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Typical Atrial Flutter - When Do You Say You Have Got It

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Introduction

Right Atrial Flutter (AFL) is a common form of macro reentrant arrhythmia.[1-3] In absence of previous cardiac surgery, the reentry circuit is usually bounded anteriorly by the tricuspid annulus (TA) and posteriorly by the ostia of vena cava and Eustachian ridge. In this case, AFL is consensually called "typical" AFL and is highly dependent of the cavotricuspid isthmus (CTI).[2] The CTI is a critical channel which represents the predominant area of slow conduction of the circuit. Therefore, this narrow isthmus has become the universally accepted target for ablation of typical AFL.[2-4] If ablation is carried out during AFL the first "intuitive" procedure endpoint is arrhythmia termination. Although this latter was initially thought to be an acceptable endpoint for ablation procedure, bidirectional CTI conduction block is actually considered as the gold standard endpoint for elimination of typical AFL recurrence.[5,6] Indeed, Schumacher et al. found a 9% recurrence rate after bidirectional CTI block achievement, 54% recurrence rate after unidirectional CTI block and 100% recurrence rate when persistent slow conduction across CTI was noted after RF application on the CTI.[7]

As cardiac electrophysiology laboratories use a wide variation of catheters, sheaths, mapping systems or energy sources for typical AFL ablation, techniques to validate bidirectional CTI conduction block are also varied.[8-10] In fact, for the last 15 years, many electrophysiological criteria were proposed at this end: reversal in activation of right atria around the ablation line, extent of prolongation of the transisthmus interval after ablation, documentation of a corridor of double potentials (DPs) along the ablation line, differential atrial pacing, analysis of the local unipolar and bipolar electrograms, incremental atrial pacing and changes in paced P wave morphology. We review these electrophysiological criteria commonly used for CTI conduction block validation.

Reversal in the Right Atrial Activation around the Ablation Line

Complete bidirectional CTI block across the line of ablation was first identified with 20-pole Halo-catheter recordings during coronary sinus (CS) ostium/low lateral right atria (LLRA) pacing .[5,11] Halo-catheter was placed around the TA for CTI conduction mapping (fig 1A). In patients in sinus rhythm before RF application, conduction across the CTI was confirmed by demonstrating bidirectional RA depolarization wavefronts with collision in the RA free wall or interatrial septum during CS ostium/LLRA pacing respectively (fig 1B). Complete bidirectional conduction block was determined by a reversal in the RA activation around the TA. In this case, clockwise only RA activation around the TA when pacing lateral to the line of ablation and counter clockwise only RA activation when pacing septal to the line of ablation were observed (fig. 1C).[5,11] Low septal atrial pacing is sometimes difficult to perform due to high pacing

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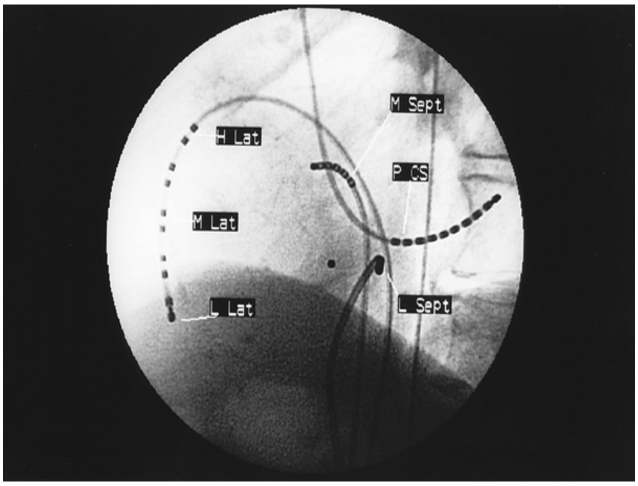
Figure 1A: Radioscopic view (60° LAO) of standard catheter position on the high, mid, and low lateral RA wall, mid septum in the His bundle region, lower septum, and proximal coronary sinus



thresholds. In this setting, right ventricular pacing and resulting retrograde atrial septal and CTI activation can be useful to validate conduction block.[12] Otherwise, pacing at slow rates (i.e ≤ 600 ms) is mandated because CTI conduction block may be functional and rate-dependant in some patients.

