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Practice Guidelines

Assessment of ablation catheter contact on valve annulus: Implications on accessory pathway ablation

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ABSTRACT

Background: Catheter-tissue contact force is an important factor influencing lesion size and efficacy and thereby potential for arrhythmia recurrence following accessory pathway (AP) radiofrequency ablation. We aim to evaluate adequacy and perception of catheter contact on the tricuspid and mitral annuli.
Methods: Data were collected from 42 patients undergoing catheter ablation. Operators were blinded to contact force information and reported perceived contact (poor, moderate, or good) while positioning the catheter at four tricuspid annular sites (12, 9, 6 and 4 o'clock positions; abbreviated as TA12, TA9, TA6 and TA4) and three mitral annular sites (3, 5 and 7 o'clock positions; abbreviated as MA3, MA5 and MA7) through long vascular sheaths.
Results: The highest and lowest mean contact forces were obtained at MA7 (13.3 ± 1.7 g) and TA12 (3.6 g ± 1.3 g) respectively. Mean contact force on tricuspid annulus (6.1 g ± 0.9 g) was lower than mitral annulus (9.8 ± 0.9 g) locations ($p = 0.0036$), with greater proportion of sites with <10 g contact force (81.7% vs 60.4%; $p = 0.0075$). Perceived contact had no impact on measured mean contact force for both mitral and tricuspid annular positions ($p = 0.959$ and 0.671 respectively). There was correlation of both impedance and atrial electrogram amplitude with contact force, though insufficient to be clinically applicable.
Conclusion: A high proportion of annular catheter applications have low contact force despite being performed with long vascular sheaths in the hands of experienced operators. In addition, there was no impact of operator perceived contact force on actual measured contact force. This may carry implications for success of AP ablation.

1. Introduction

The quality of a radiofrequency lesion is an important determinant of acute and long term ablation success. Catheter-tissue contact force is a critical factor influencing lesion size and efficacy [1–4] and thereby the potential for arrhythmia recurrence following ablation. While some operators are using contact force catheters and 3D mapping for all cases, others due to cost considerations do not. Radiofrequency ablation of atrioventricular accessory pathways (AP) is acutely successful in 95% of cases, with a recurrence rate of 3–10% [5–7]. Inadequate precision of mapping is well recognised to be a reason for or recurrence of AP conduction but the potential impact of poor tissue contact has been inadequately studied [8]. Stability and catheter-tissue contact on the mitral or tricuspid annulus is qualitatively inferred by experienced operators by assessment of tactile feedback, fluoroscopic and electrogram characteristics. However, these parameters have recently been demonstrated to be inadequate for assessment of catheter-tissue contact and ablation lesion in non-annulus atrial positions [9–11]. To date, there are no studies evaluating the

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adequacy of catheter-tissue contact at annular locations for typical AP sites.

We sought to evaluate adequacy of catheter-tissue contact on both the tricuspid and mitral annuli when experienced operators positioned the catheters without reference to contact force measurements. Although the difficulties in achieving adequate tricuspid annular contact are well recognised, adequacy of contact on the mitral annulus has been less well studied. We used conventional indirect markers of tissue contact (tactile feedback, stability, catheter motion, electrograms) and compared these with objectively-measured contact force (to which the operator was blinded) at common AP sites on the mitral and tricuspid annulus.

2. Methods

2.1. Study setting

Prospective data were collected from 42 consecutive patients undergoing catheter ablation of a variety of arrhythmias using a SmartTouch contact force sensing catheter and CARTO3 mapping system (Biosense Webster, California, USA) at Royal Melbourne and Melbourne Private Hospitals. Patients with left atrial diameter greater than 45 mm were excluded.

