Clinical research

Sub-threshold stimulation in variants of atrioventricular nodal re-entrant tachycardia: electrophysiological effects and impact for guidance of slow pathway ablation

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Aim Sub-threshold stimulation (STS) applied during atrioventricular nodal re-entrant tachycardia (AVNRT) of the common (slow–fast) type has been shown to effectively characterise target sites suitable for slow pathway (SP) ablation but has not been investigated in the setting of fast–slow and slow–slow variants.

Methods and results Seventeen consecutive patients (52 ± 16 years, 12 female) with sustained uncommon type AVNRT (fast–slow: n = 13, slow–slow: n = 4) were investigated. Mapping of the SP was started postero-septally close to the coronary sinus ostium and continued toward mid-septal sites, if required. Target sites for STS were selected according to established criteria including the recording of the earliest retrograde atrial activation during AVNRT. Long duration (5 s) constant current STS during AVNRT variants was performed in a stepwise manner (max 5 mA) at each site eligible for SP ablation until termination or capture occurred. Radiofrequency current (RFC) was delivered following successful STS termination of tachycardia (65 ± 60 s) and exclusion of catheter dislodgement. Uncommon AVNRT with a mean cycle length of 405 ± 70 ms was induced without spontaneous termination in all patients. Interruption of AVNRT variants due to selective STS-induced block of the retrograde (n = 12) or anterograde (n = 2) SP occurred without capture in 14/17 (82%) patients. This was exclusively observed at sites with successful subsequent RFC application. AVNRT was rendered non-inducible in all patients after a median of 1 (1–11) RFC pulses without complications.

Conclusions Uncommon AVNRT can be interrupted by STS delivered at subsequently successful target sites for SP ablation in most patients (82%). The high positive and negative concordance between the effects of STS and following RFC application indicates that STS-mapping is also useful in the setting of AVNRT variants.

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KEYWORDS
Atrioventricular nodal re-entrant tachycardia; Variants of AVNRT; Endocardial mapping; Slow pathway ablation; Sub-threshold stimulation

Introduction

Differential diagnosis and treatment of the fast–slow and slow–slow variants of atrioventricular nodal re-entrant tachycardia (AVNRT) is challenging: while the common (slow–fast) type of AVNRT is well recognized and treated by ablating the slow pathway, slow–slow and fast–slow AVNRT variants pose a diagnostic and therapeutic challenge.

AVNRT is a common cardiac arrhythmia characterised by a re-entrant circuit involving the atrioventricular node (AVN). The re-entrant circuit is divided into two pathways: the fast pathway and the slow pathway. AVNRT typically occurs due to a functional block between these pathways, allowing re-entry to occur. In the slow–fast AVNRT variant, the fast pathway is either blocked or functionally absent, while in the fast–slow variant, the slow pathway is blocked or functionally absent.

AVNRT is typically treated by ablating the slow pathway. This procedure is highly effective and safe, with over 95% success rate. However, the slow pathway is less consistently ablated in AVNRT variants.

Sub-threshold stimulation (STS) is a valuable tool for identifying the atrial sites suitable for ablation by characterising the earliest retrograde or anterograde atrial activation. STS is performed by delivering a low- energy stimulus during AVNRT. If the stimulus terminates the arrhythmia or results in atrial capture, the site is deemed suitable for ablation.

This study aimed to investigate the use of STS in uncommon AVNRT variants to identify target sites suitable for slow pathway ablation.

The study included 17 consecutive patients with uncommon AVNRT variants (fast–slow: n = 13, slow–slow: n = 4). Mapping of the slow pathway was started postero-septally close to the coronary sinus ostium and continued toward mid-septal sites. Target sites for STS were selected according to established criteria, including the recording of the earliest retrograde atrial activation during AVNRT.

Long duration STS (5 s) was performed in a stepwise manner (max 5 mA) at each site eligible for slow pathway ablation until termination or capture occurred. Radiofrequency current (RFC) was delivered following successful STS termination of tachycardia and exclusion of catheter dislodgement.

Uncommon AVNRT with a mean cycle length of 405 ± 70 ms was successfully induced in all patients without spontaneous termination. Interruption of AVNRT variants due to selective STS-induced block of the retrograde or anterograde pathway occurred in 14/17 (82%) patients. This was exclusively observed at sites with successful subsequent RFC application. AVNRT was rendered non-inducible in all patients after a median of 1 (1–11) RFC pulses without complications.