Main pitfall of this maneuver was that, in some patients, rapid conduction across the crista terminalis would result in a modification of the activation sequence around the Halo-catheter when not covering the CTI.[10] In this case, transverse conduction through the crista terminalis, septal to lateral, during CS pacing would depolarize the low lateral RA and thus anticipate the RA depolarization sequence on distal Halo-catheter mimicking incomplete CTI block while this latter is present. Scaglione et al. found trans-crista terminalis conduction in 3/12 patients (25%)[13] On account of this phenomenon Anselme et al. reported that in 7 of 38 patients (18%), the RA activation sequence on Halo-catheter was not sufficient to detect complete CTI block.[14] Then, difficulties in accurately positioning Halo-catheter were reported to occur in up to 10% of the cases.[14] This pitfall might be associated with significant increase in procedure duration and fluoroscopy exposure. Finally, RF applications may slow conduction velocity at the CTI without blocking it. Consequently, the two wave fronts might collide on the very LLRA (Low Lateral Right Atrium) during CS pacing mimicking complete CTI block on Halo-catheter.

Extent of Prolongation of the Transisthmus Interval After Ablation

Extent of prolongation of transisthmus conduction intervals during atrial pacing was studied to predict complete CTI conduction block after creation of a line of ablation.[15] Transisthmus conduction intervals were measured between the stimulus artifact and the local atrial activation recorded from the proximal CS electrode during pacing from LLRA in counterclockwise direction and between stimulus artifact and the local atrial activation recorded from the pair of electrodes positioned lateral to the ablation line during pacing from CS ostium in clockwise direction. This maneuver was performed before and after RF application. In 57 consecutive patients, Oral et al. reported that an increase ≥ 50% in transithmus intervals during LLRA and CS pacing predicted complete bidirectional CTI block. Conversely, complete CTI block was not observed in any patient if transisthmus conduction interval did not increase by at least 50 %. Diagnostic accuracy and positive predictive value of this technique for identification of complete CTI block was 92% and 90 % respectively. On account of these data, authors supported this criterion only as an additional indicator for evaluation of CTI ablation.

Figure 1B: Left, Pacing from the low lateral RA. Mid lateral RA is activated first, then high lateral RA. Activation of the septum occurs through dual wave fronts: Low region of septum is activated caudocranially and upper region is activated craniocaudally. Right, pacing from the PCS. Activation of the septum is caudocranial. Activation of the lateral RA is mainly caudocranial, low lateral RA being activated before mid and high lateral RA. Nevertheless, high lateral RA is activated before mid lateral RA, owing to a craniocaudal wave front

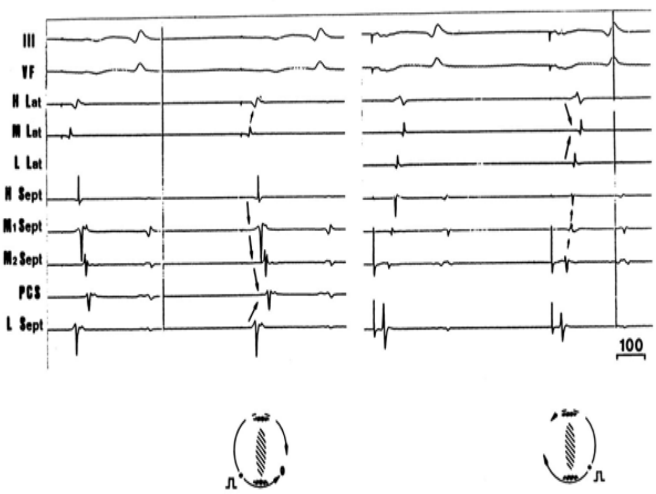
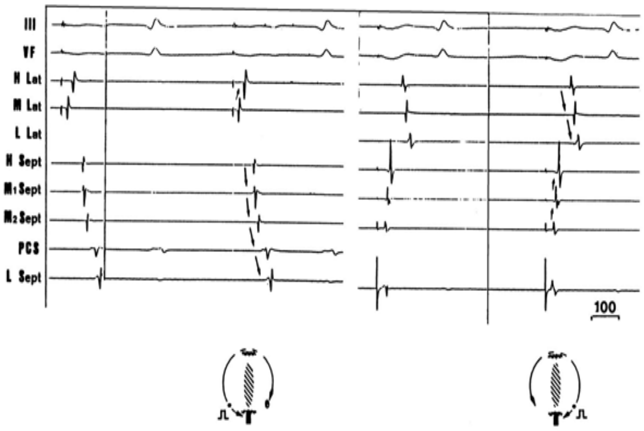