2.2. Procedural methodology

During catheter-tissue contact force data collection for this study, operators were blinded to contact force information. Operators were required to position the catheter for 10 s at four specific sites on the tricuspid annulus (12, 9, 6 and 4 o'clock positions viewing the annulus as a clockface) and three specific sites on the mitral annulus (3, 5 and 7 o'clock positions) when the clinical arrhythmia mandated left atrial access (Fig. 1). These sites were chosen as accessory pathways are commonly found in these locations. SR0 8.5Fr 63 cm and SL1 8.5F 81 cm guiding sheaths (Abbott, Illinois, USA) were used to collect tricuspid and mitral annulus data respectively. Contact force zero was obtained with the catheter floating freely in the middle of the chamber, confirmed by the absence of a recorded near-field electrogram and a flat contact trace.

2.3. Data collection

We designated each attempt to achieve stable annular catheter-tissue contact as an “Application”. The operator subjectively reported good, moderate or poor contact based on tactile feedback, stability on fluoroscopy, catheter motion and electrogram characteristics. Real-time contact force information was recorded using CARTO3 over 10 s (consisting of 200 real-time contact force recordings) and a mean value was obtained. Operators were blinded to this information during the study. Contact force was divided into categorical variables as low (<5 g), intermediate (5 to <10 g) and high (≥10 g). Impedance and bipolar electrogram amplitude and duration were recorded at each site during perceived optimal stability; each measurement was repeated by two investigators to ensure consistency. Electrogram amplitude was measured as sum of largest positive and negative deflections. Electrogram duration was measured from the onset of first to the end of last deflection from baseline.

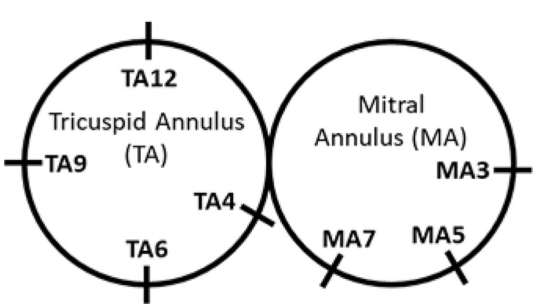

Fig. 1. Locations used for force measurement. Left anterior oblique view of atrioventricular annulus. Tricuspid annulus positions: 12 o'clock (TA12), 9 o'clock (TA9), 6 o'clock (TA6), 4 o'clock (TA4). Mitral annulus positions: 7 o'clock (MA7), 5 o'clock (MA5), 3 o'clock (MA3).

2.4. Statistics

Analysis was performed with statistical software R v3.3.2 (R Foundation, Vienna, Austria). Continuous data were expressed as mean ± standard deviation (±standard error for mean contact force data points) and compared with Student t-test or one-way ANOVA; Pearson's correlation and linear regression model (for R^2) were used. Categorical data were compared with Fisher's exact test. Statistical significance was considered at $p < 0.05$.

2.5. Research governance

The study was approved by Melbourne Health Human Research Ethics Committee (reference 2015.313). All patients provided written informed consent.

3. Results

3.1. Patient characteristics (Table 1)

A total of 42 patients were recruited (79% male; mean age 42 ± 10 years). The majority (95%) of study participants were recruited from patients scheduled for ablation for symptomatic atrial tachyarrhythmias (atrial fibrillation n = 26, focal atrial tachycardia n = 7, typical atrial flutter n = 7). One patient had non-ischaemic ventricular tachycardia and one patient had a manifest AP. Mean left atrial size was 39.8 ± 4 mm.

Annular contact data were collected during catheter manipulation by one of four experienced electrophysiologists (JK, PS, JM and PK). Data from 4 to 7 annular points in 42 patients provided 156 “Application” points (mean over 10 s) for analysis.