The high positive and negative concordance between the effects of STS and following RFC application indicates that STS-mapping is also useful in the setting of AVNRT variants.
re-entrant tachycardia (AVNRT) remain a challenge to the interventional electrophysiologist. Nonetheless, radiofrequency current (RFC) ablation of the slow pathway (SP) has emerged as the first line treatment for AVNRT variants, although limited data are currently available on the safety and efficacy of interventional therapy in this setting. Although several criteria for the selection of appropriate target sites have been established, this procedure commonly requires multiple RFC applications in the majority of patients and still carries a low but persistent risk with regard to the inadvertent induction of complete AV-block. Sub-threshold stimulation (STS) has clinically been used for the termination of a variety of supra-ventricular (SVT) and ventricular tachycardia. This technique has been introduced to selectively interrupt slow–fast (common type) AVNRT by the delivery adjacent to critical components of the re-entrant circuit. Furthermore, the impact of STS for the selection of appropriate target sites for SP ablation in the setting of slow–fast AVNRT has been demonstrated in a previous study. Additionally, it has recently been shown in a randomised study that the introduction of STS is useful as an adjunctive mapping tool to reduce the amount of required RFC pulses for SP ablation without prolonging fluoroscopy time or procedure duration. Nonetheless, despite the fact that various SVT of different origin can be reproducibly interrupted by this method, STS effects have not been analysed during fast–slow and slow–slow forms of AVNRT as yet.

Therefore, it was the aim of the present study to primarily assess the electrophysiological effects of STS in the presence of AVNRT variants. We sought to investigate the potential role of sequential STS-mapping in this setting and attempt SP ablation to treat fast–slow and slow–slow types of AVNRT with a minimal number of RFC-pulses.

### Methods

#### Patient characteristics

A total number of 17 consecutive symptomatic patients with variants of AVNRT were prospectively included (52 ± 16 years, 12 female). All patients presented with the paroxysmal pattern of AVNRT and were refractory to anti-arrhythmic drug treatment. Patients enrolled between 1999 and March 2003 were analysed to provide a follow-up period of at least 6 months. Demographic characteristics are summarised in Table 1.

#### Inclusion criteria

Sustained and reproducible induction of fast–slow and slow–slow AVNRT variants without the need for additional pharmacological provocation including orciprenalin was mandatory for inclusion to the present study. Spontaneous cessation was not observed in any patient. The definition of fast–slow and slow–slow form was made according to previously published criteria. The fast–slow form was assumed to be present if the tachycardia started with a sudden prolongation of the retrograde ventricular atrial conduction during programmed ventricular stimulation and a long HA interval was present (> 200 ms). Criteria of slow–slow type were met if a sudden AH prolongation was observed during the delivery of atrial premature beats and the subsequent AVNRT had a long (> 200 ms) anterograde AH interval. The earliest retrograde atrial activation had to be detected posteriorly to mid-septally close to the coronary sinus (CS) compatible with retrograde SP conduction.

#### Electrophysiological investigation

The electrophysiological study was performed in a fasting, lightly sedated state after written informed consent had been obtained and anti-arrhythmic therapy was discontinued for at least four to five half-lives. Catheters were placed in the right atrium, His bundle region, right ventricular apex and CS as previously described. A standard method of intra-cardiac

