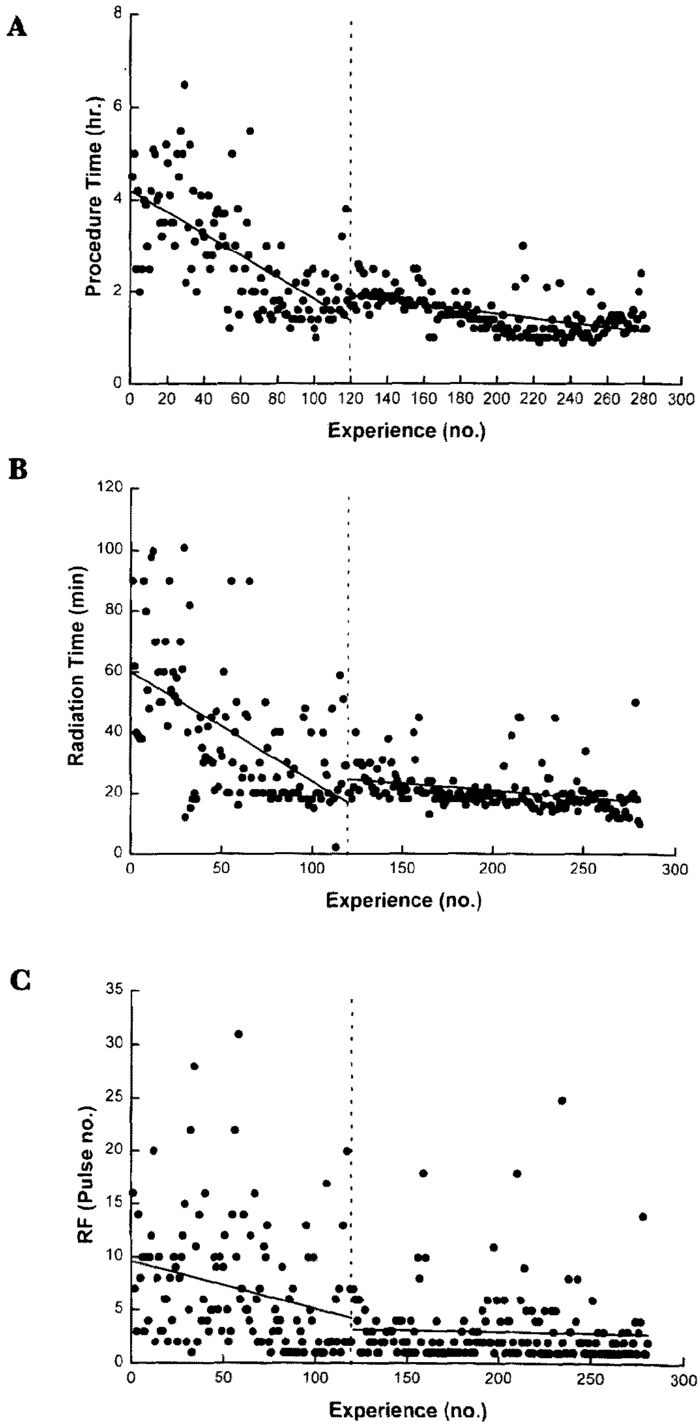

Figure 1. Panels A, B and C show progressive improvement of the procedure time, radiation time and radiofrequency (RF) pulse number required for ablation of left free wall pathways with increased experience. The cut off point was at the one hundred and twentieth procedure.