Figure 1C: Pacing from the low lateral RA. After ablation, all the septum is activated craniocaudally via a single clockwise front. Right, pacing from the PCS. The lateral RA is activated craniocaudally via a single counterclockwise front.Complete CTI conduction block is confirmed. H, M, and L Lat= high, mid, and low lateral RA wall; H, M1, M2 Sept L Sept = high, mid septum 1 and 2 and low septum; PCS = proximal coronary sinus.Reproduced from Cauchemez B et al. Circulation 1996;93:284-294



Corridor of Double Potentials along the Line of Ablation

In experimental studies, double potential (DP) separated with an isoelectric interval were shown to validate local conduction block under the exploring bipolar electrode.[16] During CS/LLRA pacing, a corridor of parallels DPs separated with an isoelectric interval along the CTI ablation line, from the RV edge to the inferior vena cava edge strongly support the presence of bidirectional CTI conduction block.[17-20] Specific characteristics of DPs predicting CTI block were analyzed. On the one hand, Tada et al demonstrated that DP interval, measured from the peak of the first component of the DP to the peak of the second component, reflected a local gap/incomplete CTI block when measured <90 ms whereas DP interval >110 ms was associated with complete CTI block (fig 2).[19] A separation >110 ms between the two components of the DP along the whole line of ablation was found to have a predictive positive value of 100 % for complete CTI block. Others studies confirmed these data.[17,18,20] On the other hand, when DP interval was between 90 and 110 ms, a maximal variation ≤15 ms in the DP intervals, an isoelectric segment separating the two components of the DP and a negative polarity of the second component of the DP were found to be additional reliable indicators of complete CTI block .[19] Otherwise, during typical AFL or CS ostium pacing, residual gaps could be identified by local electrograms with a single or a fractionated potential centered on, or spanning, the isoelectric interval of adjacent DP.[8,17] Main pitfall of this technique is that the demonstration of the existence of a corridor of large DPs at the level of the line of block needs to map strictly the whole ablation line and is frequently difficult to prove. Indeed, Anselme et al. found that in 39 % of patients, low amplitude signals, ambiguous or atypical DPs due to multiple RF applications or due to the complex anatomy of the isthmus were recorded.[14] In these cases, accuracy of this technique was significantly reduced.

Differential Pacing

As mentioned above, interpretation of DP on CTI after multiple RF applications is frequently difficult. Otherwise, separation of the two components is variable not always reaching the 110 ms cut-off.[19] In these cases, differential pacing is helpful to differentiate CTI block from persistent slow conduction.[21-24] The four pacing sites, two septal and two lateral to the line of ablation, and their relation with anatomical structures are shown (fig

Figure 2: Increase in degree of splitting within DPs during coronary sinus pacing before (left and middle) and after (right) complete CTI conduction block. The recording ablation catheter was positioned at exactly the same site in all three panels. Note in the middle panel a DP interval = 96 ms without an isoelectric interval between the two components of DP and incomplete CTI block on Halo-catheter. In left panel, DP interval increased to 126 ms with an isoelectric interval and complete CTI block on halo-catheter.(E9 through E1 = electrograms recorded on Halo catheter; CS = coronary sinus; Abl = ablation catheter) Reproduced from Tada et al. JACC 2001;38:750 –5