### Table 1 Demographic parameters and tachycardia characteristics

<table>
<thead>
<tr>
<th>Patient/gender</th>
<th>Age (years)</th>
<th>AVNRT type</th>
<th>HA interval (ms)</th>
<th>AH interval (ms)</th>
<th>AVNRT CL (ms)</th>
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<tbody>
<tr>
<td>1 Female</td>
<td>42</td>
<td>slow–slow</td>
<td>230</td>
<td>230</td>
<td>460</td>
</tr>
<tr>
<td>2 Female</td>
<td>34</td>
<td>fast–slow</td>
<td>330</td>
<td>110</td>
<td>440</td>
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<tr>
<td>3 Male</td>
<td>40</td>
<td>fast–slow</td>
<td>260</td>
<td>80</td>
<td>340</td>
</tr>
<tr>
<td>4 Female</td>
<td>29</td>
<td>fast–slow</td>
<td>230</td>
<td>100</td>
<td>330</td>
</tr>
<tr>
<td>5 Male</td>
<td>64</td>
<td>fast–slow</td>
<td>220</td>
<td>120</td>
<td>340</td>
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<tr>
<td>6 Female</td>
<td>21</td>
<td>fast–slow</td>
<td>205</td>
<td>80</td>
<td>285</td>
</tr>
<tr>
<td>7 Male</td>
<td>67</td>
<td>fast–slow</td>
<td>320</td>
<td>40</td>
<td>360</td>
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<tr>
<td>8 Female</td>
<td>33</td>
<td>fast–slow</td>
<td>200</td>
<td>120</td>
<td>320</td>
</tr>
<tr>
<td>9 Female</td>
<td>67</td>
<td>fast–slow</td>
<td>350</td>
<td>110</td>
<td>460</td>
</tr>
<tr>
<td>10 Female</td>
<td>58</td>
<td>fast–slow</td>
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<td>50</td>
<td>530</td>
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<tr>
<td>11 Female</td>
<td>58</td>
<td>fast–slow</td>
<td>365</td>
<td>50</td>
<td>415</td>
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<tr>
<td>12 Male</td>
<td>65</td>
<td>fast–slow</td>
<td>310</td>
<td>40</td>
<td>350</td>
</tr>
<tr>
<td>13 Male</td>
<td>60</td>
<td>slow–slow</td>
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<td>460</td>
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<tr>
<td>14 Female</td>
<td>60</td>
<td>slow–slow</td>
<td>240</td>
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<tr>
<td>15 Male</td>
<td>58</td>
<td>fast–slow</td>
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<td>120</td>
<td>380</td>
</tr>
<tr>
<td>16 Female</td>
<td>60</td>
<td>fast–slow</td>
<td>460</td>
<td>40</td>
<td>500</td>
</tr>
<tr>
<td>17 Female</td>
<td>80</td>
<td>slow–slow</td>
<td>220</td>
<td>210</td>
<td>430</td>
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<tr>
<td></td>
<td>52 ± 16</td>
<td></td>
<td>290 ± 85</td>
<td>115 ± 67</td>
<td>405 ± 70</td>
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</table>
Long duration constant current pulses were applied before and after ablation.\textsuperscript{8,11} Target sites for STS were selected during endocardial mapping using a commercially available 7 French deflectable electrode catheter (Dr. P. Osypka, Grenzach-Wyhlen, Germany) with a thermistor incorporated into the 4 mm catheter tip. A computer-based mapping system (EP-LAB, Quinton) with a band pass filter setting of 30–400 Hz was used for endocardial electrogram recording.\textsuperscript{8,11}

**Selection of target sites for STS**

As reported previously\textsuperscript{8,9} sequential mapping and subsequent STS was started close to the CS ostium in the postero-septal region where the most suitable local electrogram recordings were found according to well established criteria.\textsuperscript{11–13} These initially include the detection of fractionated and long duration atrial electrograms, an atrial electrogram amplitude of half or less of the ventricular electrogram (AV ratio < 0.5) and the recording of presumed SP potentials during sinus rhythm.\textsuperscript{11–13} Additionally, the retrograde SP was detected by sequential activation mapping during AVNRT. Achievement of maximal catheter stability was attempted. STS during AVNRT variants was applied at each anatomic level at target sites meeting most of the criteria mentioned above. Afterwards, the catheter was moved toward the mid-septal region in a stepwise fashion and the mapping procedure was continued, if required.\textsuperscript{8,11}

**Sub-threshold stimulation protocol**

Long duration constant current pulses were applied during AVNRT variants as previously described.\textsuperscript{8,9} A commercially available stimulator (Dr. Rissel, Datteln, Germany) with programmable output and current intensity was used. Long duration constant current pulses were applied via the distal tip-electrode of the ablation catheter in a unipolar mode for up to 5 s. The protocol was started at a constant power output level of 1.0 mA. Current strength was increased in a stepwise fashion with increments of 1.0 mA from one pulse to the following, if required. In case of catheter dislodgement, emergence of junctional beats, atrial or ventricular capture, or termination of AVNRT, the application was stopped immediately. Otherwise the protocol was continued at each site until the current strength of 5.0 mA was reached. STS was considered to be effective in case of selective block of the anterograde or retrograde SP without evidence for atrial or ventricular capture as well as catheter dislodgement. STS was considered to be successful if the effect was reproducible at the same site resulting in at least two AVNRT terminations. A maximum number of 7 target sites were mapped including the STS manoeuvre. This limit was defined arbitrarily with regard to the time of the mapping procedure.

