TOPICS IN REVIEW

Atrioventricular junctional ablation: The good, the bad, the better

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BACKGROUND The management of patients with atrial fibrillation and an abnormally fast ventricular response has been through the use of pharmacologic agents. In those cases where rate control cannot be achieved pharmacologically, a standard approach has been atrioventricular (AV) junctional ablation and ventricular pacemaker implantation to achieve a stable ventricular rate. Long-term ventricular pacing has been shown to result in diminished ventricular function that can lead to heart failure.

OBJECTIVE To describe an experimental and clinical study demonstrating a modified form of AV junction ablation.

METHODS Ablation of the slow and fast AV nodal input does not produce AV block. Ablation of the connection between the two induces AV block, leaving the AV node and His bundle intact.

RESULTS Subsequently the escape heart rate is close to normal and responds well to exercise.

CONCLUSION In a clinical study with a 42 month follow-up, the modified procedure resulted in significantly reduced pacemaker dependence and mortality compared to the standard AV ablation procedure.

KEYWORDS Atrial fibrillation; Atrioventricular junction; AV node; Catheter ablation; Fast pathway; His bundle pacing; Slow pathway

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Introduction

The management of patients with atrial fibrillation (AF) includes rate control and rhythm control.[1] The decision for either rhythm control or rate control is mainly dependent on patient symptoms and other comorbidities, but as yet there are no clinical trials suggesting superiority of one strategy over another.[2–4] Rate control may be preferred over rhythm control, given the extensive side effects associated with antiarrhythmic medications, especially in elderly asymptomatic patients. Rate control also can be used in patients who failed rhythm control strategies including ablation or electrical cardioversion. The traditional method of rate control is using atrioventricular (AV) nodal blocking agents, but their use can be limited by patient nontoleration and hypotension.[5,6] ACC/AHA/HRS AF practice guidelines indicate that AV junctional ablation (AVJA) with permanent ventricular pacing is a reasonable strategy to control the heart rate in AF, when pharmacological therapy is inadequate and rhythm control cannot be achieved (class IIa, level of evidence B).[7] Moreover, clinical trials showed that strict rate control cannot be achieved in at least one-quarter of patients.[2,8] Therefore, in specific conditions, AVJA with permanent pacemaker (PPM) implantation represents a particularly useful therapeutic intervention and last resort in rate control.[1] In this review we discuss the present role of AVJA and its undesirable effects and introduce an experimentally based and clinically demonstrated modification of this procedure to overcome the drawbacks of the standard method.

Role of AV junctional ablation and pacing

The AV node is localized in atrial tissue at the apex of the triangle of Koch (Figure 1). The goal of the ablation procedure is to damage the compact AV node at the most proximal part of the His bundle, while preserving some of the underlying automaticity.[8] Complete AVJA provides a very effective way to control the ventricular rate during AF. However, a PPM must be implanted to provide an adequate heart rate, because the junctional escape rhythm after ablation is typically slow and unreliable.[9]

A report from the prospective Ablate and Pace trial[10] showed that catheter ablation of the AV conduction system and PPM implantation were associated with improved quality of life and left ventricular function in symptomatic patients with AF refractory to medical therapy.

The role of AV nodal inputs

Investigation of the structure and function of AV nodal inputs has had a controversial history. In 1979, Sherf and James[11]

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KEY FINDINGS

- The purpose of the report was to describe an experimental and clinical study demonstrating a modified form of atrioventricular (AV) junctional ablation.
- Ablation of the slow and fast AV nodal input does not produce AV block. Ablation of the connection between the two induces AV block, leaving the AV node and His bundle intact.
- Subsequently the escape heart rate is close to normal and responds well to exercise.
- A 42-month follow-up clinical study of this modified procedure shows that pacemaker dependence was markedly diminished and mortality was significantly reduced compared to the standard AV junctional procedure.

described the existence of specialized tissues comprising 3 tracts connecting the sinoatrial and AV nodes. Such specific internodal tracts were disputed by the findings of Anderson and colleagues,[12] whose studies indicated that the atrionodal connections consisted of regular atrial myocardium. On the other hand, other studies in the rabbit heart concluded that transitional cell populations are located adjacent to the compact AV node and have differential electrophysiological properties, particularly regarding Wenckebach conduction.[13] Others showed that ventricular premature beats, conducted retrogradely, exposed functional discordance between the 2 AV nodal pathways, fast anterior and slow posterior. Retrograde conduction over the slow pathway could activate the fast pathway in an anterograde direction, establishing a tachycardia circuit in reverse of the slow-fast form.[14] These studies preempted the clinical reports by Jackman and colleagues[15] and Haissaguerre and colleagues[16] showing that slow pathway ablation in patients could terminate AV nodal reentrant tachycardia. Further studies in rabbit preparations found that surgical transection of the fast and slow pathway did not cause AV block, leading to the discovery of a third set of mid-septal transitional cells connecting the atrial myocardium to the AV node.[17]

