Does diffuse irrigation result in improved radiofrequency catheter ablation? A prospective randomized study of right atrial typical flutter ablation

Khaled Ramoul¹, Matthew Wright², Manav Sohal¹, Ashok Shah¹, Jose Castro-Rodriguez¹, Thierry Verbeet¹, and Sébastien Knecht¹*

¹Brugmann University Hospital and Université Libre de Bruxelles, Brussels, Belgium; and ²Kings College London BHF Centre, Cardiovascular Division, NIHR Biomedical Research Centre at Guy’s and St. Thomas’ NHS Foundation Trust, London, UK

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Aims

Recent developments of open irrigated catheters have sought to create uniform cooling of the entire ablating electrode. The aim of this randomized study was to assess whether the diffuse irrigation of the Coolflex™ (CF) catheter results in improved short-term procedural benefits in patients undergoing ablation of right atrial typical flutter.

Methods and results

Sixty consecutive patients (age 62 ± 13) with typical atrial flutter were prospectively randomized to ablation of the cavo-tricuspid isthmus (CTI) using either a standard 3.5 mm tip ablation catheter with six distal irrigation channels (6C) (30 patients) or a 4 mm tip fully irrigated ablation catheter (CF) (30 patients). There were no significant differences seen between procedures performed with the diffusely irrigated CF catheter and the standard six-channel irrigated-tip catheter. This concerned the total procedural duration, RF duration, fluoroscopic duration, the total amount of irrigation fluid, and the occurrence of steam pop.

Conclusions

The use of a diffuse irrigation at the ablation catheter tip does neither facilitate lesion formation nor reduce the amount of irrigation during RF ablation for typical right atrial flutter using recommended flow and power settings.

Keywords

Open irrigation • Catheter ablation • Radiofrequency • Flutter

Introduction

Although a number of alternative power sources including laser, high-intensity focused ultrasound, and cryothermal energy have or can be used for the ablation of arrhythmias, radiofrequency (RF) energy remains the primary tool for most electrophysiologists. The problems associated with RF energy delivery are well documented. Lesion size is dependent upon power delivery to the tissue, temperature achieved and contact force and complications such as thrombus formation and intramyocardial steam pops can be devastating. These complications are the direct result of overheating of the myocardium. To try to overcome these limitations of RF energy delivery, irrigation of the catheter tip with saline was developed.

There are a variety of methods to achieve cooling of the distal ablation tip of the catheter, and a number of catheter-tip designs, including one or more cooling chambers, internal or external irrigation, and multiple irrigation channels. A thorough understanding of the differences in catheter design is essential for the practising electrophysiologist to deliver safe and effective treatment to the patient. Standard irrigated catheters have 6, or in some cases 12, irrigation ports. One of the problems with this design is that the catheter tip is not uniformly cooled. Consequently, power transmission and active cooling of the myocardium occur in a non-uniform manner at the exits of the irrigation ports.

Recent developments of open irrigated catheters have sought to overcome these problems by creating uniform cooling of the entire ablating electrode. A number of designs are now available including a flexible-tip design with linear slits (Coolflex™ catheter; St. Jude Medical—Figure 1). Despite the theoretical benefits of this catheter design, there is minimal clinical evidence to support their widespread

* Corresponding author. Tel: +32 2 477 2679; fax: +32 2 477 26 32. E-mail address: sebastien.knecht@chu-brugmann.be

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What’s new?

- This paper suggests that use of a diffuse irrigation catheter during ablation of right atrial flutter offers no appreciable improvement in peri-procedural outcomes.
- To the best of our knowledge, this is the first manuscript to address the clinical value of this type of catheter.
- The results may have implications for the ablation of typical right atrial flutter and may potentially be extrapolated to ablation of other arrhythmias.
- The work may have potential implications with respect to our understanding of the biophysics of catheter ablation.

Methods

Study population

Sixty consecutive patients with typical atrial flutter were prospectively randomized to ablation of the cavitricuspid isthmus (CTI) using either a 3.5 mm tip ablation catheter with six distal irrigation channels (6C) (Thermocoool; Biosense Webster, Diamond Bar) (30 patients) or a 4 mm tip fully irrigated ablation catheter (Cool Flex) (30 patients).

Typical atrial flutter was diagnosed electrocardiographically using the following criteria:

(i) Regular saw tooth F wave with predominant negativity followed by a positive upstroke and a slow descending plateau phase in Leads II, III, and AVF.
(ii) Positive deflection in V1 and negative deflection in V6.

