Prevention of postsurgical atrial tachycardia with a modified right atrial free wall incision

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BACKGROUND Most postsurgical macroreentry atrial tachycardias (PS-MATs) are atriotomy related; however, underlying mechanisms and prevention remain undefined.

OBJECTIVE The purpose of the present study was to investigate the electrophysiological and histologic bases of right atriotomy incision arrhythmogenicity and whether a modified atriotomy that extends the incisional line to the tricuspid annulus (TA) and inferior vena cava (IVC) prevents PS-MAT.

METHODS Atrial arrhythmia induction and electrophysiological and histologic characteristics were studied 8 weeks after right atriotomy in 30 adult swine according to incision distance to TA or IVC (groups A, B, and C: broad, narrow, and closed corridors, respectively; group D, no-incision sham; n = 6 per group, except n = 12 for group B).

RESULTS Sustained PS-MATs were induced and mapped in the broad- and narrow-corridor groups (A, 1 of 6 [16.7%] vs B, 5 of 12 [41.7%]) but not in the closed-corridor (C) or sham (D) groups (P = .087). With 20-ms pacing cycle–length decrements (from 350 to 270 ms), mean conduction time over 20 mm at the atriotomy-to-TA corridor was 29.2 ± 2.2, 31.0 ± 4.2, 26.0 ± 1.9, and 17.0 ± 1.4 ms for 5 and 10 mm (both group B), 15 mm (group A), and sham incision (P = .017), respectively. Conduction properties correlated with histologic findings: the wider the corridor, the healthier its tissue. In group C (modified atriotomy), both corridors were replaced by dense scar with complete conduction block.

CONCLUSION Atriotomy corridor width determines conduction properties and contributes to arrhythmogenicity. A modified right atriotomy that extends to the TA and IVC prevents PS-MAT.

KEYWORDS Atrial tachycardia; Atriotomy; Macroreentry

ABBREVIATIONS **AF** = atrial fibrillation; **AFL** = atrial flutter; **AT** = atrial tachyarrhythmia; **CTI** = cavotricuspid isthmus; **DP** = double potential; **IVC** = inferior vena cava; **MAT** = macroreentry atrial tachycardia; **PS-MAT** = postsurgical macroreentrant atrial tachycardia; **RA** = right atrium; **RAA** = right atrial appendage; **RAFW** = right atrial free wall; **SAT** = sustained, mappable atrial tachyarrhythmia; **TA** = tricuspid annulus; **UMAT** = short, persistent, unmappable atrial tachyarrhythmia

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Introduction

Right atrial free wall (RAFW) incisions, common in open heart surgery, are associated with a high incidence of postsurgical macroreentrant atrial tachycardias (PS-MATs), usually circulating around the atriotomy or along the tricuspid annulus (TA) and refractory to medical therapy.[1–10] It is unclear which factors predispose to PS-MAT development in some but not all patients and whether altering the incisional line prevents PS-MAT. Because an anterior RAFW incisional line creates 2 corridors between the right atriotomy and either the TA or inferior vena cava (IVC), the present animal study tested 2 hypotheses: (1) RAFW arrhythmogenicity depends on the extent of corridor conduction impairment, and (2) closing corridors by extending the incisional line to join the TA superiorly to the IVC inferiorly prevents PS-MAT.

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Methods

Animal preparation

This study was performed in accordance with the guidelines of our Institutional Animal Care and Use Committee, Chinese Policy on Research Animal Use, and Chinese Public Health Service Policy on Use of Laboratory Animals, with a protocol approved by the animal ethics committees of Nanjing Medical University and the National Nature Science Foundation of China.

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Thirty adult swine (Chinese Changbai strain, weight 25 to 30 kg) were divided into 4 groups according to incision distance to the TA or IVC (groups A, B, and C having broad, narrow, and closed corridors, respectively; and group D, no-incision sham; n = 6 per group, except n = 12 for group B). All animals were anesthetized with intravenous propofol (2 mg/kg), intubated with a cuffed endotracheal tube, and mechanically ventilated with a volume-controlled respirator. Continuous infusion of propofol ($4\ mg \cdot kg^{-1} \cdot h^{-1}$) and fentanyl ($0.01\ mL \cdot kg^{-1} \cdot h^{-1}$) was used to maintain adequate anesthesia and analgesia. Heart rate was monitored by a limb-lead electrocardiogram. The pericardium was opened and the lateral right atrium (RA) exposed after right lateral thoracotomy through the fourth intercostal space. A surgical incisional line on the RA (Figure 1) was made by the closed heart technique without use of cardiopulmonary bypass[11] (Online Supplement Figure 1). TA location was indicated in the epicardial view by the right coronary artery underneath the atrioventricular groove fat tissue (Online Supplement Figure 2A). Widths of corridors between the incision and either the TA or IVC (α and β, respectively, in Figure 1) varied among groups (Table 1). In group A (broad corridors), both α and β widths were 15 mm. Three subgroups (n = 4 for each) with upper and lower corridor widths of 5 or 10 mm or both were included in group B (narrow corridors). In group C (closed corridors), incisional lines were extended to TA and IVC anatomic barriers. No incisions were performed in sham group animals except for pericardial access.

