Shall we do a DFT?
A clinical review of defibrillation threshold testing in 2014

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Background
Many ICD implanters worldwide continue to wonder about which patients need to have defibrillation threshold testing (DFT). In Oxford, our policy has been to not test primary prevention implants, but to test all patients with a secondary prevention indication. Listening to talks at the Cardiostim and HRS meetings this year confirmed that there was a wide variety of approaches worldwide, varying from testing all ICD implants to none. Some further evidence on this topic has emerged recently, in particular the SIMPLE trial presented at HRS 2014, which forms the basis for this article.

The aim of defibrillation is to interrupt the abnormal re-entry circuits that underpin ventricular fibrillation and tachycardia (VF, VT), by simultaneously depolarising enough of the areas of myocardium that are sustaining the arrhythmia. This is thought of as requiring the depolarisation of a critical mass of myocardium. Given the complexity of these circuits in VF, the amount of energy required to achieve VF defibrillation will be extremely variable, and will depend upon several factors, some due to random fluctuations and timing, and some linked to the underlying characteristics of the myocardium. Hence the threshold energy required to defibrillate will vary around a central point for a given patient. On a population basis this mean is about 11J with a standard deviation of 4J (covered in an excellent review by Swerdlow et al1 and elsewhere2).

Issues surrounding DFT
This means that DFT testing is probabilistic – one successful defibrillation at a given energy does not guarantee that the same energy would work a second time. Even when a single shock fails, there might still be a high probability of a repeat shock at the same energy subsequently working with no modification to the device. This can be defined in a sigmoid probability curve which was characterised by studies in animal models3. Various testing protocols can estimate the range of a particular patient’s defibrillation success probability curve, and help guide device output to ensure a high probability of successful defibrillation. These protocols are however complex and many require 4 or more shocks. In 2003 Gold et al showed that one successful shock at 14J identified a population in whom a device set at its maximum output of 31J would have a high VF defibrillation success rate4. This simple testing strategy has been widely adopted.

With early ICD systems, the success of defibrillation was relatively low. Devices had lower maximum outputs, and a significant proportion would not provide consistently successful defibrillation without modifications. Accordingly, all of the major trials that established the evidence base for ICDs included DFTs in their protocols. Since then, multiple improvements have been made to modern devices, including ‘active cans’ (i.e. using the pulse generator as part of the defibrillation circuit), more effective biphasic defibrillation waveforms, and high available defibrillation energies. These changes have altered the position of the vast majority of patients on the probability curve such that it would be expected that the first maximum voltage shock will be effective in over 95% of patients, with multiple shocks reaching almost 99% success5,5,4.

The clinical relevance of a successful test is also a concern. The circumstances of the patient at the time of VF induction intra-operatively may be very different to the clinical arrhythmia treated by the device at a later date. In particular, several studies have shown that induced VF is not the same as spontaneous VF, and also that a defibrillation energy that successfully treats induced VF might not
treat clinical VF in the same patient\(^1\). Furthermore, since the advent of anti-tachycardia pacing the majority of arrhythmias are often terminated by this rather than needing a shock.

How often do patients ‘fail’ DFTs, such that they are found not to have a safe margin between the defibrillation threshold and the device maximum output? This is surprisingly poorly defined. Some studies quote failure rates of 3-5\(^\%\)\(^1\), although in a large retrospective analysis of the US National Cardiovascular Data registry, 9.4% of patients were reported as having a DFT within 10J of the device maximum. This is retrospective data analysed from a large audit dataset with limited clinical details available, and it is noteworthy that they did not report how often it was not possible to successfully defibrillate the patient. In particular, others have shown that for a modern device only a 5J increase over the defibrillation threshold will increase the success rate to 99%, meaning that the 10J window this group quote may be less relevant\(^4\).

Brignole et al recently published a large ‘natural experiment’ approach to further investigating the impact of DFTs. Illustrating the variation in clinical practice, they ‘randomised’ patients according to whether they attended one of 41 Italian centres who did or did not perform DFTs. They found no difference in mortality at 2 years in the groups, although did note a non-significant increase of four more severe intra-operative complications in the DFT group\(^6\). Other non-randomised studies have similarly found that DFTs do not seem to impact mortality\(^5\).

**SIMPLE**

In this situation of a relative lack of evidence, the SIMPLE trial, reported at HRC but as yet unpublished, appears to provide a robust basis for a change in practice. The investigators randomised 2500 patients to a strategy of DFTs, aiming to achieve one success at 17J or two at 21J, or to no DFT at all. 99.2% of the Boston Scientific devices used were set to their maximum output of 31J, as specified in the protocol. About 70% of the patients were implanted for primary prevention. They were a relatively typical ICD population, including 28% CRT-D, and were dominated by ischaemic cardiomyopathy (65%) and dilated cardiomyopathy (33%).

The investigators reported that 89.9% of patients met the DFT protocol criteria with the initial configuration, another 3.1% required modifications at implant, and a further 6.9% had successful shocks but not fulfilling the DFT criteria. The modifications made in these patients were not detailed in the presentation, but it was reported that only 10 patients out of the 1253 in this arm had no successful shocks.

Over 3.1 +/- 1.0 years of follow up, there was no significant difference in the primary composite outcome of failed arrhythmic shock or sudden cardiac death (hazard ratio 0.86, 95% confidence interval 0.65-1.14). All-cause mortality also did not differ. Subgroup analysis showed no significant differences in subgroups, notably including in the large secondary prevention subgroup of 684 patients.

The investigators also reported a small number of significant complications arising from DFTs, predominantly driven by more episodes of heart failure in the DFT group, although 6 more patients having DFTs required intra-operative chest compressions and ventilation (none of whom were reported as dying). This mirrors the findings of registry data, which reports small number of deaths and prolonged resuscitations ascribed to the DFT procedure, sometimes with long-term morbidity\(^7\).

The key interpretation of this study, which agrees with the prior non-randomised data, is that there does not appear to be any impact on long-term mortality resulting from a DFT strategy, despite modifications to device configuration made in a proportion of patients. The follow-up in this study seems long enough to support this conclusion. This lack of benefit from DFTs is also highlighted by the increase in serious peri-operative complications in the DFT group. It now appears that DFTs
definitely carry a small but significant risk of harm to the patient, and do not appear to provide any benefit.

This result might have been expected given the high energy (31J) devices used, which at maximum voltage would be expected to comfortably exceed the defibrillation threshold of the vast majority of patients. Another interpretation would be that the DFT strategy used, although based on sound evidence, does not actually result in clinically relevant information due to the disconnect between induced arrhythmia and clinical events.

When to still perform a DFT?
Are there groups in whom DFTs should still be performed? SIMPLE did not include many patients with rarer pathologies, so evidence as to the benefits or not of a DFT strategy for patients with conditions such as Brugada syndrome or in particular hypertrophic cardiomyopathy (where some evidence suggests DFTs may be higher) remains limited. In patients with atypical device configurations such as right-sided devices or unusual anatomy it may be that the gap between the device maximum output and the DFT might be smaller, and that a DFT should be performed, if its results would be used to guide device modifications. Also, when low R wave amplitude must be accepted due to patient or implant features, there is an argument for inducing VF to confirm that the device can correctly sense this, although many of the same arguments about the long-term clinical reproducibility apply.

Conclusions
The results from SIMPLE provide adequate evidence to support avoiding DFTs in both primary and secondary prevention patients with dilated and ischaemic cardiomyopathies. It seems to me that it is time to stop performing DFTs in all but some specific situations. This causes concerns for training future implanters, as it will become increasingly difficult to develop or maintain competence in this skill.

References