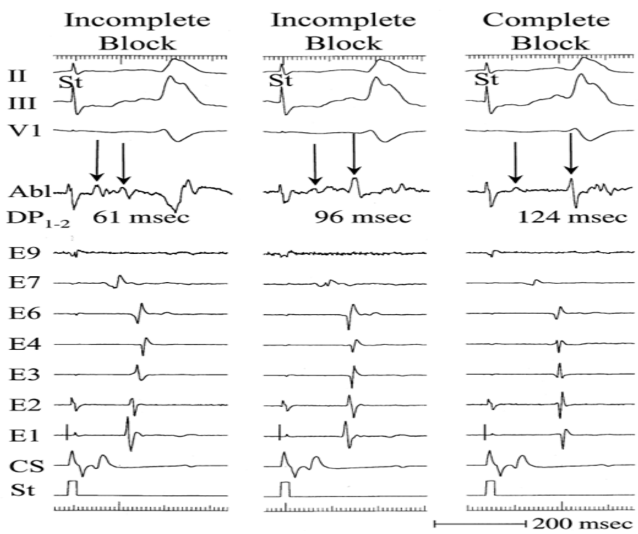
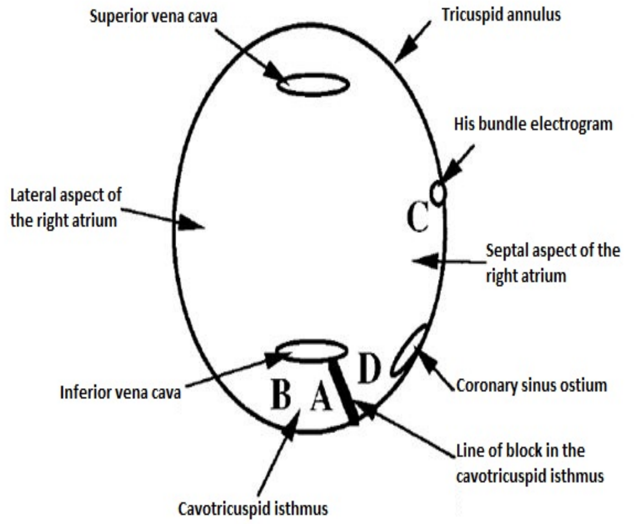


Figure 3A: Schematic representation (LAO 45° projection) of the four pacing sites. Reproduced from Chen et al. Circulation. 1999;100:2507-2513



3A). This dynamic pacing maneuver was used to determine whether the two components of the DP are due to a single depolarization wavefront penetrating through the ablation line or to two opposite wavefronts recorded on either sides of a complete line of block. If the two components of DP are induced by persistent slow conduction through the CTI, then pacing farther away from the ablation line results in an increase in the interval between stimulus and the two components of DP in similar manner (fig 3B). Therefore the interval between the two electrograms remains unchanged. Conversely, if the two components of DP are induced by two opposite wavefronts around the ablation line with complete conduction block, then preceding maneuver results in similar effect on electrogram corresponding to the same side of the ablation line but that due to activation on other side of the line is advanced. Therefore the separation between the two electrograms decreases. In a large series of 255 consecutive patients, long-term results of CTI ablation with conduction block validated with this simplified method were comparable to those obtained with standard approaches.[24] Otherwise, this technique, using only one quadripolar mapping electrode in addition to the ablation catheter, rules out the use of a multipolar catheter and thus reduces the cost of the procedure. Differential pacing can be performed using a multipolar Halo catheter (2-8-2 spacing) and the ablation catheter as recently reported by Pastor et al..[25] The Halo catheter is coiled in the RA, as a reference electrode, and the ablation catheter, as the recording electrode, is positioned at either the posterior or anterior edge of the CTI (fig 3C). The authors considered that CCW CTI block was achieved when, during pacing with the distal electrodes A4 of the Halo-catheter: - septal (posterior) RA activation was descending, - the late component of the CTI EGM (recorded with the ablation catheter) was later than the low septal EGM (recorded with the Halo-catheter), and - pacing at a distance from the CTI (A4 vs A3 in fig 3C) shortened the interval between the pacing stimulus and the late CTI EGM. Conversely, CW was considered to be achieved when: - lateral (anterior) RA activation was completely descending when pacing with the ablation catheter at the septal end of the CTI, - criteria of differential pacing at the RA septum (S4 vs S3 in fig 3C), with recording electrode at the anterior end of the CTI, was validated. Pastor et al. reported a low rate of AFL recurrence (3%) during a mean follow-up of 37 months when bidirectional CTI block was validated with the aforementioned criteria.[25] With this approach, CTI block can both be validated with differential pacing and activation sequence of the RA around the ablation line.

