# Predictive value of impedance changes for real-time contact force measurements during catheter ablation of atrial arrhythmias in humans

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**BACKGROUND** Catheter-tissue contact force (CF) determines radiofrequency (RF) ablation lesion size. Impedance changes during RF delivery are used as surrogate markers for CF. The relationship between impedance and real-time CF in humans remains unknown.

**OBJECTIVES** To determine whether impedance changes have predictive value for real-time CF during catheter ablation of atrial arrhythmias.

**METHODS** Real-time CF, force-time integral, and impedance were measured in 2265 RF lesions for atrial fibrillation or flutter in 34 patients. Operators were blinded to CF measurements. Impedance preablation, at 5-second intervals for 30 seconds after the RF onset, maximal impedance fall and time to impedance plateau during RF were correlated with CF. Average CF was divided into low (≤20 g), intermediate (21–60 g), and high (>60 g) categories.

**RESULTS** Preablation impedance poorly correlated with preablation CF ($R = .07$). Maximal impedance fall modestly correlated with average CF and force-time integral ($R = .32$ and .37, respectively). There was a large degree of overlap in impedance fall between different CF categories. A maximal impedance fall of 10 Ω could predict average CF of >20 g, with a sensitivity and specificity of 71% and 53% and a positive and negative predictive value of 51% and 49%, respectively. Impedance fall was only able to differentiate between different CF categories ≥15 seconds after the RF onset. Higher CFs moderately correlated with delayed plateau in impedance ($R = .41$).

**CONCLUSIONS** Impedance measurements (both baseline and impedance fall) are, at best, moderately efficacious as surrogate markers for predicting real-time catheter-tissue CF. These findings highlight the importance of real-time CF measurements, rather than impedance changes to optimize ablation efficacy.

**KEYWORDS** Catheter-tissue contact force; Contact force sensing; Atrial fibrillation; Atrial flutter; Average contact force; Force-time integral; Impedance

**ABBREVIATIONS 3D** = 3-dimensional; **AF** = atrial fibrillation; **AFL** = atrial flutter; **AUC** = area under the curve; **CF** = contact force; **CTI** = cavotricuspid isthmus; **FTI** = force-time integral; **IQR** = interquartile range; **PV** = pulmonary vein; **PVI** = pulmonary vein isolation; **RF** = radiofrequency ablation

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## Introduction

Catheter-tissue contact force (CF) is a critical determinant of radiofrequency (RF) ablation lesion quality.[1–3] Baseline tissue impedance and magnitude of impedance fall with ablation have a demonstrable correlation with catheter-tissue CF[4,5] as well as lesion diameter and depth in in vivo and ex vivo animal experimental models.[1,6–9] Impedance changes are thus widely used in clinical practice as surrogate markers for catheter-tissue CF.[10]

Real-time catheter-tissue CF measurements are now possible with a CF-sensing catheter.[2,11] In bench models, average CF and the force-time integral (FTI; the product of average force and ablation duration) strongly correlate with lesion size, depth, and volume.[2,3] Moreover, real-time CF monitoring predicts important clinical outcomes such as the amount of ablation needed to achieve pulmonary vein

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isolation (PVI) or bidirectional block across the cavotricuspid isthmus (CTI),[12,13] acute and chronic pulmonary vein (PV) reconnection,[12,13] and atrial fibrillation (AF) recurrence in medium-term follow-up.[14]

Despite extensive clinical experience with the use of impedance changes as surrogate markers for CF during catheter ablation, their correlation with *real-time* CF has not been possible until now. On the basis of preclinical evidence, we hypothesized that baseline impedance and subsequent changes with ablation would be able to predict real-time catheter-tissue CF during catheter ablation of atrial arrhythmias in humans.