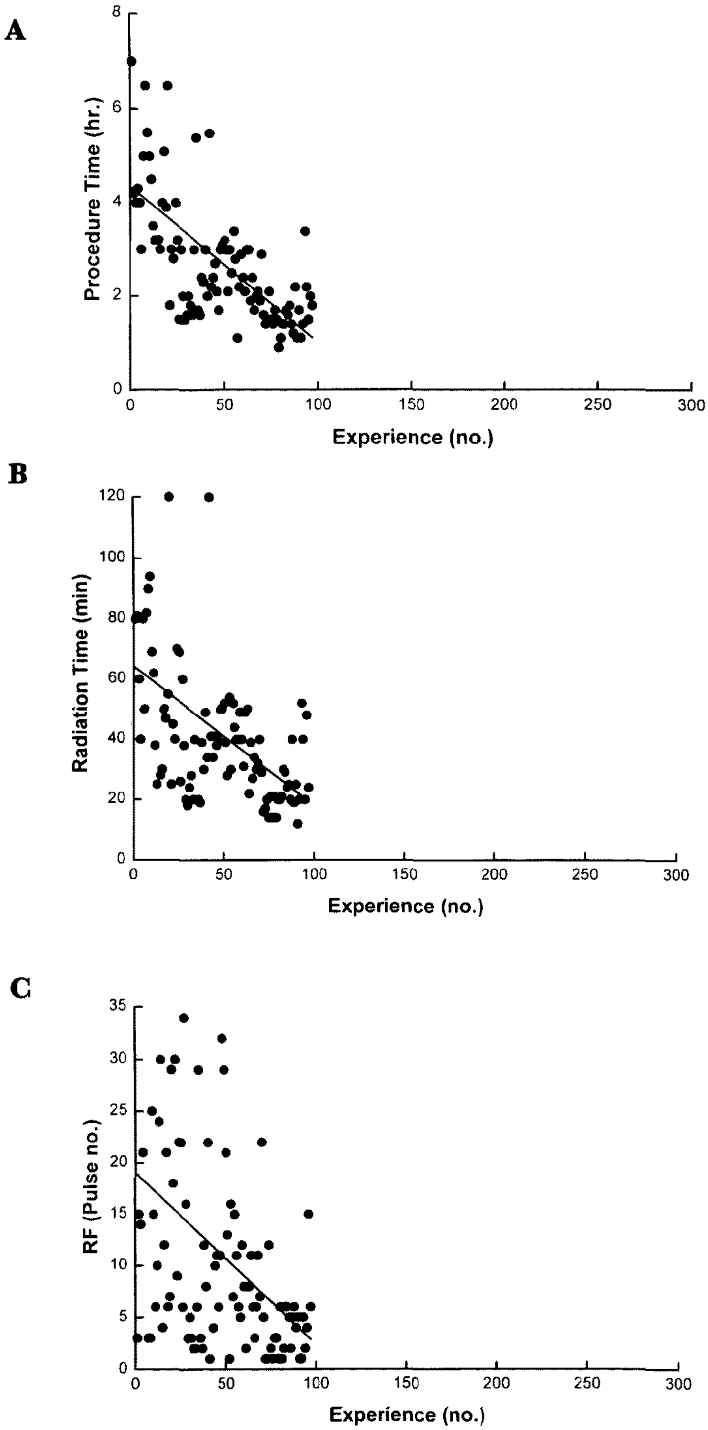

Figure 2. Panels A, B and C show progressive improvement of the procedure parameters required for ablation of right free wall pathways.

Table. Regression Analysis ($y = ax + b$) of the Procedure Time, Radiation Time and Radiofrequency (RF) Pulse Number in Different Locations of Accessory Pathways (APs)

	LFW		RFW	PS	AMS
Patients (n)	120 (1st)	161 (2nd)	97	103	31
Procedure time (hour)					
$y = ax + b$	−0.024, 4.202	−0.005, 2.499	−0.033, 4.349	−0.023, 3.600	−0.045, 3.393
r value	0.670	0.538	0.656	0.677	0.457
p value	<0.0001	<0.0001	<0.0001	<0.0001	0.0097
Radiation time (min)					
$y = ax + b$	−0.362, 60.056	−0.047, 30.229	−0.463, 64.302	−0.374, 55.787	−0.707, 50.445
r value	0.571	0.318	0.526	0.530	0.325
p value	<0.0001	<0.0001	<0.0001	<0.0001	0.075
RF pulses (n)					
$y = ax + b$	−0.045, 9.588	−0.003, 3.485	−0.167, 19.059	−0.089, 12.364	−0.233, 13.722
r value	0.264	0.035	0.442	0.362	0.162
p value	0.0035	0.6557	<0.0001	0.0002	0.3832