Unipolar and Bipolar Local Electrograms

Unipolar electrograms are commonly used for the guidance of ablation of arrhythmia such as focal ventricular/atrial tachycardia or accessory

Figure 3B: Validation of complete bidirectional CTI block using differential pacing. Note the greater activation delay at site D when pacing at site A than when pacing at site B (AD delay>BD delay), and greater activation delay at site A when pacing at site D than when pacing at site C (DA delay>CA delay)

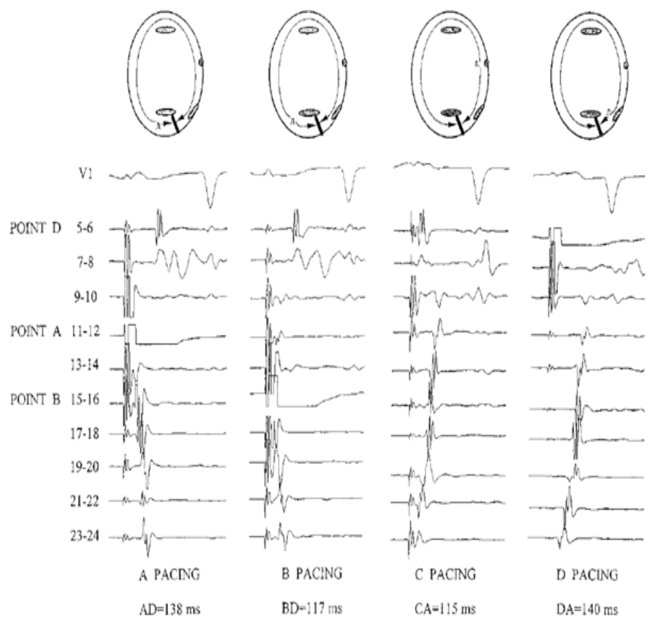
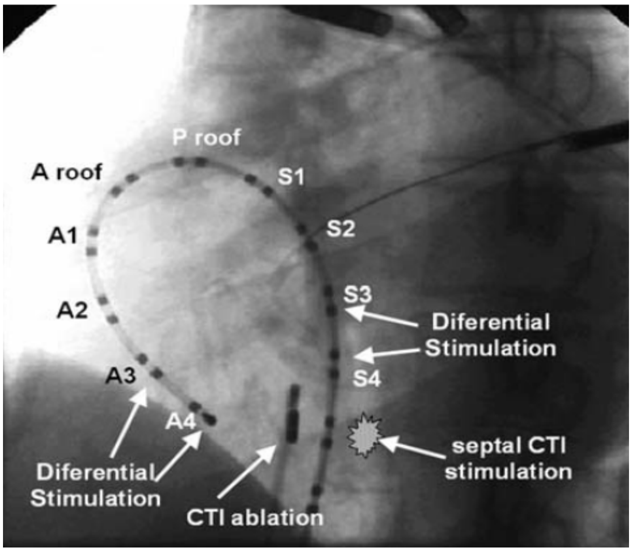


Figure 3C: LAO view of the two electrode catheters, 24 pole Halo catheter and ablation catheter, set-up for CTI conduction assessment as reported by Pastor et al. Differential pacing can be performed using A3 and A4 electrode pairs or S3 and S4 electrode pairs with the ablation catheter, as the recording electrode, positioned at the posterior or anterior edge of the CTI respectively. Reproduced from Pastor et al. Europace. 2010; 12:1290-5