**Radiofrequency current ablation**

The radiofrequency current generator HAT 300 S (Dr. P. Osypka, Grenzach-Wyhlen, Germany) was used for energy application (500 kHz unmodulated current) during sinus rhythm via the tip-electrode of the ablation catheter and the indifferent patch electrode placed at the midposterior chest wall.\textsuperscript{8,11} RFC was delivered for 60 s (maximal tip temperature 60–65\textdegree C, power output up to 50 W). RFC application was discontinued in case of catheter dislodgement, sudden rise in impedance, retrograde ventricular atrial block during junctional rhythms or in case of anterograde Wenckebach periodicity.

**Target site selection for radiofrequency current ablation**

There were two options for target site selection according to the protocol. (1) Reproducible termination of AVNRT variants by STS due to selective SP block at target sites according to the criteria mentioned above (= STS guided RFC ablation). This was initially attempted in all patients. (2) Target site selection solely based on anatomical and electrogram criteria as described above following ineffective STS at 7 selected sites or inadvertent fast pathway block (= conventional mapping). The endpoint of procedure was the non-inducibility of AVNRT at baseline and following infusion of orciprenalin (5 mg/500 ml NaCl 0.9%) until a 20% heart rate increase compared to that at baseline was observed.

**Data analysis**

Continuous data are expressed as mean values ± standard deviation (SD) or medians as appropriate.

**Results**

**Electrophysiological study**

Variants of sustained AVNRT were reproducibly inducible in all 17 patients. The fast–slow type was observed in 13 and the slow–slow form in 4 patients, respectively (Table 1). Both types were not observed in the same patient. The mean HA interval measured 290 ± 85 ms and the AH interval 115 ± 67 ms (mean tachycardia cycle length 405 ± 70 ms).

**STS-mapping**

STS was applied during ongoing AVNRT at 3.3 ± 2.2 different target sites. Termination of AVNRT was achieved in 14 out of 17 patients (82%) due to selective SP block. The results of STS-mapping are depicted in Table 2. Interruption of AVNRT was obtained due to reproducible block of the retrograde SP in 12 (Fig. 1) and following block of the anterograde pathway in 2 patients, respectively. A discrete prolongation of the tachycardia cycle length (30–90 ms) due to an increased HA-interval was observed in 3 patients during STS (see Fig. 2). Interruption of AVNRT occurred following 1.2 ± 1.4 s of STS with a mean current strength of 2.5 ± 1.4 mA. The mapping sites with successful STS were distributed in the posteroseptal to mid-septal region as indicated in Table 2 and Fig. 3. Successful sites were predominantly located around the CS os with only one case of true mid-septal catheter positioning (see Fig. 3).

Selective SP-block was not obtained in 3 cases despite STS-mapping of 7 target sites. In 1 patient only block of the anterograde fast pathway was achieved in the mid-septal region and in 2 others atrial capture was the only effect leading to AVNRT termination. Ineffective STS was
associated with the shortest tachycardia cycle lengths of 285 and 320 ms noted in the present cohort, thus favoring increased catheter instability.

Effective STS was followed by a single successful RFC application with abolition of AVNRT inducibility in all but 3 patients. In those 3 patients discrete dislodgement of the catheter due to the occurrence of junction and ectopic beats led to the interruption and subsequent delivery of 1 ($n = 2$) or 2 additional RFC pulses ($n = 1$) at the initial site with effective STS.

Thus, STS had a sensitivity of 82% and a specificity of 100% with respect to the detection of target sites for successful SP ablation.

Radiofrequency current ablation

AVNRT was rendered non-inducible in all patients following RFC application with concomitant emergence of junctional escape beats without induction of transient or permanent high degree AV-block. RFC had to be interrupted once due to the emergence of retrograde ventricular atrial block during junctional rhythms in one patient. A median of 1 (1–11) RFC pulse was applied to the postero-septal to mid-septal region (see Table 2 and Fig. 3). A single RFC application was required in 11 out of 14 patients with previously successful STS-mapping in contrast to 4 to 11 applications in those 3 patients with ineffective STS. Following block of the fast pathway as the only effect associated with STS in one of these 3 patients endocardial mapping using conventional electrogram criteria was continued and ablation was successful at a postero-septal to mid-septal site. Anterograde SP conduction was present post-ablation in 4 patients (single echo beats: $n = 3$) and in the retrograde direction in 2 patients (single echobeat: $n = 1$), respectively. Inadvertent block of the fast pathway induced by RFC application could be avoided in all cases. The average study duration was 167 ± 65 min and the fluoroscopy time 18.8 ± 10.7 min.