Experimental and clinical modification

Antz and colleagues[18] subsequently demonstrated that in the dog heart, the ablation of the anterior fast pathway and posterior slow pathway and the atrial myocardium between the 2 induced complete AV block. Importantly, the resulting high junctional rhythm was significantly faster (~60 beats/min) than would be found if the AV junction were ablated providing a slow escape rate (~35–45 beats/min).[19] Histological findings indicated that the compact AV node and His bundle were undamaged. In a follow-up clinical study by Strohmer and colleagues[20] in 76 consecutive patients with uncontrollable AF, the fast and slow pathways were first ablated. If there was no AV block, additional ablation was added to the atrial septum connecting the 2 areas. The specifics of the atrionodal ablation procedure are indicated in the Methods section of their report, which is paraphrased as follows: The ablation was performed following a stepwise approach. (1) The fast pathway was ablated, characterized by junctional rhythm during energy application. The endpoint of the successful ablation was a >50 ms prolongation of the A-H interval. (2) The slow pathway ablation endpoint was lengthening of the A-H interval by at least another 50 ms. (3) If ablations of both fast and slow pathways did not result in complete heart block, ablations of additional atrionodal inputs by energy applications between the fast and slow pathways were performed. The ablation catheter was positioned progressively more anterior starting from the coronary sinus region moving toward the mid-septal region at the anterior limbus of the fossa ovalis. The ablation continued until complete heart block occurred or until a total of 15 energy applications.

The follow-up period was 42 ± 11 months. Group 1 (n = 57) were patients with complete heart block and junctional escape rates of 53 ± 4 beats/min, which remained stable during the follow-up period. Group 2 (n = 15) were patients who failed the stepwise atrionodal input ablation and required AVJA guided by His bundle potential recording to achieve complete AV block. Of those 15 that had AVJA, only 4 had a slow escape rhythm (~33 beats/min). All 15 remained pacemaker dependent. Compared to the standard AVJA, the 3-pronged procedure was associated with a lower mortality (32% compared to 67%) over the follow-up period. Table 1 summarizes the ablation results.

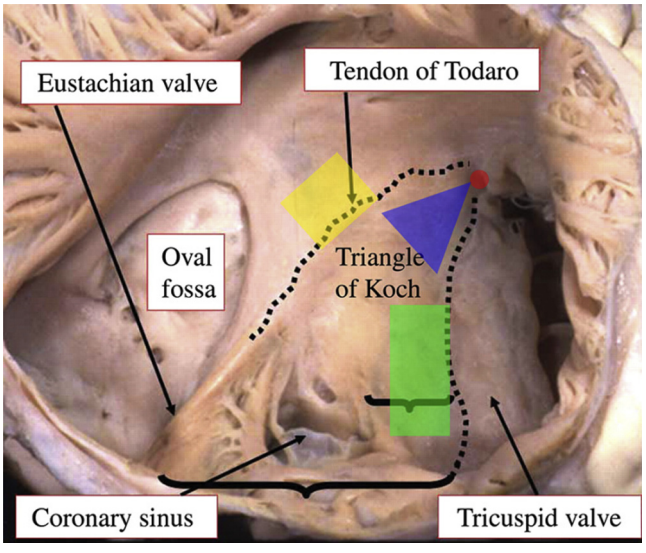

Figure 1 Diagrammatic view of the atrial septum in the right atrium to identify the various atrial nodal inputs to the atrioventricular (AV) node and His bundle. The fast pathway (yellow) runs along the anterior limbus of the oval fossa to enter the AV node (blue triangle), at the apex of which is the His bundle (red dot). The slow pathway runs from the coronary sinus (green area) to the AV node, whereas the central transitional cells traverse the area between the slow and fast pathways to input to the AV node. (Reproduced from Figure 1 in Patel D, Daoud EG. Atrioventricular junction ablation for atrial fibrillation. Heart Failure Clinics 2016;12:245–255, which was adapted from Anderson RH, Cook AC. The structure and components of the atrial chambers. Europace 2007;9(Suppl6):vi3; with permission.)

