Journal of Cardiology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Journal of Cardiology

journal homepage: www.elsevier.com/locate/jjcc

Original article

Minimal energy requirement for external cardioversion and catheter ablation for long-standing persistent atrial fibrillation

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ARTICLE INFO

Article history:
Received 12 December 2015
Received in revised form 1 February 2016
Accepted 15 February 2016
Available online xxx

Keywords:
Atrial fibrillation
Catheter ablation
Recurrence
Cardioversion

ABSTRACT

Background: The minimal energy requirement (E_{min}) for electrical cardioversion (ECV) reflects the atrial substrate in patients with long-standing persistent atrial fibrillation (L-PeAF), but the relationship between E_{min}ECV and radiofrequency catheter ablation (RFCA) has not yet been studied. We hypothesize that E_{min}ECV before ablation (E_{min}ECVpre) predicts clinical outcome of RFCA, and that catheter ablation reduces E_{min}ECVpost.

Methods: We included 172 patients with L-PeAF who underwent RFCA (79.7% males, 57.5 ± 10.0 years) due to AF recurrence after ECV with an anti-arrhythmic drug (AAD). ECV began with 70 J (patch electrode on anterior–posterior position) and was serially increased to 100, 150, 200, and 250 J until sinus rhythm was achieved, at an average 5.0 ± 5.6 months before RFCA. After RFCA, ECV was repeated (ECVpost) in 42 patients with recurrent AF that was not controlled by AAD.

Results: (1) During 34.8 ± 20.0 months of follow-up after RFCA, 103 patients (59.9%) showed clinical recurrence of AF after RFCA. E_{min}ECVpre was significantly higher in patients with recurrent AF (129.0 ± 58.6 J) than those who remained in sinus rhythm (94.2 ± 39.4 J, $p < 0.001$). (2) E_{min}ECVpre ≥150 J (HR = 3.31, 95% CI 2.18–5.03, $p < 0.001$) and left atrial volume index (HR = 1.02, 95% CI 1.00–1.04, $p = 0.021$) were significantly associated with post-RFCA recurrence. (3) Shorter post-RFCA recurrence timing was also independently related to E_{min}ECVpre ($\beta = -0.147$, 95% CI −0.20 to −0.09, $p < 0.001$). (4) Among 103 patients with recurrent AF after RFCA, 42 AAD-resistant AF patients underwent ECVpost. E_{min}ECVpost (100.9 ± 50.8 J) was significantly lower than E_{min}ECVpre (130.0 ± 66.1 J, $p = 0.006$).

Conclusions: Higher E_{min}ECVpre was independently associated with clinical recurrence and earlier recurrence timing of AF after catheter ablation among patients with AAD-resistant L-PeAF. Catheter ablation for L-PeAF significantly reduces E_{min}ECV.

Introduction

Although radiofrequency catheter ablation (RFCA) for atrial fibrillation (AF) is the standard therapy for the patients with anti-arrhythmic drug (AAD)-resistant AF [1,2], it is still challenging for long-standing persistent AF (L-PeAF) [3]. Although there is some controversy [4], circumferential pulmonary vein isolation (CPVI) may not be sufficient for L-PeAF ablation, so various ablation strategies, such as additional linear ablation [5], complex fractionated atrial electrogram (CFAE)-guided ablation [6], right atrial (RA) ablation [7], non-pulmonary veins (PV) foci ablation [8], and rotor ablation [9] have been applied to improve clinical outcomes. However, the single-procedure success rate has been reported to be no more than 20–60% [10], and 1.3–2.3 times of multiple procedures resulted in about 79% long-term AF control rate with or without AAD [11] in previous data from world-class experienced institutions. Therefore, the search for pre-procedural surrogate markers for clinical recurrence might be useful to improve clinical success rate and to avoid unnecessary AF ablation, especially in patients with L-PeAF. Because most patients with L-PeAF undergo electrical cardioversion (ECV) with AAD before deciding to undergo RFCA therapy, we explored patient factors related to ECV that may predict ablation outcome. Although Kang et al. [12] reported that the number of shocks, total energy requirement, and higher energy during CV are related to the long-term success rate of catheter ablation, there was no systematic prospective study comparing pre- and post-RFCA

