REVIEW ARTICLE

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Strategies for Temporary Cardiac Pacing in Pediatric Patients With Postoperative Junctional Ectopic Tachycardia

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POSTOPERATIVE JUNCTIONAL ectopic tachycardia (JET) occurs in 6% to 14% of all pediatric patients after surgery for repair of congenital heart defects.[1] In combination with postoperative systolic and diastolic ventricular dysfunction, the tachycardia and the absence of synchrony of atrial and ventricular contraction result in relevant hemodynamic compromise. Without adequate treatment, such rhythm disorder is associated with increased morbidity and mortality.[1,2] Therapy for JET comprises administration of antiarrhythmic drugs, deep sedation, and induced hypothermia.[3] Temporary pacing is a further important pillar of treatment. Different techniques of temporary pacing exist that aim either to reduce the effective heart rate or to resynchronize atrial and ventricular contraction.[4] The aim of this article is to describe 4 different strategies of external cardiac pacing in pediatric patients with postoperative JET (atrial demand pacing [AAI], dual-chamber pacing [DDD], paired ventricular pacing [PVP], and ventricular-triggered atrial pacing [AVT]). Advantages and disadvantages of the described strategies will be discussed.

CHARACTERISTICS OF POSTOPERATIVE JUNCTIONAL ECTOPIC TACHYCARDIA

Postoperative JET is a focal supraventricular tachycardia caused by abnormal automaticity arising from the compact atrioventricular (AV) node or the bundle of His. In the absence of a branch block, the QRS complexes remain narrow. Postoperative JET is associated with either atrioventricular dissociation, resulting in the ventricular rate exceeding the atrial rate, or retrograde 1:1 or variously blocked conduction to the atria. Retrograde 1:1 conduction may be most detrimental to hemodynamics as atrial contraction regularly occurs against closed atrioventricular valves.[5] The definition of postoperative JET often is based on a critical heart rate (eg, 170 beats/min)[6] to discriminate between an accelerated junctional rhythm against junctional ectopic tachycardia. Significantly, there is an acceleration phase with an initial increase in frequency of heart rate at the onset of JET. Either spontaneously or therapeutically, the heart rate peaks and then begins to slow down during the deceleration phase. Applying external pacing, the time point when the patient´s spontaneous pulse rate becomes less than the critical heart rate, as well as the reconstitution of atrioventricular synchrony, can be reached earlier than the return of sinus rhythm (Fig 1).

ATRIAL DEMAND PACING

According to the Generic Pacemaker Code, the type of a pacemaker is described by 3 characteristics: the pacing site, the sensing site, and pacing mode.[7] The pacing mode can be either triggered (T), inhibited (I), dual (D) or none of the above (0). In atrial demand pacing (AAI pacing), the pacing and sensing sites are located within the atrium, and sensed atrial activity inhibits atrial stimulation by the pacemaker. In the context of postoperative JET, AAI pacing is used to overdrive the patient's ventricular heart rate to establish a pacemaker-driven atrial rhythm with atrioventricular synchrony (Fig 1). The applied mode could be described more correctly as AAO pacing, because the aim is not to sense atrial activity, but rather to overdrive it.

To use this method, the pacing rate must be slightly higher (5-10 beats/min) than the patient's heart rate.[8] Advantages of AAI pacing are that it commonly is used and easy to apply. A single-chamber external pacemaker is suitable as long as pacing rates higher than the patient´s ventricular rate can be obtained. The main disadvantages are: (1) this method requires intact atrioventricular conduction, which often is disturbed in patients with postoperative JET;[9] (2) the pacing rate must be greater than the patient's heart rate, which implies an even shorter diastolic filling time; (3) several readjustments may be necessary, particularly during the acceleration phase; and (4) the decrease in heart rate during the deceleration phase may not be recognized during AAI pacing.

In a recently published study, Barker et al investigated the impact of postoperative AAI pacing in pediatric patients not exhibiting tachycardia after congenital heart surgery.[10] Patients were paced at a stimulation rate that was 15% higher than the patient's sinus rhythm. The authors detected a decrease in tissue oxygenation on head and flank near-infrared

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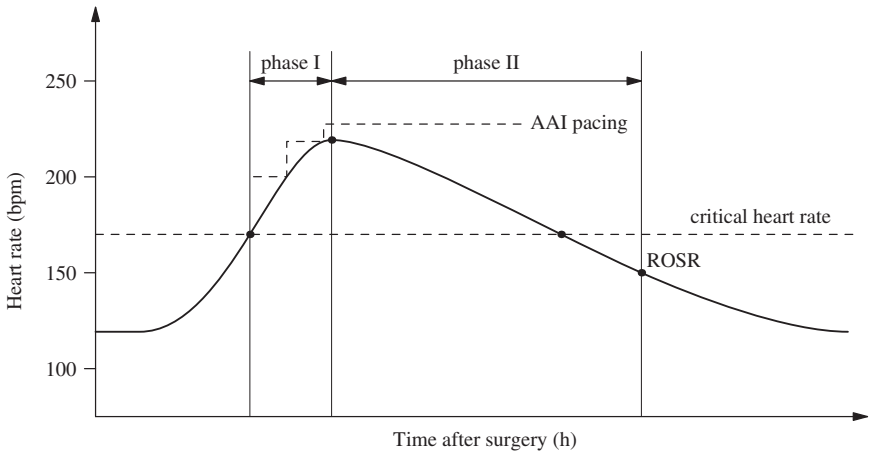