Follow-up

All patients remained free of any symptomatic or documented AVNRT recurrences during a follow-up period of 26.5 (range: 6–42) months.

Discussion

The present study primarily showed that STS applied to the SP region could selectively and reproducibly interrupt fast–slow and slow–slow forms of AVNRT in the majority of cases. Additionally, successful STS showed a good correlation with the subsequent effect of RFC reflected by the high sensitivity and specificity of this method with regard to the prediction of the ablation result. Consequently, STS-mapping led to a limited number of RFC pulses required for safe and effective abolition of AVNRT variants.

Electrophysiological effect of STS

It is well known that STS applied to critical components of re-entrant circuits can successfully terminate the underlying tachycardia. Although the mechanism of tachycardia interruption is still not completely clarified, termination of ventricular tachycardia, atrioventricular re-entrant tachycardia and slow–fast (common type) AVNRT have been described. In the present study the area of SP conduction was identified according to conventional mapping criteria and STS was applied in

<table>
<thead>
<tr>
<th>Patient</th>
<th>STS at effective ablation site</th>
<th>STS current (mA)</th>
<th>Effective ablation site</th>
<th>No. of RF</th>
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<tr>
<td>1</td>
<td>+</td>
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<td>misep</td>
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<tr>
<td>2</td>
<td>+</td>
<td>5.0</td>
<td>pomisep</td>
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<td>+</td>
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</table>

Abbreviations: +, termination of atrioventricular nodal reentrant tachycardia due to sub-threshold-induced selective block of the slow retrograde pathway; −, no termination of atrioventricular nodal re-entrant tachycardia achieved by sub-threshold stimulation; + #, termination of atrioventricular nodal reentrant tachycardia due to sub-threshold-induced selective block of the anterograde slow pathway; + *, termination with prior cycle length prolongation of 30–90 ms due to an increase of the HA interval; − §, interruption due to anterograde block of the fast pathway; misep, mid-septal; posep, postero-septal; pomisep, postero-septal to mid-septal; RF, radiofrequency current.
Fig. 1  (a) Fluoroscopic image of a postero-septal to mid-septal position in RAO (left) and LAO (right) projection at the roof of the coronary sinus ostium (HRA = high right atrium, HIS = His bundle recording, RVA = right ventricular apex, CS = coronary sinus, MAP = mapping catheter). (b) Recording during sinus rhythm at the same mapping position showing an atrial electrogram with low amplitude and fractionated activation compatible with a presumable SP potential. (c) Same position with identification of earliest retrograde VA conduction during “fast–slow” AVNRT before onset of antero-septal (HIS) and septal and postero-septal (CS) atrial activity. (d) Sub-threshold stimulation (STS) during fast–slow AVNRT (see arrows). The tachycardia is interrupted due to selective block within the slow retrograde pathway after 2 s of STS (1.0 mA) and normal sinus rhythm is established. Note that no apparent capture is visible on the surface ECG or intracardiac recordings.
a systematic fashion during AVNRT variants. Concordant to previous studies in slow–fast AVNRT the uncommon variants could also be interrupted following a short period of direct STS current in most cases. Time to onset of STS effect and overall efficacy are comparable to reported results in common type AVNRT.\textsuperscript{7–9} In most cases selective block of the slow retrograde pathway could be achieved. Since the initial observations the exact underlying effect of STS is still a matter of debate.\textsuperscript{15,16} However, the observed discrete prolongation of SP conduction in a subset of patients strongly suggests slowing of conduction as the potential STS-induced mechanism. Accordingly, prior clinical studies demonstrated an increased conduction time via the SP prior to tachycardia termination during STS in a subset of patients.\textsuperscript{8,9} This mechanism has also been previously observed in an experimental study as well as local conduction block mediated via electrotonic effects.\textsuperscript{17} In concordance with previous studies STS-induced AVNRT termination was not observed in all patients. Proximity to the arrhythmogenic substrate and stable wall contact are prerequisites for the induction of local electrotonic effects. As known from prior reports this is a specific limitation related to the fact that this method has to be applied during ongoing tachycardia. Therefore, especially in the setting of a rapid tachycardic rate, the STS technique can be difficult leading to a false negative result. This aspect is also underscored by the fact that ineffective STS was observed in those three patients with the shortest tachycardia cycle length of the present cohort.