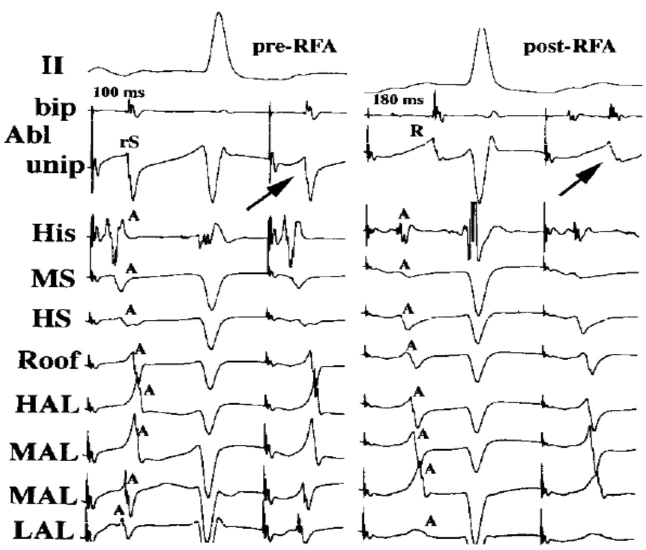


pathways.[26,27] Background for the use of unipolar electrograms is that RS morphology of the unipolar electrogram is associated with propagation of the wave front through the exploring electrode, whereas positive monophasic R unipolar electrogram is characteristic of the termination of the activation wavefront.[28,29] Villacastin et al. studied unipolar atrial electrograms recorded along the line of ablation in 45 consecutive patients with typical AFL.[30] The authors found that local unipolar atrial electrograms obtained at the LLRA during CS pacing changed from RS, rS, or QS before CTI ablation to R or Rs after clockwise CTI block was obtained (fig 4A). Similar changes were observed when counterclockwise conduction block was obtained. Main pitfall of this technique was that the mapping catheter has to be placed very accurately, in the very close vicinity of the ablation line, increasing both time of procedure and radiation exposure. Bipolar atrial electrograms morphology were also evaluated as an additional criterion for complete CTI block.[19,32] Complete CTI could be validated when a change in the morphology of bipolar electrograms adjacent and lateral to the line of block from an RS pattern to a QR pattern was observed. A 100% correlation was found between bipolar atrial electrograms morphology and previously validated change of the atrial activation sequence and differential pacing.[32] This report was concordant with study from Tada et al who showed that reversal of bipolar electrogram polarity recorded lateral to the line of ablation was a simple and accurate indicator of CTI conduction block.[19]

Incremental Pacing

Incremental pacing from CS or LLRA is the most recently local electrogram-based maneuver proposed for validation of CTI conduction block .[33] It consists in monitoring of DP distance along the CTI line during CS and LLRA pacing from 600 ms to 250 ms. Authors hypothesized that a significant increase in DP distance during incremental pacing would indicate persistent slow conduction through the isthmus, while continuity in DP distance would validate complete CTI conduction block. Measurements of DP distance and response to this pacing maneuver should be performed at a CTI point with a maximum separation of the two potentials. In this observational study, a <20 ms increase in DP distance during incremental pacing

Figure 4: Local electrograms registered during CS ostium pacing with ablation catheter used as exploring electrode recording bipolar (Bip) and unipolar (Unip) signals at the very close lateral side of ablation line before and after RFA. We observe a change from rS pattern (pre-RFA) to a monophasic R wave (post-RFA) at Unip consistent with CTI conduction block. Note post-RFA double potentials observed at Bip and loss of caudo-cranial activation of the lateral wall on Halo-catheter. (MS = mid interatrialseptum; HS = high interatrial septum; Roof = roof of right atrium; HAL = high anterolateral; MAL = mid anterolateral; LAL = low anterolateral.) Reproduced from Villacastin J et al. Circulation.2000 Dec 19;102(25):3080-5

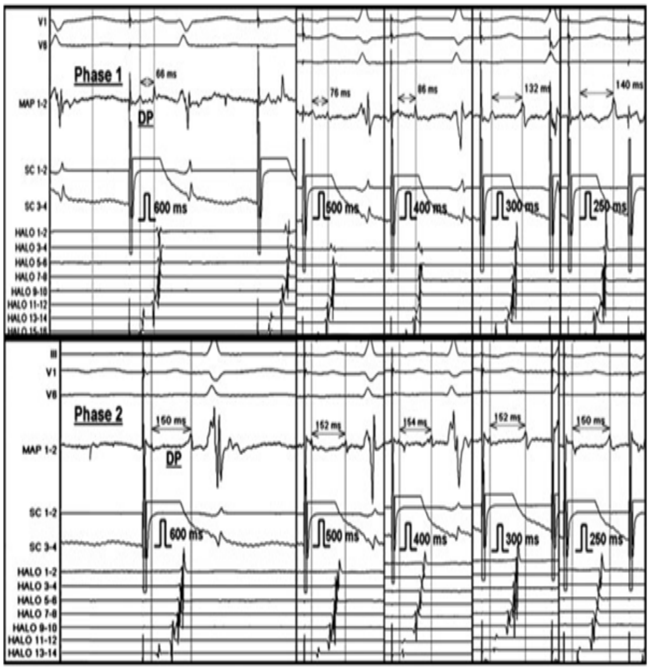


maneuver confirmed CTI block (fig 5). Conversely, a >20 ms increase in DPs distance indicated persistence of conduction through the isthmus and necessity for further RF applications. Main advantage of this maneuver is that extensive mapping of the whole ablation line is not mandated. Limitation of this technique was reached in presence of transversal conduction across the crista terminalis which anticipated the second DP component and might lead to misdiagnose complete CTI block. In this setting, incremental pacing should be combined to assessment of polarity of second DP component unipolar electrogram obtained during LLRA/CS ostium pacing.