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http://dx.doi.org/10.1016/j.jjcc.2016.02.014
0914-5087/

minimal energy requirements for ECV (E_{min}ECV) [12,13]. Therefore, we hypothesized that pre-ablation E_{min}ECV (E_{min}ECVpre) is associated with clinical outcome of radiofrequency catheter ablation (RFCA) in patients with L-PeAF. The objectives of this study were to reveal the clinical usefulness of E_{min}ECVpre as a surrogate marker for clinical recurrence or recurrence after L-PeAF ablation, and to compare E_{min}ECVpre and post-ablation E_{min}ECV (E_{min}ECVpost).

Materials and methods

Study population

The study protocol adhered to the Declaration of Helsinki and was approved by the institutional review board of Severance Hospital of Yonsei University. All patients provided written informed consent. Among 538 patients who underwent ECV for rhythm control of L-PeAF, we included 172 patients who underwent RFCA (79.7% males, 57.5 ± 10.0 years) between March 2009 and June 2012 due to recurrent PeAF despite AAD (Fig. 1). All 172 patients who underwent RFCA were included in the Yonsei AF Ablation Cohort (clinicaltrials.gov; NCT02138695). The exclusion criteria were as follows: (1) permanent AF refractory to ECV; (2) AF with significant mitral valve disease (>Grade II); and (3) prior AF ablation or cardiac surgery. According to the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society Expert Consensus Statement guidelines [1], L-PeAF was defined as AF lasting for longer than one year. All anti-arrhythmic drugs were discontinued for at least five half-lives before RFCA. Anti-coagulation therapy was maintained before ECV and catheter ablation.

Echocardiogram and three-dimensional spiral computed tomography scan

All patients underwent trans-thoracic echocardiography (TTE; Sonos 5500, Philips Medical System, Andover, MA, USA or Vivid 7, GE Vingmed Ultrasound, Horten, Norway) prior to ECV and 12 months after RFCA. Left atrial (LA) chamber size [LA dimension and LA volume index (LAVI)] was acquired according to the American Society of Echocardiography guidelines [14]. Transesophageal echocardiography (TEE) was performed to exclude intra-cardiac thrombi in all patients before ECV and RFCA. Three-dimensional spiral computed tomography (CT) (64-channel, Light Speed Volume CT, Philips, Brilliance 63, Amsterdam, The Netherlands) was used to visually define the anatomy of the LA and PVs.

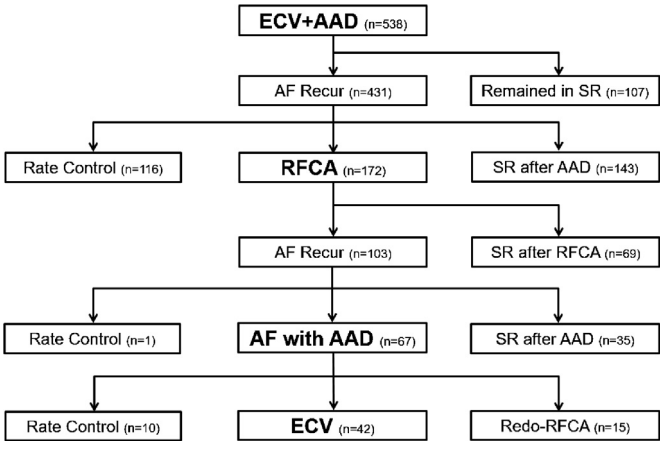

Fig. 1. Diagram of study protocol. Among 538 patients who underwent ECV (pre-RFCA ECV, first ECV) for rhythm control of persistent AF, we included 172 patients who underwent RFCA due to AAD-resistant persistent AF. Of these 172 patients, 103 had recurrence and another 69 remained in sinus rhythm after RFCA. In the 103 patients with recurrence, 42 underwent post-RFCA ECV (second ECV) due to AAD-resistant persistent AF after recurrence of RFCA. AAD, anti-arrhythmic drug; AF, atrial fibrillation; ECV, electrical cardioversion; RFCA, radiofrequency catheter ablation; SR, sinus rhythm.