Fig 1. A schematic diagram of the heart rate course in postoperative junctional ectopic tachycardia. The heart rate increases during the acceleration phase (phase I) and decreases during the deceleration phase (phase II). In AAI pacing, the stimulation rate has to be higher than the patient´s ventricular heart rate. Abbreviations: bpm, beats per minute; AAI, atrial demand pacing; ROSR, return of sinus rhythm.

spectroscopy and a decrease in mean arterial pressure. Therefore, AAI pacing with a stimulation rate higher than the patient's heart rate may have objective effects on the postoperative course of patients who do not develop arrhythmia. The negative impact of increasing the heart rate in the presence of a tachycardic rhythm disorder has to be considered carefully against the benefit of atrioventricular synchrony. Even though AAI pacing is recommended as an important therapeutic measure in postoperative JET, there is no published systematic clinical evaluation confirming the positive effects of the therapy.

DUAL-CHAMBER PACING

Dual-chamber pacing (DDD pacing) presents an alternative option in patients in whom AAI pacing is not possible due to atrioventricular conduction disturbances (Fig 2). In such patients, DDD pacing can provide effective sequential atrioventricular stimulation. Moreover, the technique and specific settings associated with this pacing mode are familiar to most physicians. As in AAI pacing, the pacing rate must exceed the patient's heart rate. However, in contrast to the automatic focus in JET, the site of ventricular stimulation in DDD pacing is not located within the conduction system. Prolonged and dyssynchronous ventricular activation may negatively influence the ventricular performance.[11] With respect to hemodynamic status, DDD pacing may not always be beneficial in patients with JET. Therefore, patients have to be monitored carefully during the pacing procedure to identify unfavorable effects.

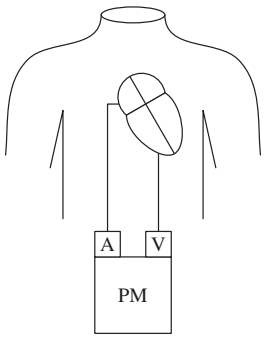

Fig 2. Dual-chamber pacing (DDD). In postoperative junctional ectopic tachycardia, the atria are paced via the pacemaker´s atrial output channel with a stimulation rate higher than the patient´s heart rate. At the end of the adjustable AV delay, ventricles are paced via the ventricular output channel with the same stimulation rate. Abbreviations: PM, pacemaker; A, atrial channel; V, ventricular channel.

PAIRED VENTRICULAR PACING

In the context of postoperative JET, the sophisticated pacing mode, PVP, first was described by Waldo et al in 1976.[12] Originally, PVP was developed for the treatment of adult patients with severe heart failure but was deemed unfeasible for this purpose.[13] The aim of PVP is to halve the patient's mechanical heart rate (rate of myocardial contraction) by the implementation of an artificial myocardial refractory period. The PVP method requires the use of a stimulator for electrophysiologic studies. Those stimulators offer the option of

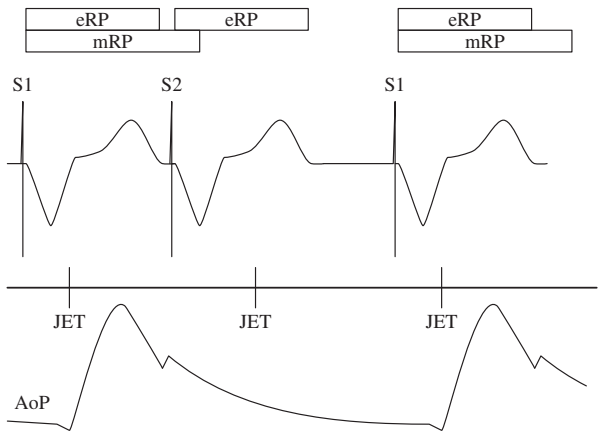

Fig 3. Paired ventricular pacing. Two ventricular stimuli (S1, S2) are used to implement a myocardial refractory period. The rate of effective cardiac contractions is halved. Abbreviations: eRP, electric refractory period; mRP, myocardial refractory period; JET, junctional ectopic tachycardia; AoP, aortic pressure.