3.2. Contact force values

Mean contact force values are shown in Table 2 and Fig. 2. On the tricuspid annulus, lowest contact was obtained at TA12 (mean 3.6 ± 1.3 g; 80%<5 g; 7% ≥ 10 g) and the highest at TA6 (mean

Table 1
Patient characteristics (n = 42). LA Left atrium, TA Tricuspid annulus, MA Mitral annulus, SD standard deviation, n number.

	n (%) or Mean ± SD
Male sex	33 (79)
Age ± SD (years)	42 ± 10
Procedure type	
• Focal atrial tachycardia	7 (17)
• Typical atrial flutter	7 (17)
• Pulmonary vein isolation (atrial fibrillation)	26 (62)
• Ventricular tachycardia	1 (2)
• Accessory pathway	1 (2)
LA size ± SD (mm)	40 ± 4
TA positions	15 (36)
MA positions	33 (79)

Table 2
Measured mean contact force for each annular site. Number of patients provided for each category of contact force (percentages provided in parentheses). Annular site abbreviations as Fig. 1.

	TA12	TA4	TA6	TA9	MA3	MA5	MA7
Mean force (g)	3.6	5.1	10.4	5.3	6.6	9.2	13.3
<5 g	12 (80%)	11 (69%)	7 (47%)	10 (72%)	17 (55%)	12 (38%)	9 (27%)
5 to <10 g	2 (13%)	2 (12%)	2 (13%)	3 (21%)	7 (22.5%)	7 (22%)	6 (18%)
≥10 g	1 (7%)	3 (19%)	6 (40%)	1 (7%)	7 (22.5%)	13 (40%)	18 (55%)