Electrical cardioversion

We performed ECV for rhythm control in AAD-resistant AF patients as described in the Heart Rhythm Society (HRS)/European Heart Rhythm Association (EHRA)/European Cardiac Arrhythmia Society (ECAS) Expert Consensus Statement guidelines [2]. ECV was performed during sedation with intravenous pentothal (1.5–2.0 mg/kg) in a fasting state. ECV was applied by two oval adhesive pre-gelled pads (each pad is 78 cm^2 area) placed in an anterior–posterior position between the right sternal body at the third intercostal space and an area of the left scapular angle within the third to fifth intercostal space uniformly by physician [15]. And ECV was performed as a QRS-synchronized biphasic direct current shock and began with 70 J and was then serially increased to 100 J and then 150 J until achieving sinus rhythm (SR). If SR was not achieved after ECV with 150 J, or if immediate recurrence of AF (IRAF) developed after converting for a couple of sinus beats, intravenous amiodarone (150 mg within 20 min) was infused, and then ECV was serially increased to 200 J and then 250 J [16]. We waited for 5 min before raising the shock energy to the next level, and the minimal shock energy for successful CV was determined as E_{min}ECV. We defined successful cardioversion as restoration and maintenance of SR by ECV until the patient had left the clinic. Anti-coagulation was strictly maintained within the therapeutic range before and after ECV [2]. E_{min}ECV, presence of IRAF, post-ECV atrial premature contractions (APCs), and post-ECV symptomatic bradycardia were measured or evaluated. E_{min}ECVpre was defined as pre-ablational minimal energy for ECV to restore SR. After RFCA, if recurred AF was not controlled by AAD, ECV was repeated (ECVpost) with the same protocol.

Electrophysiological mapping and radiofrequency catheter ablation

A 3D electroanatomical map (NavX, St. Jude Medical Inc., Minnetonka, MN, USA; CARTO 3, Johnson and Johnson Inc., Diamond Bar, CA, USA.) was generated using a circular PV mapping catheter (Lasso; Biosense-Webster Inc., Diamond Bar, CA, USA). Electroanatomical mapping system-generated 3D geometry of the LA and the PVs was merged with corresponding 3D spiral CT images. An open irrigation, 3.5-mm tip deflectable catheter (Celsius, Johnson & Johnson Inc. Coolflex, St. Jude Medical Inc., 30–35 W; 47 °C) was used for RFCA. All patients initially underwent CPVI and an additional roof line [5], posterior inferior line, anterior line, and cavo-tricuspid isthmus block as a standard lesion set for L-PeAF ablation. Circumferential PV isolation was achieved in all patients, and bidirectional blocks were generated for linear ablation when possible. However, if we could not achieve a bidirectional block by three times of additional ablation, they remained in an unblocked state. The operators could opt to perform additional ablations in the non-PV foci (17.4%) or CFAE (16.3%) at their discretion. All RFCA procedures were conducted according to the above protocol by two operators with more than 10 years of experience.

Post-ablation management and follow-up

After RFCA, patients were discharged and followed-up at the outpatient clinic 1, 3, 6, 9, and 12 months post-therapy and then

Please cite this article in press as: Kim I-S, et al. Minimal energy requirement for external cardioversion and catheter ablation for long-standing persistent atrial fibrillation. J Cardiol (2016), http://dx.doi.org/10.1016/j.jjcc.2016.02.014