AMS = anteromidseptal; LFW = left free wall; PS = posteroseptal; RFW = right free wall; $y = ax + b$, representing the linear regression, a = regression coefficient, b = constant; 1st and 2nd represent the first and second halves of patients.

revealed, approximately 0.024 hours and 0.362 minutes less procedure and radiation time, respectively, was required with each successive procedure for the next ablation of the left free wall pathway. In patients with anteromidseptal accessory pathways, the procedure time and radiation time showed a tendency to shorten with increased experience, but the pulse number did not show a significant decrease. The rate of improvement was also examined separately for all eight subgroups as derived for manifest or concealed pathways and the results showed that the rate of improvement did not differ significantly whether the pathway was manifest or concealed. Furthermore, analysis of covariance P values for procedure time, radiation time and number of radiofrequency pulses among the four accessory pathway locations were 0.2170, 0.4387, and 0.5908, respectively.

For all patients, mean and median durations for the whole procedure were 2.7 ± 0.9 hours and 2.8 hours, respectively; those for radiation exposure were 44 ± 10 and 20 minutes, respectively; those for the number of radiofrequency pulses were 10 ± 13 and 6, respectively. The median radiofrequency pulse number was 3, 6, 6 and 5 for left free wall, right free wall, posteroseptal and anteromidseptal accessory pathways, respectively. Results of the mean procedure time, radiation time and number of radiofrequency pulses for the left free wall pathways in the first and second halves were 2.8 ± 1.2 hours, 38 ± 22 minutes, 7 ± 6 pulses and 1.5 ± 0.4 hours, 21 ± 7 minutes, 3 ± 3 pulses, respectively ($p < 0.01$, < 0.01, < 0.01, respectively); all the subgroups are shown in Figure 3. Two-way analysis of variance in the patients with manifest or concealed pathways showed that the procedure time ($p < 0.0001$), radiation time ($p < 0.0001$)

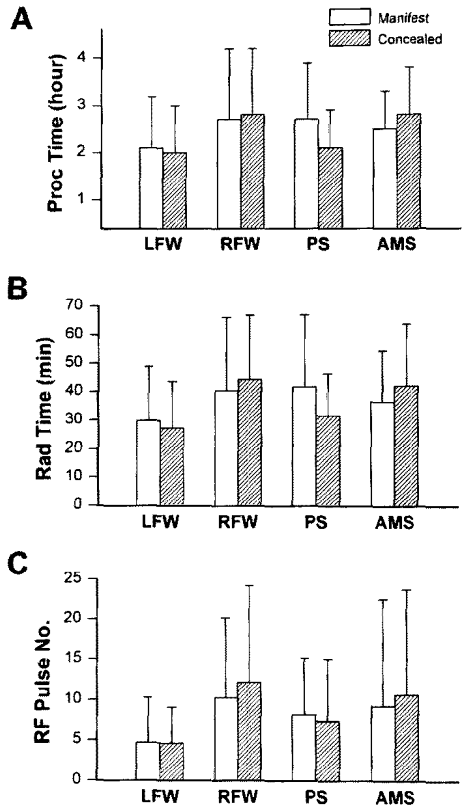

Figure 3. Procedure time, radiation time and radiofrequency pulse number required for ablation of accessory pathways with different locations and conduction directions. AMS = anteromidseptal; LFW = left free wall; PS = posteroseptal; RFW = right free wall.

and radiofrequency pulse number ($p < 0.0001$) differed significantly among different pathway groups. However, comparisons between manifest and concealed pathways in each pathway location did not show a significant difference with respect to these parameters.

Discussion

The major findings showed that significant improvement of procedure parameters are demonstrated when ablation experience increases. Furthermore, the rate of improvement was similar among patients with accessory pathways in different locations.