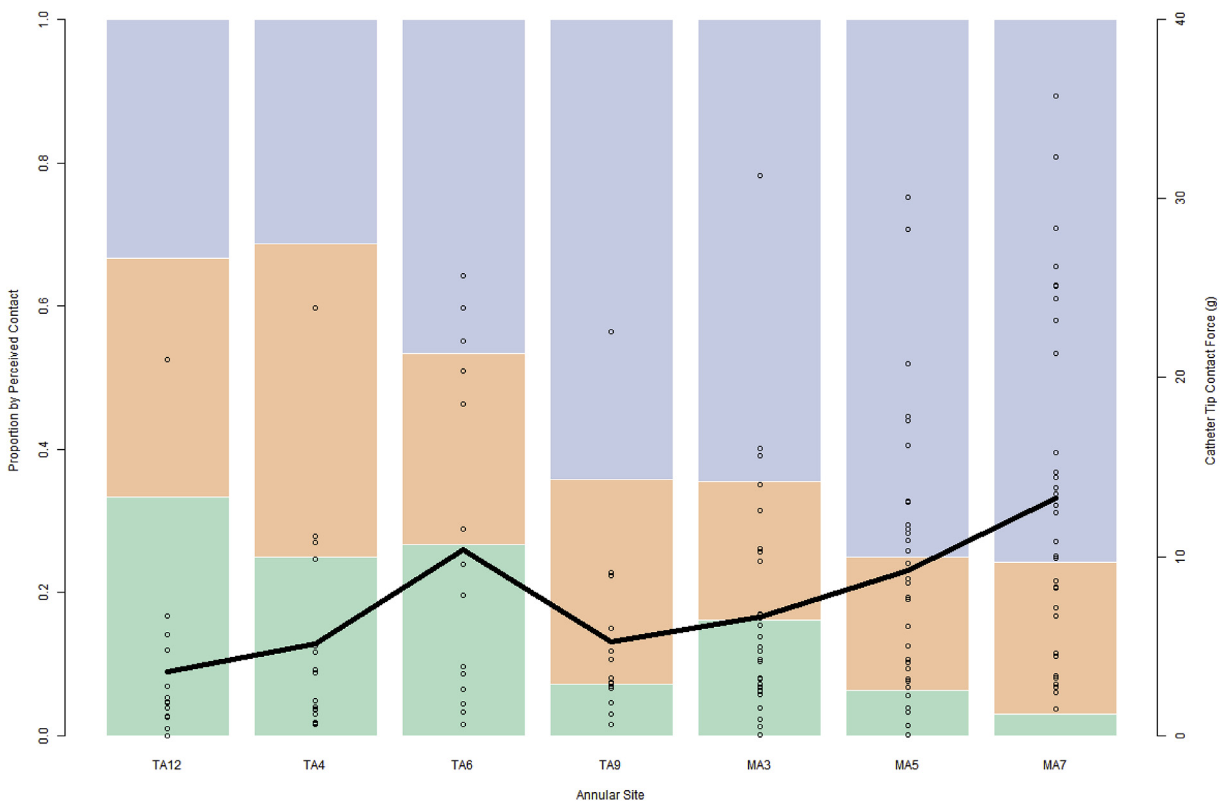

Fig. 2. Catheter to tissue contact by location. Stacked bars represent proportion of points collected at poor (bottom, green), moderate (middle, peach) and good (top, blue) perception of contact (left y axis). Dots represent scatter of measured contact force values obtained from each annulus position; line connects mean measured contact force obtained from each annulus position (right y axis). Annular site abbreviations as Fig. 1.

10.4 ± 2.4 g; 47%<5 g; 40% ≥ 10 g). Notably, TA4 in the midseptal region where slow pathway ablation is commonly performed also had a low mean contact force and a high proportion of low contact applications (mean 5.1 ± 1.5 g; 69%<5 g; 19% ≥ 10 g).

On the mitral annulus, lowest contact was obtained at MA3 in a typical left lateral pathway location (mean 6.6 ± 1.1 g; 55%<5 g; 22.5% ≥ 10 g) and the highest at MA7 (mean 13.3 ± 1.7 g; 27%<5 g; 56% ≥ 10 g). Mean contact force on the tricuspid annulus was lower than on the mitral annulus (6.1 g ± 0.9 g vs 9.8 ± 0.9 g, $p = 0.0036$; Fig. 2); and there were a significantly greater percentage of applications with <10 g contact force (81.7% vs 60.4% respectively, $p = 0.0075$). Despite a significantly higher mean mitral valve contact force reading, we note the mean remains below 10 g. No applications recorded excessive contact force of >40 g. The greatest contact force on the tricuspid annulus was 25.7 g and on the mitral annulus was 35.8 g.

Percentages of measured and perceived contact force according to categories are displayed in Tables 2 and 3. Operators perceived better contact with mitral annular than tricuspid annular positions ($p = 0.001$). When perceived and measured contact force was analysed by individual site, a visual trend of increasing mean measured contact force was seen with increasing proportion

Table 3
Perceived contact force for each annular site. Number of patients provided for each category of perceived contact (percentages provided in parentheses). Annular site abbreviations as Fig. 1.

	TA12	TA4	TA6	TA9	MA3	MA5	MA7
Poor	5 (33.3%)	4 (25%)	4 (27%)	1 (7%)	5 (16%)	2 (6%)	1 (3%)
Moderate	5 (33.3%)	7 (44%)	4 (27%)	4 (29%)	6 (19%)	6 (19%)	7 (21%)
Good	5 (33.3%)	5 (31%)	7 (46%)	9 (64%)	20 (65%)	24 (75%)	25 (76%)

perceived to be in good contact (Fig. 2).

Mean contact force values for mitral annulus applications were similar for all levels of perception of contact (9.9 g, 9.3 g and 9.7 g for good, moderate and poor perception of contact; $p = 0.959$). Likewise, mean contact force values for tricuspid annulus points were 6.5 g, 4.9 g and 6.9 g for good, moderate and poor perception of contact, with no significant difference between levels of perceived contact ($p = 0.671$) (Fig. 3). Thus, perceived contact had no impact on measured mean contact force for both mitral and tricuspid annular positions.

3.3. *Relationship between impedance, electrograms characteristics and contact force*

Impedance values ($p = 0.014$) and atrial electrogram amplitude ($p = 0.003$) correlate with measured contact force values (Supplemental Figures 1 and 2A). However, there was a large distribution of values obtained, evidenced by the poor model fit ($R^2 = 0.04$ and 0.05 respectively). Atrial electrogram duration ($p = 0.646$), ventricular electrogram amplitude ($p = 0.316$) and duration ($p = 0.102$) did not correlate with measured contact force values (Supplemental Figures 2B and 3).