The chest was closed in layers after right lung re-expansion, and an antibiotic drug was administered (ceftazidime 0.25 g/d intramuscularly for 3 days). Eight weeks after initial surgery, swine were anesthetized, intubated, mechanically ventilated, and monitored as in the initial procedure. The pericardium was opened and the lateral RA exposed after thoracotomy through the former skin incisional scar. Conduction properties of corridors and inducibility of atrial tachyarrhythmia (AT) were evaluated, the incisional line was measured endocardially (Online Supplement Figures 2, 3, and 4), and tissue in corridors was resected for histologic examination.

Electrophysiological evaluation

A decapolar fixed-curve, high-density mapping catheter (Synaptic Medical, Beijing, China) with 1-mm interelectrode spacing was positioned on the RAFW epicardial surface for continuous pacing at the RA appendage (RAA) with a programmable pulse generator (EP-WorkMate, St. Jude Medical, St. Paul, MN) at a 2-ms pulse width and twice the diastolic threshold (Figure 1, right panel) at cycle lengths from 350 ms to local refractory period in 20-ms decrements. Conduction time through the incision-to-TA corridor was recorded in groups A and B, with a similar location in the sham group, and across the corridor in group C.

AT induction was attempted with continuous S_1 and programmed S_1S_2 stimuli at the RAA with decremental pacing down to the atrial refractory period, and if there was no induction, with the addition of isoproterenol. ATs were defined as follows: (1) short, persistent, unmappable AT (UMAT): fast, regular atrial activation that did not persist long enough to complete mapping, usually <30 seconds; (2) sustained, mappable AT (SAT): persistent, reproducible AT that enabled entrainment and 3-dimensional mapping; and (3) atrial fibrillation (AF): fast, irregular atrial activation (>300 bpm).

Activation mapping and entrainment pacing maneuvers were performed during AT with a 3-dimensional electroanatomic mapping system and a 4-mm-tip catheter (CARTO and NAVI-STAR, respectively, Biosense-Webster, Diamond Bar, CA). Pacing sites with a postpacing interval ≤ 30 ms over the cycle length were considered part of the circuit.

Pathological examination

After electrophysiological measurements were taken, animals were euthanized, and the RAFW was excised for microscopic examination. Tissue blocks containing upper and lower corridors were resected perpendicular and parallel to the incisional lines, respectively, fixed with 10% formalin solution, embedded in paraffin, and cut; deparaffinized sections were stained with hematoxylin-

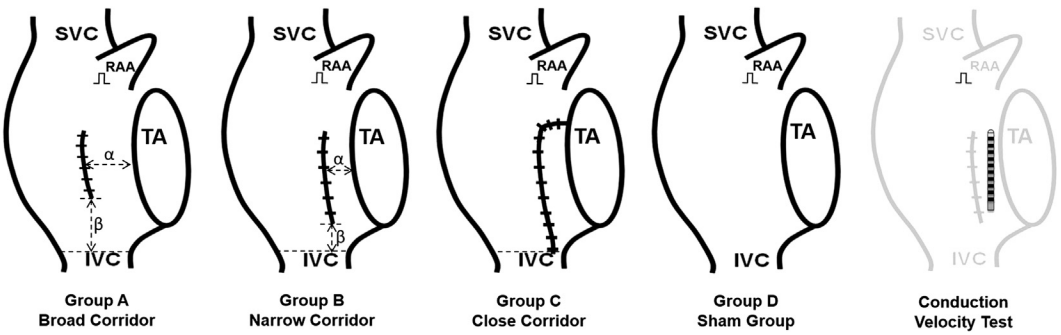

Figure 1 Schematic representation of the swine right atrium showing location of surgical incisional line without use of cardiopulmonary bypass. α and β indicate the widths of the corridor between incision and either tricuspid annulus (TA) or inferior vena cava (IVC), respectively. The ⎍ indicates the stimulation site. In group A, both α and β widths exceeded 15 mm. In group B, α and β widths ranged from 5 to 10 mm. In group C, both corridors were closed by incision extension to anatomic barriers (TA and IVC). Group D was the sham group; no incisional lesion was made after pericardial access was gained. The right panel represents corridor conduction measurement via a high-density mapping catheter located on the epicardial surface of the right atrial free wall when pacing at the right atrial appendage (RAA) with incremental stimuli. SVC = superior vena cava.