## Methods

Patients undergoing PVI for paroxysmal AF or CTI ablation for isthmus-dependent atrial flutter (AFL) using RF energy under general anesthesia were recruited. The study was approved by the Melbourne Health Human Research Ethics Committee.[12]

### PVI procedure

Double transseptal punctures were performed as described previously.[12,13] On completion of the transseptal puncture, patients received intravenous heparin to maintain an activated clotting time of $>350$ seconds. Intracardiac catheters were positioned as follows: (1) 10-pole coronary sinus catheter, (2) His-bundle catheter, (3) multipolar circular mapping catheter via an 8-F long sheath, and (4) irrigated ablation catheter introduced via an 8.5-F long sheath. Detailed left atrial geometry was created guided by a 3-dimensional (3D) mapping system (NavX, St Jude Medical, Minneapolis, MN), which was subsequently used to assist catheter navigation and logging of RF lesions.

Point-by-point ablation was performed at the PV antra with each lesion set for a duration of 30 seconds. The ablation strategy consisted of wide encirclement of the ipsilateral pairs of the PV antra without additional adjunctive left atrial ablation. The end point of the procedure was the isolation of all PVs as determined by entrance and exit block.

Anatomical sites were characterized by viewing the PV ostia internally as a modified clock face.[13] Based on the distribution around the clock face, lesions were grouped according to anatomic location as anterior, posterior, superior, and inferior quadrants. Power was limited to 30 W at anterior, superior, and inferior PV quadrants (as defined by viewing the PV ostia internally as a modified clock face) and 25 W at all posterior sites, with temperature limited to 48°C for each lesion.[12]

### CTI ablation

Intracardiac catheters were positioned as follows: (1) 10-pole coronary sinus catheter, (2) 20-pole deflectable catheter positioned along either the right atrial free wall or the tricuspid annulus, (3) His-bundle catheter, and (4) mapping and ablation catheter delivered through an 8.5-F SRO sheath (St Jude Medical).[12] At the start of each procedure, the limited right atrial geometry was created by using a 3D mapping system (NavX, St Jude Medical) to define the annular and caval ends of the tricuspid isthmus. Thereafter, the operator was blinded to the use of this system as per the ablation protocol (described below).

Point-by-point ablation was performed from the annular to the caval end of the CTI. For ablation, power was limited to 35 W, irrigation set to 17 mL/min, and temperature limited to 48°C.

### Ablation catheter

A CF-sensing catheter and viewing platform were used (TactiCath, Endosense SA, Meyrin/Geneva, Switzerland, distributed by Biotronik, Berlin, Germany) to assess catheter-tissue contact.[2,11,14] Its mechanism of action is described in detail elsewhere.[2,11–14]

### CF-sensing data

For each RF lesion, the following were recorded: CF immediately before the onset of RF and average CF (g) and FTI (g*s) for the duration of the lesion. Data from each case were exported from the viewing station and real-time CF readings for every 100 ms for every lesion were stored and analyzed in a statistical package.

For the purpose of analysis, average CF was divided into 3 categories:

1. low CF ($\leq$20 g),
2. intermediate CF (21–60 g), and
3. high CF ($>$60 g).

FTI was divided into 3 categories:

1. low ($\leq$500 g*s),
2. intermediate (501–1000 g*s), and
3. high FTI ($>$1000 g*s).

These cutoffs chosen as average CF $>$20 g and FTI $>$1000 g*s have been shown to be associated with superior outcomes after AF ablation compared to CF $<$10 g and FTI $<$500 g*s, respectively.[14]

### Ablation protocol

Ablation was performed with the use of "traditional" markers of catheter-tissue contact, such as catheter tip motion and stability on fluoroscopy (all procedures) and on the 3D mapping system (for PVI only), electrogram quality, electrogram abatement, baseline impedance, and impedance fall with ablation. The operators were blinded to CF data. In all procedures, the operator systematically delivered point-point ablation lesions for 30 seconds. RF was terminated prematurely (before 30 seconds) if one of these factors was absent or if the operator felt that a significant lesion was created on the basis of electrogram attenuation.[10,12,13] Lesions where there was an inadvertent abrupt movement of the catheter from the original site of energy delivery were excluded.