4. Discussion

The current study demonstrates that a very high proportion of annular catheter applications are of low contact with the tricuspid annulus being significantly worse than the mitral annulus for good contact force applications. Approximately 67% of tricuspid annular applications and 40% of mitral annular applications had contact force <5 g despite being performed with long vascular sheaths in the hands of experienced operators. Furthermore, as previously described for other anatomic locations, operator-perceived contact based on tactile feedback, catheter electrograms and fluoroscopy did not provide a reliable indication of mean contact force measured at the catheter tip [9–11]. These observations may have

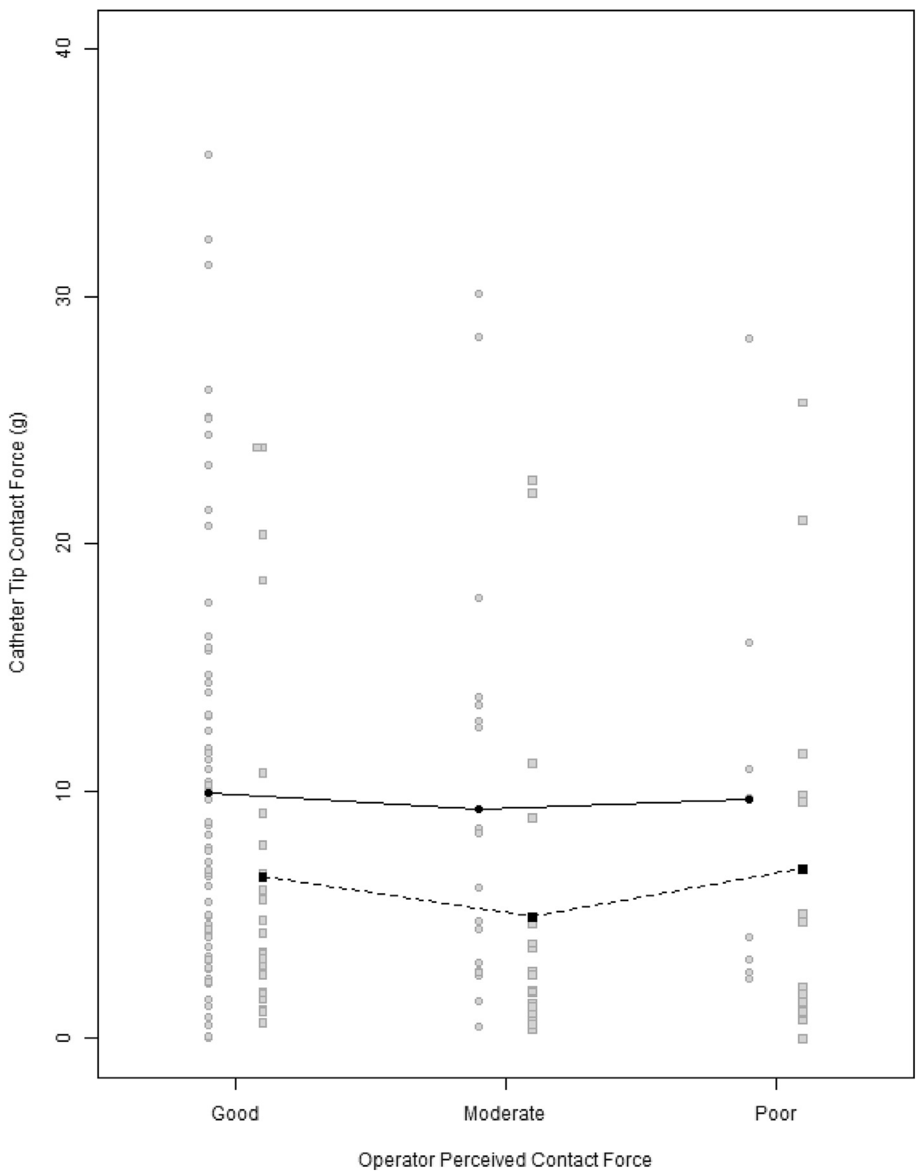

Fig. 3. Measured mean contact and perceived contact force. Dots represent scatter of measured mean contact force values (grams) obtained at mitral annular positions and squares represent those at tricuspid annular positions. Continuous line connects mean measured contact force obtained at mitral annular positions for each category of perceived contact force; dashed lines connect those at tricuspid annular positions.

important implications for successful ablation of AP in all locations.