If the surface electrocardiogram (ECG) was equivocal, entrainment was used to verify that the CTI was in the circuit.

Electrophysiological study

Oral anticoagulation (target INR, 2–3) was maintained for at least 3 weeks prior to the procedure. If there were any deviations from this, anticoagulation was continued. If the surface ECG was equivocal, entrainment was used to verify that the CTI was in the circuit.

Anticoagulation continued during the procedure and if the patient was not fully anticoagulated, a single bolus of heparin (50 IU/kg) was administered after femoral punctures. Electrophysiological studies were performed in the fasting state using mild sedation. A steerable quadripolar catheter (5 mm electrode spacing, Xtrem, ELA Medical) was introduced via the right femoral vein and positioned within the coronary sinus.

Surface ECGs and bipolar endocardial electrograms were continuously monitored and stored on a computer-based digital amplifier/recorder system for off-line analysis (Bard Electrophysiology). Intracardiac electrograms were filtered from 30 to 500 Hz and measured with computer-assisted callipers at a sweep speed of 100 mm/s. The operator was protected with a dedicated radiation protection cabin (Cathpx, Lemer Px).

Ablation protocol

Radiofrequency ablation was performed in 6C patients in temperature-control mode with a target tip temperature of 42 °C. The upper temperature limit was set at 45 °C. A power of 35 W was applied throughout the procedure with a fixed 15 mL/min flow rate. In the case of increased temperature (and a subsequent automatic decrease of the power), manual titration of the irrigation flow rates (up to 60 mL/min) with progressive 5 mL increments was applied to reach 35 W.

In CF patients, the saline perfusate was systematically and continuously set at 15 mL/min as recommended by the manufacturer and manual titration was not applied.

The total irrigation fluid used was calculated at the end of the procedure. Ablation was preferentially performed using a drag approach with the distal electrode parallel to the targeted atrial tissue (rather than perpendicular) in order to allow bipolar electrograms to be more accurately recorded from the proximal electrode.

The ablation line started at the ventricular side of the CTI (1 : 1 ratio between ventricular and atrial electrograms), and the catheter was progressively dragged towards the IVC. Radiofrequency applications were <90 s each. After the initial pass, if bidirectional block had not been achieved, the ablation line was mapped for a residual gap using bipolar electrograms, and subsequent RF applications were directed to this gap. Bidirectional isthmus block was validated using the standard criteria. A steam pop was defined by both the presence of an audible sound associated with a sudden rise in impedance.

After the procedure, all patients underwent telemetry for 24 h, and transthoracic echocardiography was carried out to assess for pericardial effusion. Subcutaneous low-molecular-weight heparin was given for 1 week, except in patients with a history of atrial fibrillation, in whom oral anticoagulation was continued.

Statistical analysis

Continuous variables are expressed as mean ± SD except for count and time variables, which are expressed as median and interquartile (IQ) range. Statistical significance was assessed using the unpaired Student’s t test or Mann–Whitney test if necessary. Categorical variables, expressed as numbers or percentages, were analysed with the Chi-square test or Fisher’s exact test. All tests were two-tailed and a P value of <0.05 was considered statistically significant.

Results

Patients’ characteristics

Patients’ characteristics are summarized in Table 1. Sixty consecutive patients (40 males) with typical atrial flutter with a mean age of
Impact of diffuse irrigation in catheter ablation for right typical flutter

62 ± 13 (from 28 to 86) were included in this study. Ablation was performed during ongoing arrhythmia in 21 patients (35%).

Left ventricular ejection fraction (LVEF) was 56 ± 13% (20–79), left ventricular diastolic diameter was 49 ± 8 mm (32–72), and left atrial diameter was 43 ± 7 mm (26–60) in the parasternal long axis view. The median CHA2DS2 VASC score was 2 (IQ range 0–4).

Twenty-four patients (40%) had a history of structural heart disease. There were no significant differences in clinical characteristics between the 6C and CF groups.

Procedural results

Bidirectional conduction block was achieved in all patients with a mean delay across the CTI of 162 ± 25 ms. The total procedural duration was 47 ± 24 min (range from 15 to 120 min) with a median duration of 6 min of pulsed fluoroscopy (IQ range 4–11). The median duration of RF application was 544 s (IQ range 379–874) and a median of 124 mL (IQ range 82–223) of irrigation fluid was used.