Correlation between STS effect and RFC application

Comparable to slow–fast (common type) AVNRT, STS can also be used for identification of target sites for effective SP-ablation in the setting of the uncommon AVNRT variants. This technique can be incorporated into the mapping strategy as an adjunctive tool following the pre-selection of presumably suitable areas for energy delivery according to established electrophysiological criteria. STS demonstrated a sensitivity of 82\% and a specificity of 100\% with respect to the detection of target sites for successful SP-ablation. No case of inadvertently induced transient or permanent high degree AV-block was observed in the present study. Furthermore, effective SP-ablation was associated with a very limited number of subsequently required RFC pulses. Variants of AVNRT do not only represent an arrhythmic entity associated with a complex differential diagnosis.

Fig. 2  Termination of fast–slow AVNRT preceded by prolongation of the cycle length from 350 to 440 ms during STS (4.0 mA). This is suggestive of slowing of conduction within the slow retrograde pathway due to prolongation of the H to A but not the A to H interval.

Fig. 3  Distribution of all sites with successful RFC-application. The target sites with abolition of AVNRT following either effective STS (solid circles) or ineffective STS attempts (open circles) are depicted. The ablation points are predominantly located postero-septally around the coronary sinus os (CS) with only one lower mid-septal ablation point (AVN = AV-node, TA = tricuspid annulus).
but also require the application of multiple RFC pulses for SP ablation in the majority of patients. Overall, only limited reported experience exists with respect to the treatment of AVNRT variants in the current literature. Also, the occasional induction of complete AV block or fast pathway ablation has been described. This underscores the clinical need for an adjunctive mapping tool to facilitate the diagnostic and ablative procedure in the setting of AVNRT variants. The technique introduced in the present study may add safety to the current approach of SP ablation by reducing the absolute number of required RF pulses and by the fact that a more precise delivery can be obtained by STS-guided detection of target sites.

Limitations

The STS-approach is limited to the inducible and sus-
cryo-mapping and also in the clinical setting showing
in the present study. This is supported by previous
inadvertent fast pathway interruption as also observed
in the present study. This is supported by previous
studies demonstrating the potential variation of the lo-
calisation of SP and fast pathway during intra-operative
cryo-mapping and also in the clinical setting showing
an atypical postero-septal localisation of the fast path-
way during mapping of slow–fast common type
AVNRT.

Clinical implications

The results of the present study demonstrate the po-
tential clinical use of STS as a novel mapping tool to
guide SP-ablation even in the rare forms of AVNRT. This method provides a reliable, easy to use approach to
AVNRT mapping. Interruption of anterograde or espe-
cially retrograde SP conduction can be used as an ad-
citional criterion to identify target sites for safe and
effective SP-ablation comparable to the results in the
setting of common type AVNRT. On the other hand the
mapping procedure should be continued in case of
inadvertent fast pathway interruption as also observed
in the present study. This is supported by previous
studies demonstrating the potential variation of the lo-
calisation of SP and fast pathway during intra-operative
cryo-mapping and also in the clinical setting showing
an atypical postero-septal localisation of the fast path-
way during mapping of slow–fast common type
AVNRT.

Limitations

The STS-approach is limited to the inducible and sus-
tained forms of AVNRT. Fast rates of tachycardia may
lead to catheter instability as reflected by a negative STS
result in the three patients who had the most rapid AV-
NRT forms of our cohort. A randomised, prospective
study would of course be the preferable way to prove
the potential advantage of the STS-guided strategy.
However, since a previous randomised study including
patients with common (slow–fast) AVNRT has demon-
strated exactly this with regard to the number of re-
quired RF pulses we believe that it is not mandatory to
repeat this in the setting of AVNRT-variants. Whether STS
is able to improve the overall results with respect to
inadvertent fast pathway ablation or induction of com-
plete AV-block has to be demonstrated in large-scale
future studies.

Conclusions

STS can be used for selective termination of fast–slow
and slow–slow uncommon AVNRT variants providing im-
portant additional diagnostic information. Effective STS
is a good marker for safe and successful SP ablation
leading to a minimal number of required RFC applica-
tions. Therefore, STS can be introduced as a useful ad-
junctive mapping tool in the setting of AVNRT variants.

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