# Antitachycardia pacing reduces appropriate and inappropriate shocks in children and congenital heart disease patients

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**BACKGROUND** Antitachycardia pacing (ATP) can reduce implantable cardioverter-defibrillator shocks, but its use in children and patients with congenital heart disease (CHD) is not well described.

**OBJECTIVE** To review the efficacy of ATP in children and patients with CHD.

**METHODS** We reviewed implantable cardioverter-defibrillator therapies in children and patients with CHD (aged 2–52 years) at our institution. Appropriate therapies were defined as those delivered for true ventricular tachycardia (VT) or ventricular fibrillation; other therapies were defined as inappropriate.

**RESULTS** During a median follow-up of 4 years (range 0.5–15 years), 17 of 79 patients (23%) received appropriate therapy and 14 received ATP for 100 episodes of VT. ATP was highly successful (88%) in terminating VT, and only 10 of 100 episodes required a shock. Shocks were effective in terminating VT/ventricular fibrillation in 21 of 24 episodes (87%). The outcomes of appropriate therapy were similar for ATP and shocks (success 88% vs 87%, failure 9% vs 8%, acceleration 3% vs 4% for ATP and shocks, respectively). Thirty-one patients (39%) received inappropriate therapy. Inappropriate ATP (without subsequent shocks) was delivered to 11 patients for the following: sinus tachycardia (19 episodes in 7 patients) with slowing of the rate after ATP, T-wave oversensing (2 episodes in 2 patients) with loss of oversensing after ATP, and reentrant supraventricular tachycardia (14 episodes in 2 patients) terminated with ventricular ATP.

**CONCLUSIONS** ATP is highly efficacious for VT in children and patients with CHD. In addition to reducing appropriate shocks, inappropriate shocks due to sinus or supraventricular tachycardia can be significantly reduced with ATP.

**KEYWORDS** Antitachycardia pacing; Implantable cardioverter-defibrillator; Ventricular tachycardia; Ventricular fibrillation; Pediatrics; Congenital heart disease

**ABBREVIATIONS** **ATP** = antitachycardia pacing; **CHD** = congenital heart disease; **CM** = cardiomyopathy; **HCM** = hypertrophic cardiomyopathy; **ICD** = implantable cardioverter-defibrillator; **VF** = ventricular fibrillation; **VT** = ventricular tachycardia

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## Introduction

The use of an implantable cardioverter-defibrillator (ICD) to prevent sudden cardiac death is well established, with indications for primary and secondary prevention in patients at risk for ventricular arrhythmias.[1] While efficacious, ICD shocks can have adverse consequences, including reduced quality of life and possibly increased mortality.[2,3] ICD therapy has also become the primary modality for children and patients with congenital heart disease (CHD) at risk for ventricular arrhythmias,[4,5] with a 4-fold increase in ICD implants in children from 1997 to 2006.[6,7] In addition to potential adverse consequences of appropriate ICD shocks, young patients have a high rate of inappropriate shocks ranging from 18% to 50%.[8–10] Antitachycardia pacing (ATP) is a painless ICD modality to treat ventricular tachycardia (VT), and multiple studies have shown its benefit in terminating VT.[11–18] The Pain FREE Rx II trial confirmed its efficacy in a broad ICD population and showed that ATP did not cause significant event acceleration, arrhythmic syncope, or increase in mortality when compared with primary shock therapy.[13]

Despite the long-standing and encouraging data on ATP safety and efficacy in specific and general ICD populations, there is limited literature on ATP results in children and young patients with CHD. Concern regarding ATP being ineffective, resulting in delay in treatment, arrhythmic syncope, or proarrhythmia, has led some practitioners to avoid its use in young patients.[19] The purpose of the present study was to examine the safety and efficacy of ATP in an ICD cohort consisting of pediatric and CHD patients when ATP therapy is empirically and routinely programmed ON as the initial therapy for VT.

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## Methods

We performed a retrospective review of all the pediatric and CHD patients with ICDs implanted at our institution from May 1996 to May 2010. We also included patients with ICDs implanted at other facilities but followed at our institution. Patients were excluded if there was little or no follow-up after the ICD implantation. We collected information on patient characteristics, including age, underlying diagnosis, details of ICD implantation, the delivered therapy, and the ICD follow-up duration. The indication and technique of the ICD placement were noted. While ICD programming was not dictated as part of this study, the implanting physicians at our institution program multiple VT detection zones, including monitor-only zones, usually with rates >240 beats/min for ventricular fibrillation (VF) detection. ATP (8-pulse burst pacing train at 88% of the VT cycle length) with multiple (2–6) sequences and occasionally more aggressive decremental (ramp, ramp +) protocols is routinely programmed for VT and fast VT and during charging for VF if available. The efficacy of ATP for terminating VT is not tested at implant, but the lowest effective energy for defibrillation is generally ensured to be at least 10 J lower than the maximal output of the device.