Six steam pops were noted in five patients; however, there were no clinical sequelae associated with these steam pops. There were no other peri-procedural complications. In addition, no coagulum or charring was noted on either catheter at the end of each case.

Comparison between six-channel irrigation and diffuse irrigation

There were no significant differences seen between procedures performed with the new diffusely irrigated CF catheter and the standard six-channel irrigated-tip catheter (Table 2). Specifically, the total procedural duration (47 ± 25 vs. 47 ± 24 min, P = 0.865), the RF duration (720 ± 488 vs. 690 ± 512 s, P = 0.787), and the fluoroscopic duration (5 ± 7 min, P = 0.128) were no different between the CF and the 6C irrigated groups.

Similarly, there were no significant differences seen regarding the total amount of irrigation fluid used between the CF and the 6C irrigated-tip catheter (147 ± 93 vs. 176 ± 136 mL, respectively, P = 0.484) or the occurrence of steam pop (10% vs. 7%, respectively, P = 0.493).

Discussion

Main findings

This randomized prospective study demonstrates that a fully-irrigated and flexible electrode does not facilitate catheter ablation of the CTI when compared with a standard irrigated-tip electrode. Furthermore, this configuration does not reduce the amount of irrigation fluid used and has a similar incidence of steam pop when compared with conventional irrigated-tip ablation catheters.

Biophysics of radiofrequency catheter ablation: risks and benefits from open irrigation

Radiofrequency current delivered during catheter ablation causes resistive heating of tissue in contact with the electrode, with conduction of thermal energy within the tissue leading to lesion formation. Irreversible tissue damage is created by a temperature greater than ≥ 50 °C but overheating of the tissue may lead to an increased risk of steam pop. The addition of open irrigation during RF application does not directly lead to increased lesion dimensions however, because of the cooling effect it allows a higher potential power delivery in the setting of temperature-controlled ablation without causing thrombus formation. Electrode temperature can be measured with thermocouples or thermistors inside the tip of the ablation catheter; however, this gives an indirect estimation of the tissue temperature. As the exact temperature within the tissue is not measured, excessive thermal injury resulting in steam pops cannot be accurately predicted and as a result, irrigation systems may create a false impression of temperature control.

Conventional irrigation catheters have theoretical limitations with respect to the efficiency of irrigation. Indeed, on a planar tissue surface, irrigation holes positioned at the interface between the catheter and the tissue surface are obstructed by the tissue itself and most of the irrigation will be delivered through the unobstructed holes into the blood pool. A more ‘intelligent’ design of irrigation, i.e. mainly distributed to the tissue—electrode interface during RF application with parallel positioning of the catheter, has theoretical benefits, as does internal global irrigation. One of the problems with conventional irrigation is unequal cooling of the catheter tip and the tissue, such that lesion size and growth are dependent upon catheter-tip orientation relative to the tissue. The multiple variables that effect power delivery and lesion growth (contact force, current density, edge effects, active, and passive cooling of the tissue) mean that in clinical practice the electrophysiologist only has the vaguest of notions as to how a lesion is being formed, although catheters for direct lesion assessment are being developed. It is this variability that can
result in complications from RF catheter ablation including steam pops, which can result in perforation and cardiac tamponade and may also lead to inadequate lesion formation resulting in either procedural failure or recurrence of arrhythmia due to temporary, sub-lethal myocardial damage.

The CF catheter has a specific design with a fully irrigated and flexible tip. However, the theoretical benefits of this catheter-tip design of uniform cooling and hence more predictable lesion formation did not result in demonstrable clinical benefit in the present study.

Clinical implications

Conventional open irrigation results in non-uniform saline perfusion, i.e. mainly distributed away from the tissue–electrode interface during RF application with parallel positioning of the catheter. Open irrigation directed to the electrode–tissue interface with the rest of the electrode being cooled by blood pool seemed to be an elegant option to improve ablation performance while decreasing irrigation; however, our study does not confirm this theoretical advantage. Contrary to a previous study on an irrigation catheter with more irrigation holes, this was not associated with an increased risk of steam pop when compared with conventional catheter, which was still present (10% of the CF cases). Careful attention must therefore still be paid to adequate irrigation and temperature monitoring while using irrigated-tip ablation catheters.

Evaluation of ablation catheters with diffuse irrigation has to be performed in more complex arrhythmias (such as for atrial fibrillation ablation) as this type of irrigation has potential advantages regarding the amount of strokes and subclinical thromboembolic events.