Ablation for left-sided AP carries a high acute success rate exceeding 92% and low recurrence rates ranging from 2 to 5%. Patients undergoing right-sided AP ablation have reportedly lower acute success rates ranging between 67 and 100% and higher recurrence rates of approximately 9–17% [8]. Poor precision in mapping has been considered the predominant reason for AP ablation failure or conduction recurrence after initial success [12]. However, while the importance of catheter contact and stability has been extensively demonstrated for atrial ablation [13–16], limited data exist describing contact force at the tricuspid and mitral annuli for accessory pathway ablation. In particular, the prevalence of poor tissue contact as a cause of either failure of AP ablation or recurrent AP conduction following acute ablation success is less well understood. In a classical study, Morady et al. estimated that poor contact or stability was the reason for prolonged or failed ablation in 23% of such cases but in 1996, contact force measurement was not available [12]. Successful ablation could not be achieved despite using highest 50W power [12].

The challenges of achieving catheter stability on the tricuspid annulus with its unique anatomical characteristics [8] are well-recognised. Techniques such as deployment of the catheter underneath the tricuspid valve have been utilised when previous conventional approaches to achieve successful ablation have failed [17]. In the current study, sites on the tricuspid annulus were associated with lower contact force than mitral annular sites and this may in part explain the difficulty of right-sided pathway ablation [8]. However, we have also shown a strikingly high prevalence of poor or inadequate tissue contact at mitral annular sites where poor stability or catheter contact is less well appreciated as a clinical problem.

Indirect markers of catheter-tissue contact such as impedance and electrogram amplitude have been reported in a study correlating contact force in left ventricular ablation, but their clinical value was thought to be limited due to a large overlap of values between groups [18]. We similarly observed that impedance and atrial electrogram amplitude correlated with contact force but that the wide variability limits clinical utility.

The current study suggests the use of contact force catheters during mapping and ablation of accessory pathways may be beneficial. With knowledge of inadequate contact force during mapping at certain annular sites, operators may utilise various catheter manoeuvres, deploy deflectable sheaths or take a subvalvular approach in order to improve tissue contact [17,19]. This study also highlights the important role of using contact force, especially for cases where AP conduction recovers.

4.1. Limitations

We designed this study to evaluate adequacy of tissue contact in a range of sites around both annular structures. In the current era of relatively low volume AP ablation, it would not have been possible to collect adequate numbers of patients with APs in each of these locations to perform the detailed analysis in this study. We did not systematically evaluate the use of deflectable sheaths and unblinding of tissue contact to the operator and so cannot describe in what percentage of patients poor contact could be improved to levels above 10 g. Furthermore, the levels of contact required to achieve successful ablation of an accessory pathway are unknown and there is some evidence that this may be less than required for transmural atrial ablation [20].

5. Conclusion

The current study demonstrates that a very high proportion of annular catheter applications have low contact force despite being performed with long vascular sheaths in the hands of experienced operators. In addition, there was no impact of operator perceived contact force on actual measured contact force. Lower catheter contact was observed at sites on the tricuspid annulus compared with mitral annulus, and may in part explain the higher recurrence rates at these sites. In additional, mitral annulus contact force is also overall poor which is often less well appreciated. Although radiofrequency ablation of accessory pathway currently carries good success rates, the use of contact force sensing catheters should be considered for any failed AP ablation.

Conflicts of interest

None.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ipej.2019.03.007.

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