Review

Recommendations for the Programming of Implantable Cardioverter-Defibrillators in New Zealand

Matthew R. Webber, MB ChB, FCSANZ[1] and Martin K. Stiles, MB ChB, PhD, FCSANZ*,[1]

Waikato Hospital and The University of Auckland, New Zealand

Aim: **Our manuscript proposes recommendations to standardise implantable cardioverter-defibrillator (ICD) programming practice in New Zealand (NZ) and provides a review of the literature behind such an initiative.**

Background: **Shocks have traditionally been the mainstay of ICD therapy for ventricular tachyarrhythmia. There is substantial evidence to suggest shocks may cause psychological harm, are often painful and may increase hospitalisation for heart failure. Shock therapy may be reduced by avoiding unnecessary therapy of non-sustained arrhythmia, utilising anti-tachycardia pacing to terminate ventricular tachycardia and by using algorithms to identify non-ventricular rhythms with rates overlapping therapy zones. This manuscript outlines evidence-based strategies to safely reduce unnecessary shocks from ICDs and includes manufacturer-specific parameters for ease of practical use.**

Conclusion: **These recommendations aim to optimise programming of ICD devices in NZ. Developed from a substantial evidence base they are intended to align national programming practice in the hope that we achieve fewer hospitalisations, improved quality of life and possibly achieve greater survival for our ICD-treated patients.**

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Keywords. Defibrillators; Implantable; Programming recommendations; Anti-tachycardia pacing; Ventricular fibrillation; Tachycardia; Supraventricular; Shocks

Introduction

The implantable cardioverter-defibrillator (ICD) has proven efficacy in the primary and secondary prevention of sudden cardiac death [1–5]. Until the availability of anti-tachycardia pacing (ATP), delivery of shocks was the only anti-tachycardia therapy of ICDs. Shocks can be uncomfortable and are associated with adverse psychological sequelae [6], premature battery depletion and inferior quality of life [7–10]. Although no causal relationship has been established, patients receiving a shock have higher mortality, most commonly due to progressive heart failure [11]. It is estimated that in the SCDHeFT [1] population up to 30% of patients will receive a shock over five years, many of which may be unnecessary. If contemporary programming parameters are applied to this population, computer modelling hypothesises a 59% reduction in shocked ventricular tachycardia (VT)/ventricular fibrillation (VF) episodes [12].

Strategies to reduce shocks are invariably a combination of device-based initiatives with more than 100 programmable parameters [13] such as ATP and improved discrimination of non-ventricular rhythms, together with non-device-based initiatives such as pharmacologic therapy [14–16] and targeted ablative procedures [17,18]. Recent studies [7,19,20] aiming to safely reduce the number of shocks have allowed more confidence to employ such algorithms in clinical practice. Nevertheless, shock therapy remains a mandatory component in all ICDs as ATP may be unsuccessful or be proarrhythmic.

These recommendations aim to become the standard of practice for ICD programming in New Zealand (NZ). They are intended to align national practice in the hope

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Abbreviations: A, atrial; AF, atrial fibrillation; AFL, atrial flutter; ATU, automatic template update; AV, Atrioventricular; AVA, AV association; BiV, Biventricular; bpm, beats per minute; CL, cycle length; CRT, cardiac resynchronisation therapy; Disc, discriminator; FVT, fast ventricular tachycardia; HCM, hypertrophic cardiomyopathy; HRTO, high rate time out; ICD, implantable cardioverter-defibrillator; LQTS, long QT syndrome; LV, left ventricle; ms, milliseconds; MVP, managed ventricular pacing; NSVT, non-sustained ventricular tachycardia; PW, pulse width; SCD-HeFT, sudden cardiac death in heart failure patients; SIH, sinus interval history; ST, sinus tachycardia; v, volts; V, ventricular; VF, ventricular fibrillation; VT, ventricular tachycardia.

* Corresponding author at: Department of Cardiology, Waikato Hospital, Hamilton 3840, New Zealand. Tel.: +64 7 8398899; fax: +64 7 8398760.

E-mail address: martin.stiles@waikatodhb.health.nz (M.K. Stiles).

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that we achieve fewer hospitalisations, improve quality of life and possibly achieve greater survival for our ICD-treated patients. Although they are developed from a large body of literature we acknowledge that the programming of defibrillators is a highly complex, changing field subject to evolving technologies and diverse patient characteristics. We recognise that there is currently no international consensus on optimal ICD programming and whilst programming may utilise the general strategies outlined, the specific requirements of each patient must be addressed. Although there are no randomised data to buttress many of our recommendations, there are reasonable inferences that can be drawn from the considerable observational data available. As such, these recommendations are an attempt to bridge the gap between the practical need for guidance and the evidence as it emerges.

Draft versions of this manuscript were circulated amongst senior members of Heart Rhythm NZ and significant changes were made. The version submitted to Heart, Lung and Circulation was approved by all members of the NZ Division of the Cardiac Society of Australia and New Zealand (CSANZ).