Study limitations

This was a small study that may not have demonstrated a difference due to being underpowered as a result of overestimation of the benefit of uniform cooling in the CF catheter. However, there was no difference in steam pops, despite the relatively high incidence of this phenomenon.

We evaluated irrigation efficiency in two different catheters, with a very small difference in the size of the distal ablating electrode tip (3.5 vs. 4 mm). Given that identical powers were used there is a higher current density on the smaller electrode which should result in larger lesions, although due to the shorter length more lesions should be required.

Other variables that affect lesion formation were not measured such as contact force and anatomical characteristics of the CTI, which may have affected the results. The most common anatomical reasons for failure to achieve bidirectional block across the CTI are large sub-Eustachian pouches, large pectinates traversing onto the CTI, variable thickness of myocardium, and a prominent Eustachian ridge. Some, but not all of these variations are overcome by means of catheter-tip irrigation and it is possible that there was a discordant distribution of these variations between both the groups of patients. Pectinate muscles are thought to extend into the CTI in up to 70% of hearts with a sub-Eustachian pouch present in 16% (and always located on the septal aspect of the CTI). Both of these abnormalities are either sufficiently common or rare to be unlikely to affect the results of this study comparing two catheter irrigation systems. Anatomical variations not overcome by irrigation include the presence of a prominent Eustachian ridge. The ridge divides the CTI into the anterior ‘sub-Eustachian’ portion and a more posterior portion leading to the RA—IVC junction. The ridge itself is often partly or largely made up of fibrous tissue that does not require high-powered or prolonged RF application to produce a permanent lesion. The main difficulty is one of catheter manipulation and maintaining adequate contact—both issues that cannot be overcome with catheter-tip irrigation. It is possible that there were differences between the two groups in this regard and the use of additional mechanical aids (long-sheaths) was not recorded.

Finally, as this study was performed in the clinical setting, no estimation of intramural tissue temperature or thrombus formation on the electrode–tissue interface was possible.

Conclusion

The use of a diffuse irrigation at the ablation catheter tip does neither facilitate lesion formation nor reduce the amount of irrigation during RF ablation for typical right atrial flutter using recommended flow and power settings.

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Conflict of interest: none declared.

References

Successful ablation at the left coronary sinus cusp of an accessory pathway at the aortic-mitral continuity

Tina Lin*, Erik Wissner, and Feifan Ouyang

Department of Cardiology, Asklepios Klinik St. Georg, Lohmühlenstraße 5, Hamburg 20099, Germany

* Corresponding author. Tel: +49 40 1818853616; fax: +49 40 1818854433; E-mail address: tina9989@gmail.com

Accessory pathways are rarely seen at the aortic-mitral continuity. A 27-year-old male presented with wide-complex tachycardia. Sinus rhythm electrocardiogram demonstrated pre-excitation, positive in V1-6, I-III, aVF, negative in aVL and aVR. Programmed stimulation showed non-decremental conduction. Morphology of pre-excited beats was similar to ventricular arrhythmias from the left coronary cusp (LCC). Earliest ventricular activation was identified above the LCC leaflet.

Accessory pathways (APs) are rarely found at the left coronary cusp (LCC) aortic-mitral continuity. A 27-year-old male presented with wide QRS tachycardia. Baseline electrocardiogram (ECG) showed delta-waves positive in V1–V6, I, II, III, aVF, and negative in aVL and aVR. Electrophysiological mapping in the left ventricle found earliest ventricular activation below the LCC leaflet preceding the delta-wave onset by 27 ms. The catheter was unable to be maintained in a stable position below the valve leaflet and dislodged into the aorta after 34 s of radiofrequency application. Further mapping above the LCC leaflet showed earliest ventricular activation preceding the delta-wave onset by 35 ms. This allowed for a more stable catheter position. Conventional radiofrequency energy (25 W) was applied after aortic angiography was performed using the irrigated-tip ablation catheter to simultaneously visualize the left main coronary artery ostium and the catheter tip to minimize the risk of coronary artery complications. Using these techniques, the AP was eliminated 7 s after the start of radiofrequency application.

This case demonstrates our ablation approach for rare APs at the LCC and our recommendation to ablate from above the valve leaflet. It also emphasizes the importance of considering this rare location when the delta-wave suggests an anterior location.

The full-length version of this report can be viewed at: http://www.escardio.org/communities/EHRA/publications/ep-case-reports/Documents/Successful-ablation-at-the-left.pdf.