All appropriate and inappropriate ICD therapies during follow-up were analyzed. Therapy was considered appropriate when delivered for true VT or VF, and inappropriate in all other cases. Episodes in which VT or VF detection criteria were met but therapy was not delivered because of spontaneous termination prior to therapy were excluded. Atrial therapies for device-detected atrial arrhythmias were not analyzed, but if therapy for VT/VF was delivered because of an atrial arrhythmia, the episode was analyzed as an inappropriate therapy. Categorical data were compared with chi-square, and continuous variables were compared with Student's *t* test. A 2-tailed *P* value of <.05 was considered statistically significant. The data collection was performed in accordance with the regulations of the Vanderbilt University Institutional Review Board.

## Results

### Patient characteristics

After excluding patients with no or very limited follow-up, there were 79 patients aged 2–52 years (median 22 years; interquartile range 17–27 years) who were followed for a median of 4 years (6 months to 15 years) after ICD implantation. Age at implant ranged from 6 months to 49 years (median 17 years; interquartile range 13–21 years). A total of 28 (35%) patients had CHD, 26 (33%) had primary electrical disease, and 25 (32%) had cardiomyopathy (CM). Transvenous systems were used in 71 (90%), and the remaining 8 (10%) had epicardial systems. No deaths at implant occurred. Baseline characteristics are listed in Table 1. A total of 41 patients (52%) received at least 1 ICD therapy: 10 received appropriate therapies only, 24 received inappropriate therapies only, and 7 received both appropriate and inappropriate therapies. None of the patients experienced syncope with appropriate or inappropriate ATP therapy. During follow-up, there was 1 death due to an unknown cause and 1 heart transplant 40 months after ICD implant in a patient with dilated CM.

**Table 1** Baseline characteristics (n = 79)

| | |
|---|---|
| Males | 47 (60) |
| Age (y) | 22 (2–52) |
| Age at implant (y) | 17 (0.5–49) |
| Diagnoses | |
| Congenital heart disease | 28 (35) |
| Tetralogy of Fallot | 7 |
| Single ventricle physiology | 3 |
| Palliated CHD with ventricular dysfunction | 3 |
| Truncus arteriosus | 2 |
| Semilunar valve insufficiency with VT | 2 |
| Ebstein's anomaly | 1 |
| Primary electrical disease | 26 (33) |
| LQTS | 11 |
| CPVT | 4 |
| Idiopathic VT/VF | 4 |
| Brugada syndrome | 3 |
| Short QT syndrome | 2 |
| Progressive cardiac conduction disease | 1 |
| Andersen-Tawil syndrome | 1 |
| Cardiomyopathy | 25 (32) |
| HCM | 25 |
| DCM | 5 |
| ARVC | 2 |
| Primary prevention indication | 47 (59) |
| Transvenous system | 71 (90) |

Data listed as n (%) or median (range).

ARVC = arrhythmogenic right ventricular cardiomyopathy; CHD = congenital heart disease; CPVT = catecholaminergic polymorphic ventricular tachycardia; DCM = dilated cardiomyopathy; HCM = hypertrophic cardiomyopathy; LQTS = long QT syndrome; VF = ventricular fibrillation; VT = ventricular tachycardia.

### Appropriate therapies

Of the 17 (21%) who received appropriate therapies, 14 received ATP for 100 episodes of VT (1–31 episodes per patient; median 3.5). ATP was successful in terminating VT in 88 of 100 episodes (88%). After eliminating 2 subjects with a high number of ATP episodes (30 and 31 episodes, respectively), ATP success was still fairly high (28 of 39 episodes or 72% in 12 patients with 1–10 episodes each; median 2 per patient). In 14 patients who received at least 1 episode of ATP for VT, all ATP attempts were successful in 8 (57%), all were unsuccessful in 4 (29%), and both successful and unsuccessful attempts occurred in 2 (14%). The majority of VT episodes were terminated with 1 (75) or 2 (10) ATP attempts, with 4, 5, and 8 attempts required for termination in 1 instance each. Nine episodes of VT were unaffected by ATP and required shocks for termination. Acceleration of the VT cycle length by ATP was observed in 3 instances with the following outcomes: successful termination of the faster VT by subsequent ATP (1), spontaneous termination of the faster VT while the ICD was charging (1), and successful termination of the faster VT with 1 shock (1). Thus, of 100 true VT episodes that received ATP, only 10 required a shock.