Anti-tachycardia Pacing

Our aim is to minimise shock therapy for non-sustained arrhythmia by extending detection times and utilising ATP instead of shocks as first-line therapy for sustained ventricular arrhythmia.

Use of ATP has increased significantly in recent years with studies showing it is effective, reduces shocks and improves patient quality of life [7,13,19–21]. ATP reduces 'appropriate' shocks by terminating ventricular tachyarrhythmias and also 'inappropriate' shocks by a number of mechanisms including termination of atrioventricular (AV) node-dependent re-entry and by delaying shocks to permit spontaneous slowing or termination of non-sustained arrhythmia [22]. Furthermore, diagnostic benefit may be gained from ATP by analysing the post-pacing interval in the ventricle and the atrial cycle length (CL) in the atrial channel (if present) for 1:1 tachycardias [23].

ATP may be programmed in a number of ways. Although burst ATP (a sequence of pacing stimuli equally spaced in time) and ramp ATP (a sequence of pacing stimuli that sequentially decrement in time) have similar efficacy in slower VT, the PITAGORA ICD [24] trial has demonstrated greater effectiveness and a lower incidence of acceleration with one burst (eight stimuli, 88% CL) over one ramp (eight stimuli, 91% CL) in the fast VT (FVT) zone (188–250 beats per minute (bpm)).

Concerns raised with early ICD experience regarding the effectiveness of ATP for VT rates above 200 bpm [25] have now been addressed. PainFREE [20], a prospective non-randomised trial of 220 patients, studied the efficacy of two ATP sequences (eight-pulse burst pacing at 88% CL with 10 ms scan decrement) for detected tachycardia episodes with CL > 240 ms. Programming included a VF zone for tachycardia CL < 240 ms, and FVT between 240 and 320 ms. A slow VT zone (CL > 320 ms) was included at the physicians' discretion and was not requisite for study participation. Of 1100 arrhythmia events detected, 446 (40%) were FVT, 378 (85%) of which were terminated by ATP. Rates of acceleration (4%) and syncope (2%) were low, and were comparable with other ICD studies.

The incidence of ventricular arrhythmias in primary prevention patients is lower than that in secondary prevention patients, [26] motivating some clinicians to advocate no ATP in patients with no history of clinical tachycardia [1]. Yet we have learned from secondary prevention trials that most spontaneous VF begins with rapid VT and most rapid VT can be terminated by ATP [20,27]. The PROVE trial [28] demonstrated that ATP is also beneficial for primary prevention ICD patients. ATP (two eight-pulse bursts, CL 88%, scan 12 ms, ramp *OFF*) was programmed in the VT zone (182–222 bpm) and supraventricular tachycardia (SVT) discriminators were applied up to 222 bpm. There was a monitor zone from 150 to 181 bpm and a shock-only VF zone from 223 bpm. In a cohort of 830 patients, ATP was attempted for 112 VT episodes in 71 patients, and 103 (92%) of the VT episodes were successfully terminated. Three VT episodes were accelerated by ATP and required termination by ICD shock; six episodes terminated spontaneously or by ICD shock.

With regard to the optimal stimulation rate of an ATP sequence, published data is scarce. Peinado et al. [29] compared the efficacy and safety of different ATPs, namely 15 vs 7 pulses at 91 vs 81% of tachycardia CL. For an isolated stimulation sequence they showed that a 15-pulse burst is more effective than seven pulses and stimulation rates of 91% CL were better than 81% (80 vs 56%, $P < 0.001$). In contrast, the more recent results of ADVANCE-D [30] suggest a 15-pulse train may be as effective and safe as, but not superior to, an eight-pulse train for FVT.

Consistent with the programming utilised in PainFreeII, EMPIRIC, PROVE, PREPARE and the study by Peinado et al. we recommend an eight-pulse, readaptive burst of ATP at 85–91% of the VT CL with a 10 ms scan decrement. This ATP scheme does not employ any proprietary algorithms or features specific to any one device and as such it is applicable to all the manufacturers.

Until recently the optimal number of pacing attempts for FVT was unknown. While the majority of FVT episodes will terminate with two ATP sequences [20,31] there is potential to further reduce unnecessary shocks with more ATP attempts. This has been evaluated in slow VT (140–220 bpm) in which at least four and up to six ATP (eight pulses, 81% CL) attempts have been shown to be safe and effective [32], but the safety of such a strategy in FVT was unknown.

A recent study has shown up to five ATP attempts for tachycardia rates 200–240 bpm is safe and effective for primary and secondary prevention patients with ICDs for ischaemic or non-ischaemic cardiomyopathy [33]. In this prospective, non-randomised trial of 770 patients ICDs were programmed to deliver 10 attempts of ATP (five bursts, then five ramps; 8–10 extra stimuli at 81–88% FVT CL; minimal CL 180 ms) for FVT between rates 200–240 bpm (250–300 ms). A total of 137 patients