Clinical implications

Since the earliest experimental studies comparing right ventricular apical pacing and His bundle pacing (HBP)[21] and decades of clinical experience with the former procedure, it has become evident that long-term right ventricular apical pacing may lead to adverse clinical outcomes, including deterioration of left ventricular function and the so-called "pacemaker syndrome." Recent studies have reverted to HBP, particularly in patients requiring AVJA for AF with rapid heart rates unresponsive to pharmacological agents.[22] In their discussion Vijayaraman and colleagues[22] stated that "Ablation of the AV node in the presence of a HBP lead can be a cause of apprehension." For example, Occhetta and colleagues[23] performed the standard AVJA procedure followed by His bundle lead implantation. In 3 patients, HBP could not be achieved owing to technical difficulties. On the other hand, when implantation of the HBP lead occurred prior to AVJA, His bundle capture was achieved, albeit with a high His capture threshold.[22] In view of the experimental[18] and clinical[20] evidence, the method for AVJA using sequential fast-slow pathway and connecting the 2 to induce complete heart block would provide several significant benefits. First, this approach would make implantation of the His pacing lead much less problematic, since either or both the AV node and His bundle would remain undamaged, ensuring a clinically acceptable junctional escape rhythm and less pacemaker dependence.

An important finding of the study by Strohmer and colleagues[20] was the significant decrease in mortality in those patients with "atrionodal" ablation compared to the group with the standard AVJA procedure. The authors hypothesize that the junctional escape rhythm may have a beneficial influence on the death rate. At a pacing rate of 75 beats/min in both groups, atrionodal input ablation rendered patients less pacemaker dependent immediately after the procedure as well as during long-term follow-up, as opposed to those with standard AVJA, who were pacemaker dependent throughout. Not only would normal activity in the former group, even during exercise, result in heart rates greater than 75 beats/min, but activation of the conduction system would be normal. A recent study by Abdelrahaman and colleagues[24] compared clinical outcomes of HBP (normal ventricular activation) with right ventricular pacing (dyssynchronous ventricular activation). Abdelrahaman and colleagues concluded that, over a 3-year period, "His bundle pacing was associated with a reduction in the combined endpoint of death and heart failure hospitalization."

Limitations

Strohmer and colleagues[20] had a 25% failure rate for the atrionodal approach (5% with AV nodal block during fast pathway ablation and 20% failure to achieve AV block). It is seems likely that the initial learning curve of a new procedure may have added to the higher failure rate for the atrionodal procedure. Even with a possible learning curve, the procedure was successful in 71% of the patients. This learning curve would not be relevant for experienced operators applying the standard procedure for inducing AV block. Proximal left bundle pacing may overcome some of the limitations of HBP in the setting of AVJA.[25]

Table 1 Ablation results

	All patients, n = 76 (100%)*	
	Group 1, n = 57 (75%)	Group 2, n = 15 (20%)
AVB—FP ablation	4 (5%)	
AVB—FP and SP ablation	7 (9%)	
AVB—FP, SP, and intermediate ablation	50 (66%)	
AVB—His bundle ablation		15 (20%)
Stable escape rhythm	54 (71%)	4 (5%)
Mean HR ± SD, range (beats/min)	53 ± 4, 44–66	33.1 ± 4.2, 25–42
RF energy applications, n	8.7 ± 3.8	14.6 ± 3.1

Data are mean + SD or number of patients (%).
AVB = atrioventricular block; FP = fast pathway; HR = heart rate; RF = radiofrequency; SP = slow pathway.
*Four patients were excluded from study.

Conclusions

The standard procedure for many patients whose excessive ventricular response during AF cannot be controlled by pharmacological means has been ablation of the AV junction and the implantation of a ventricular pacemaker. Long-term dependence of ventricular pacing for rate control have been shown to be associated with deterioration of ventricular function ("pacemaker syndrome"). An experimental and a clinical study have provided a proof-of-concept that ablation of the slow and fast AV nodal input plus an ablative lesion connecting the two induces AV heart block with the following advantages over the standard AVJA method: the AV node and His bundle are intact; and the escape heart rate is close to normal and should appropriately respond to exercise. This 3-pronged ablation warrants further clinical trials, which up to now have been lacking.

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Disclosures

The authors declare no conflicts of interest.

References

1. Wyse DG, Waldo AL, DiMarco JP, et al. A comparison of rate control and rhythm control in patients with atrial fibrillation. N Engl J Med 2002;347:1825–1833.
2. Roy D, Talajic M, Nattel S, et al. Rhythm control versus rate control for atrial fibrillation and heart failure. N Engl J Med 2008;358:2667–2677.
3. Hohnloser SH, Kuck KH, Lilienthal J. Rhythm or rate control in atrial fibrillation – Pharmacological Intervention in Atrial Fibrillation (PIAF): a randomized trial. Lancet 2000;356:1789–1794.