Monitoring of changes in the paced P wave morphology

Changes in the paced P wave morphology have been reported as a marker of CTI block achievement.[34,35] Shah et al. reported that, in a prospective group of 30 patients, CTI block achievement was associated with a terminal positivity of the P wave during LLRA pacing, best seen in inferior leads, in

Figure 5: Incremental pacing from CS ostium with cycle lengths at 600 ms, 500 ms, 400 ms, 300 ms and 250 ms. Top panel: Significant > 20 ms increase in DPs distance during incremental pacing maneuver consistent with persistent slow conduction across the ablation line. Bottom panel: Absence of increase > 20 ms in DP distance with incremental pacing indicating CTI conduction block. (CTI = cavotricuspid isthmus; DPs = double potentials; Halo = 20-pole Halo catheter; MAP = ablation catheter; CS = coronary sinus.) Reproduced from Bazan V et al. J Cardiovasc Electrophysiol. 2010 Jan;21(1):33-9



29 patients.[35] Otherwise the authors reported that conduction recovery through the isthmus, validated with intracardiac mapping, could be recognized by the regression of this morphologic P wave change.[35] However, this technique provides information only on counter clockwise conduction recovery.

Cavotricuspid isthmus ablation in the era of electroanatomical mapping

Three-dimensional electroanatomical mapping systems are currently used in the majority of cardiac electrophysiology laboratories for the guidance of various arrhythmia ablations such as atrial fibrillation, non CTI-dependant atrial flutter or ventricular tachycardia. Electroanatomical mapping technologies were demonstrated to be safe and effective to guide placement of linear lesion at the level of the CTI.[36-39] All authors reported significant reduction of radiation exposure with 3-D mapping systems compared to conventional approach.[36-40] Visualization of CTI conduction on activation maps during LLRA/CS ostium pacing, in association with registration of wide > 100 ms DPs along the line of ablation, might help the validation of CTI block.[36,40] Main limitation with the non-fluoroscopic approach was that the material cost per procedure is significantly increased (42%) compared to the conventional strategy with the Halo catheter.[37] Otherwise, no favorable impact on procedure duration, number of RF applications or clinical outcome was encountered with 3-D mapping system which may explain that this technology remains a marginal tool for typical AFL ablation in absence of previous complex cardiac surgery.[36-39]

Observation period after achievement of bidirectional conduction block

Recovery of CTI conduction can occur after initial achievement of complete CTI block [9,21,23,41]. Most of recurrences of CTI conduction occur within 20-30 minutes. Bru et al. found recovery of conduction across the isthmus in 5/35 patients (14%) within 20 minutes after initial successful CTI ablation.[41] Shah et al. observed transient CTI conduction block in 20/40 patients (50%) during observation period.[23] In 39 patients, Chen et al. reported resumption of conduction once in 10 patients (25.6%) and twice in 3 patients (7.7%) within 30 minutes after end of initial CTI ablation.[21] These reports support the necessity of a 30-minutes observation period after achievement of CTI block to detect early recovery of conduction. Isoproterenol administration was proposed to unmask transient CTI block.[42] However, no evidence was found this was superior to the 30-minutes observation period.[9]

Conclusions

Complete CTI conduction block provides an objective endpoint for typical AFL ablation. All electrophysiological criteria proposed to validate this procedural endpoint have their own limitations. Therefore, in order to reduce arrhythmia recurrence, validation of CTI conduction block should combine different techniques. In our experience, reversal in the RA activation sequence during CS/LLRA pacing, validated by differential pacing, actually represents the most accurate and commonly used criteria. In difficult cases, interpretation of local unipolar or bipolar electrograms adjacent to the line of ablation may be helpful to validate complete CTI conduction block.

Disclosures

No disclosures relevant to this article were made by the authors.

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