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LETTER TO THE EDITOR

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Impedance drop determines ablation lesion volume at the same level of ablation index

Seil Oh[1*], Won-Seok Choe[2], So-Ryoung Lee[1] and Eue-Keun Choi[1]

Abstract

New parameters such as ablation index (AI) have been developed to create reliable ablation lesions. This study was performed to evaluate whether RF energy delivery with the same ablation index creates the similar ablation lesion volume. Ablation lesions were created in 5 pig hearts at ex-vivo state. Ablation was performed using an external-irrigation contact-force sensing catheter on the epicardial side of the left ventricle with 90-degree of angle. RF ablation time was adjusted for targeting AI 600 at 8 different conditions. Lesion volume created with 0–5 g of contact force at 20 W was significantly lower than that of 11–20 g at 40W despite of the same AI (125 ± 76.2 vs. 272 ± 49.5 mm^3, $P < 0.05$). Quality of ablation lesion was variable in the condition of poor contact at low power for the ablation of ex-vivo swine left ventricle, and high-quality lesions could be expected when the impedance drop is satisfactory even though the same level of AI is applied during ablation.

Keywords Ablation index, Impedance, Contact force

New parameters for radiofrequency (RF) ablation, such as force–time–power integral and ablation index (AI), have been developed to create reliable ablation lesions. AI is a lesion-quality marker that utilizes contact force, time, and power in a weighted formula [1–3].

This study was performed to evaluate whether RF-energy delivery with the same AI creates a similar ablation lesion volume despite various conditions of power and contact force levels. Experiments were performed in a custom-made water bath system as described in the author's previous study [4]. Briefly, cardiac specimens were submerged in a 37 °C saline bath and an indifferent electrode was placed at the bottom of the system. Five commercially obtained porcine heart specimens were used in this ex vivo study. Ablation was performed using an external irrigation contact-force sensing catheter (ThermoCool SmartTouch, Biosense-Webster, Diamond Bar, CA, USA) on the epicardial side of the left ventricle perpendicularly. RF-ablation time was adjusted for targeting AI 600 under eight different conditions: a combination of two power settings (20 and 40 W) and four contact-force levels (1–5 g; 6–10 g; 11–20 g; and 21–30 g). The irrigation flow was 8 and 15 mL/min for the 20 and 40 W power settings, respectively. Each contact-force level was used to maintain each pre-defined range manually during ablation. Ablation lesion dimensions were measured after cutting the center of each ablation lesion. The ablation volume was calculated using the following equation under the assumption of spheroid shape ($a = 1/2$ of the maximal horizontal diameter of the lesion; b = total lesion depth—c; c = depth of the level of the maximal horizontal diameter from the surface):

$$Volume = \pi \int_{-b}^{c} a^2\left(1 - \frac{y^2}{b^2}\right)dy$$

*Correspondence:
Seil Oh
seil@snu.ac.kr
[1] Department of Internal Medicine, Seoul National University Hospital and Seoul National University College of Medicine, 103 Daehak-ro, Jongno-gu, Seoul 03080, Republic of Korea
[2] Department of Internal Medicine, Sejong General Hospital, Bucheon, Korea

Ablation time for reaching AI 600 at 20 W of power was as follows: 254 ± 229 s, 201 ± 17.7 s, 124 ± 9.2 s, 79 ± 3.2 s for 1–5 g, 6–10 g, 11–20 g, and 21–30 g of contact-force levels, respectively. Ablation time for reaching AI 600 at 40 W was as follows: 82 ± 7.6 s, 64 ± 10.9 s, 45 ± 2.1 s, 30 ± 1.4 s for 1–5 g, 6–10 g, 11–20 g, and 21–30 g of contact-force levels, respectively. The lesion volumes for each setting are illustrated in the Fig. 1. The lesion volume created with 1–5 g of contact force at 20 W was significantly lower than that of other ablation settings despite the same AI (Fig. 1). Ablations with impedance drop < 10% resulted in significantly smaller lesion volume than those with impedance drop ≥ 10% (147 ± 78.1 vs. 267 ± 73.1 mm^3, $P < 0.05$).

The quality of the ablation lesion was variable in the condition of low contact force at low power settings despite the same level of AI. Two of five ablation sessions with 21–30 g of contact force at 20 W created relatively small ablation lesions despite a high contact force (Fig. 1). The impedance drop was < 10% (5.9% and 9.4%) in these two cases. Most ablation sessions showing low impedance-drop profiles during RF-energy delivery created small lesions. Therefore, (1) AI-guided ablation cannot create reliable lesions in the condition of poor contact in a low-power setting, and (2) high-quality lesions could be expected when the impedance drop is satisfactory even though the same level of AI is applied during ablation.

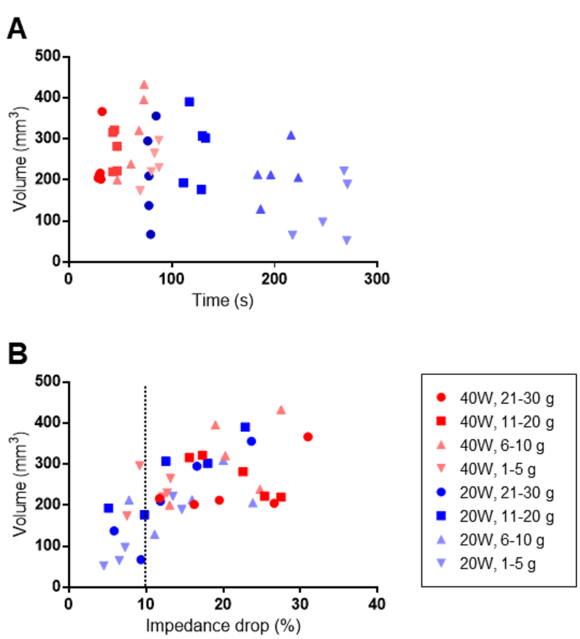

Fig. 1 A Lesion volumes and ablation time (s) for reaching ablation index 600. **B** Lesion volumes and impedance drop (%). Vertical dotted line indicates 10% drop of impedance during RF energy delivery

The importance of impedance is compatible with that of previous studies such as Bourier et al.'s report that impedance and current are clinically relevant parameters that should be considered during RF ablation [5]. Although the present study has limitations because ex vivo conditions are different from that of the clinical setting, we believe that impedance drop in addition to AI should be monitored to create better-quality RF lesions. Development of a new lesion quality marker involving impedance would be a future research target, and it could provide more reliable information to interventional electrophysiologists.

Abbreviations

AI	Ablation index
RF	Radiofrequency

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SO contributed to the conception, design, acquisition and analysis of data, drafting and revision of the manuscript. WSC contributed to the acquisition and analysis of data. SRL and EKC contributed to the critical revision of the manuscript. All authors read and approved the final manuscript.

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Availability of supporting data
The data that support the findings of this study are available from the authors upon reasonable request.

Declarations

Ethics approval and consent to participate
This work utilized ex-vivo animal heart tissue, hence it did not require ethical approval.

Consent for publication
Not applicable.

Competing interests
SO, WSC, and SRL declare that there is no conflict of interest relevant to the submitted work. EKC received a research grant not relevant to the submitted work from Biosense Webster.

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