4. Carlsson J, Miketic S, Windeler J, et al. Randomized trial of rater-control versus rhythm-control in persistent atrial fibrillation. J Am Coll Cardiol 2003;41:1690.
5. Kotecha D, Piccini JP. Atrial fibrillation in heart failure: what should we do? Eur Heart J 2015;34:3250–3257.
6. Passos LC, Oliveira MG, Duraes AR, et al. Initiation or maintenance of beta-blocker therapy in patients hospitalized for acute heart failure. Int J Clin Pharm 2016;38:802–807.
7. January CT, Wann LS, Alpert JS, et al. 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on practice guidelines and Heart Rhythm Society. J Am Coll Cardiol 2014; 130:e270–e271.
8. Van Gelder IC, Groenveld HF, Crijns HJ, et al. Lenient versus strict rate control in patients with atrial fibrillation. N Engl J Med 2010;362:1363–1373.
9. Curtis AB, Kutalek SP, Prior M, Newhouse TT. Prevalence and characteristics of escape rhythms after radiofrequency ablation of the atrioventricular junction: results from the registry for AV junction ablation and pacing in atrial fibrillation. Am Heart J 2001;139:122–125.
10. Kay GN, Ellenbogen KA, Giudici M, et al. The Ablate and Pace trial: a prospective study of catheter ablation of the AV conduction system and permanent pacemaker implantation for treatment of atrial fibrillation. APT Investigators. J Interv Card Electrophysiol 1998;2:121–135.
11. Sherf L, James TN. Fine structure of cells and their histologic organization within intermodal pathways of the heart: clinical and electrocardiographic implications. Am J Cardiol 1979;44:345–369.
12. Anderson RH, Becker AE, Tranum-Jensen J, et al. Anatomico-electrophysiological correlations in the conduction system – a review. Br Heart J 1981;45:67–82.
13. Patterson E, Scherlag BJ. Delineation of AV conduction pathways by selective surgical transection: effects on antegrade and retrograde transmission. J Interv Card Electrophysiol 2005;13:95–105.
14. Sung RJ, Styperek JL, Myerburg RJ, et al. Initiation of two distinct forms atrioventricular nodal reentrant tachycardia during programmed ventricular stimulation in man. Am J Cardiol 1978;42:404–415.
15. Jackman WM, Beckman KJ, McClelland JH, et al. Treatment of supraventricular tachycardia due to atrioventricular nodal reentry by radiofrequency catheter ablation of slow-pathway conduction. N Engl J Med 992;30:313–318.
16. Haissaguerre M, Fischer B, Le Métayer P, et al. Ablation of junctional tachycardia by radiofrequency currents. Experience with 538 patients [in French]. Ann Cardiol Angeiol (Paris) 1993;42:528–536.
17. Patterson E, Scherlag BJ. Functional anatomy of AV conduction: changing concepts in the ablation era. J Electrocardiol 2001;34:135–141.
18. Antz M, Scherlag BJ, Otomo K, et al. Evidence for multiple atrio-nodal inputs in the normal dog heart. J Cardiovasc Electropysiol 1998;9:395–408.
19. Scherlag BJ, Abelleira JL, Narula OS, et al. The differential effects of ouabain on sinus, A-V nodal, HIS bundle, and idioventricular rhythms. Am Heart J 1971; 81:227–235.
20. Strohmer B, Hwang C, Peter CT, et al. Selective atrionodal input ablation for induction of proximal complete heart black with stable junctional escape rhythm in patients with uncontrolled atrial fibrillation. J Interv Card Electrophysiol 2003; 8:49–57.
21. Kosowsky BD, Scherlag BJ, Damato AN. Re-evaluation of the atrial contribution to ventricular function: study using His bundle pacing. Am J Cardiol 1968; 21:518–524.
22. Vijayaraman P, Subzposh FA, Naperkowski A. Atrioventricular node ablation and His bundle pacing. Eurospace 2017;19:iv10–iv16.
23. Occhetta E, Bortnik M, Magnani A, et al. Prevention of ventricular desynchronization by permanent para-Hisian pacing after atrioventricular node ablation in chronic atrial fibrillation: a crossover, blinded, randomized study versus apical right ventricular pacing. J Am Coll Cardiol 2006;47:1938–1945.
24. Abdelrahaman M, Subzposh FA, Beer D, et al. Clinical outcomes of His bundle pacing compared to right ventricular pacing. J Am Coll Cardiol 2018; 71:2319–2330.
25. Wu S, Su L, Zheng R, Xu L, Huang W. New-onset intrinsic and paced QRS morphology of right bundle branch block pattern after atrioventricular nodal ablation: longitudinal dissociation or anatomical bifurcation? J Cardiovasc Electrophysiol 2020;31:1218–1221.