The radiofrequency ablation technique has been applied to almost all types of arrhythmias, including accessory pathway-mediated tachyarrhythmias, atrioventricular nodal reentry tachycardia, atrial tachycardia, common type atrial

flutter, idiopathic ventricular tachycardia and modification of AV junction for control of ventricular rate in atrial fibrillation. However, fears of long radiation exposure time and complications because of long procedure times have been causes for concern.[9] Jackman et al reported the first large series of radiofrequency ablations in 166 patients with Wolff-Parkinson-White syndrome; the success rate was 99%, but the average procedure time was 8.3 ± 3.5 hours.[1] Calkins et al reported a large series using an abbreviated protocol for ablation of accessory pathways with an 88% success rate at the first ablation attempt and average procedure and radiation times of 134 ± 7.5 and 47 ± 33 minutes, respectively.[2] Lesh et al reported that the median total procedure time was 240 minutes and mean radiation time was 66 ± 9 minutes in radiofrequency ablation of the first 100 patients with accessory pathways, but the first ablation success rate was 77%.[4] The report of radiofrequency ablation in the first 62 patients with accessory pathways from this laboratory showed that procedure and radiation times were 4.1 ± 0.4 hours and 46 ± 9 minutes, respectively, with a 96% success rate.[5]

Schluter et al reported that cumulative experience and improved catheter technology (use of large-tip ablation electrode) could increase the success rate.[4] Leather et al attempted to limit their radiation time to less than 1 hour and reported an overall 66% success rate for 84 pathways at first ablation sessions.[6] However, the overall success rates showed a clear improvement with increasing experience, ranging from 52% for the first 23 patients, followed by 60% for the next 23 and 90% for the last 38 patients. Although improved success rates were noted for all groups of pathways (left, posteroseptal and right free wall), their learning curve for left lateral pathways was steeper than for other pathway locations. However, systematic analysis of determining factors and experience in anteromidseptal pathways was not.[6] Calkins et al reported the operator experience and outcome of radiofrequency catheter ablation in 400 patients with accessory pathways.[10] They found that a statistically significant decrease in the percentage of patients with an unsuccessful initial catheter ablation session was observed only after 250 ablation procedures were performed. From this they concluded that a progressive increase in the success rate of radiofrequency ablation and decrease in the duration of successful ablation sessions resulted from a progressive increase in operator experience.[11] Kay et al also reported that there was an important effect of experience on the likelihood of successful ablation, with a 93.2% and 99.9% ($P = 0.004$) success rate in the first and second halves of 384 consecutive accessory pathway ablations.[11]

To the best of our knowledge, this report is the first study to systematically analyze the effect of accumulating experience on ablation of accessory pathways and to analyze other possible reasons for the expected improvement with time by the same ablation team treating 512 consecutive patients with a single accessory

pathway. Although the average pulse number, and procedure and radiation time differed significantly, the learning curves of these procedure parameters did not differ significantly among different pathway groups. The right free wall and posteroseptal pathways seemed to be difficult to ablate, probably because of the instability of the ablating catheter against the free wall aspects of the tricuspid annulus and the complex anatomy of the posteroseptal space. In spite of this the learning curve did not display different characteristics among these study groups. This clearly suggested that the decisive determinant of the learning curve was the procedure number regardless of pathway location. This finding was similar to that of Calkins et al that each pathway can be efficiently approached with a certain amount of experience.[10] Furthermore, this study also showed that procedure parameters of left free wall pathways would reach a plateau phase after 120 ablation procedures were performed. However, it is not clear whether this plateau phase would be found in patients with pathways in other locations. Although the learning curve in radiofrequency ablation of anteromidseptal pathways did not show significant improvement, more experience with this pathway location might improve the learning curve.

The skills required for successful ablation included detailed electrophysiologic study, endocardial mapping, quick identification of the presumed ablation sites and delicate manipulation of the ablation catheter. In this study, the same type of ablation catheter and equipment were used for mapping and ablation in all patients; thus the progressive improvement in the procedure parameters could not have been the result of technological improvement in the catheter design. Furthermore, the finding that the number of radiofrequency pulses required for successful ablation decreased progressively as experience increased suggests that the skills required for catheter manipulation and identification of target sites were important.

It is concluded that the learning curves showed similar characteristics, regardless of the location or conduction direction of accessory pathways, and that the accumulation of a certain amount of ablation experience was necessary for a high success rate associated with shorter procedure and radiation times and a lower number of radiofrequency pulses.

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