High defibrillation threshold in patients with implantable defibrillator: how effective is the subcutaneous finger lead?

Brigitte R. Osswald a,⁎, Raffaele De Simone b, Sabine Most b, Ursula Tochtermann b, Ahmed Tanzeem b, Matthias Karck b

a Department of Thoracic and Cardiovascular Surgery, University of Essen, Hufelandstr. 55, 45147 Essen, Germany
b Department of Cardiac Surgery, University of Heidelberg, Germany

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Abstract

Objective: Even in the era of high output implantable cardioverter defibrillator (ICD) devices, a certain proportion of patients cannot be successfully defibrillated with 10 J safety margin. In practice, either the use of a single- or double-coil lead does not guarantee successful termination of induced ventricular fibrillation. Therefore, we investigated the effectiveness of the subcutaneous finger lead placed at the subcutaneous tissue dorsal to the left ventricle in terms of defibrillation threshold (DFT) lowering.

Methods: Two thousand, eight hundred and three consecutive, unselected patients underwent first-time ICD implantation or ICD device exchange from 6/1999 through 3/2007. The mean age of the patients was 65.4 years. A total of 79.3% of the patients were male. The only implanted subcutaneous lead was the 6996 model by Medtronic Inc.

Results: One hundred and seventy-seven patients (6.3%) received a subcutaneous finger lead implantation. According to the current institutional DFT testing protocol, any failure of the two standard DFT tests in first-time ICD implantation or a failure at the single test in ICD exchange operations was the trigger for subcutaneous finger lead implantation. The proportion of subcutaneous finger lead implantations increased parallel to a markedly larger amount of implantations. Since high output devices became standard, the implantation number of subcutaneous finger leads decreases. The mean of unsuccessful DFTs prior to subcutaneous finger lead implantation was 27.2 ± 5.3 J. After subcutaneous finger lead implantation, the mean successful DFT was 17.9 ± 3.3 J. No complication due to subcutaneous finger lead implantation occurred.

Conclusion: The subcutaneous finger lead is a quick, safe and effective method for DFT lowering.

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Keywords: Ventricular arrhythmia; ICD; Defibrillation threshold

1. Introduction

Implantable cardioverter defibrillator (ICD) therapy has become a standard in the primary and secondary prevention of sudden cardiac death [1,2]. At least 10 J safety margin between intraoperative defibrillation threshold (DFT) testing and maximum output of the ICD device have become widely accepted practice. Although the safety margin can be achieved in the vast majority of patients, there are still patients where a 10 J safety margin cannot be confirmed. Whether to accept even higher DFT or to change the electrical field by insertion of further electrodes remains, so far, the individual physician’s decision. The aim of our study was to analyse the clinical impression of having a powerful tool for DFT lowering if an additional subcutaneous finger lead is added to the standard configuration (single-coil RV lead and subpectoral active can).

2. Patients and methods

A total of 2803 consecutive patients underwent either first-time ICD implantation or ICD device exchange from 6/1999 through 3/2007 at the University of Heidelberg. The mean age of the patients was 65.4 years. A total of 79.3% of the patients were male (n = 2223). All patients had a single-coil RV lead and an active ICD device in subpectoral position. Implanted lead and device manufacturer were Medtronic, St. Jude, Biotronik and Guidant, respectively Boston Scientific. No other but the subcutaneous 6996 lead by Medtronic Inc., Minneapolis, USA was used to achieve an altered electrical field.

2.1. Statistical analysis

Statistics included descriptive analysis. For the comparison of DFT prior to and after subcutaneous finger lead implantation, the paired t-test was used. For statistical analysis, SAS V.9.01 (SAS Institute Inc., Cary, NC) was used.
3. Results

Out of the 2803 total patients, 177 patients (6.3%) received an additional subcutaneous finger lead implantation in retrocardiac position (Fig. 1a and b). For insertion of the subcutaneous finger lead, no additional incision was performed, but the insertion tool was tunneled from the subpectoral pocket through the submuscular space around the ribs as close to the spine as possible. It is important that the subcutaneous finger lead was at about the same height in a.p. fluoroscopy as the coil of the RV lead. According to the current institutional DFT testing protocol, any failure of the two standard DFT tests in first-time ICD implantation or a failure at the single test in ICD exchange operations was the trigger for subcutaneous finger lead implantation. The absolute values changed over time, since the maximum output of the ICD devices became higher in the more recent period; a DFT 10 J less to the maximum output of the device was accepted, so in case of a maximum output of 30 J, a failure at 20 J induced the implantation of an additional subcutaneous finger lead. The finger lead was inserted in the SVC or HVX DF-1 connector having the same polarity as the active can which was placed in the standard subclavicular subpectoral pocket.

In Fig. 2, the numbers of implantations are shown. The proportion of subcutaneous finger lead implantations increased in the former era parallel to a markedly larger amount of implantations. Since high output devices became standard, the implantation number of subcutaneous finger leads decreases.

The mean of unsuccessful DFTs prior to subcutaneous finger lead implantation was 27.2 ± 5.3 J (median: 25 J, interquartile range: 25–30 J). As illustrated in Fig. 3, after subcutaneous finger lead implantation, the mean successful DFT dropped down to 17.9 ± 3.3 J (median: 17 J, interquartile range: 15–20 J) (paired t-test: t-value: 26.3, p < 0.001). No complication due to subcutaneous finger lead implantation occurred.

Fig. 1. Configuration of a standard transvenous ICD system after implantation of an additional subcutaneous finger lead. The p.a. projection (a) shows the position of a double-coil ICD lead. Because of high DFT values with and without connection of the SVC coil, the subcutaneous finger lead was implanted and a sufficient safety margin was achieved. The lateral view (b) indicates the tunnel of the subcutaneous finger lead beginning at the ICD pocket heading to the patient’s back.

Fig. 2. Number of subcutaneous finger lead implantations (black columns) versus total number of implantations (grey columns) over the investigated time period.

Fig. 3. The implantation of a subcutaneous finger (SQ) lead significantly reduces the effective DFT.
4. Discussion

Unsuccessful intraoperative DFT testing in terms of at least less than 10 J safety margin or necessity for external defibrillation was observed in 6.3% of our patients. This is very similar to the numbers published from Russo et al. [3] reporting a proportion of 6.2% of the patients undergoing ICD implantations.

Whether or not 'risk factors' are available consistently predicting a high DFT is controversially discussed. The most recent study on 'risk factors' did not reveal any correlation to preoperatively available data [4]. Gold et al. correlated higher DFT with increased body mass and echocardiographically measured larger left ventricular diameter [5] and Khalighi et al. found the preoperative use of amiodarone to represent another risk factor for higher DFTs [6].

The waveforms used are still a matter of debate concerning DFT lowering; however, a straightforward strategy to reduce shock energy necessary for successful termination of ventricular fibrillation for example by variation of tilt does not exist [7]. Without any doubt, the introduction of biphasic defibrillation significantly reduced effective peak voltages and allowed substantial decreases of device size [8]. The role of polarity has been repeatedly reported to be important [9], although a reverse polarity in the same electrical configuration lacks theoretical background.

High DFT during ICD implantation occur in habitual cocaine use [10]. In daily practice so far a more relevant fact may be that halothane, isoflurane and fentanyl increase the minimally effective defibrillation threshold, whereas lidocaine plus IV propofol lowers the required energy [11].

Despite minor disadvantages in DFT for subcutaneous versus submuscular placement, the subcutaneous position of an ICD implanted at the pectoral site does not clinically affect the DFT [12].

The meaning of a redesigned electrical field to obtain better DFT can be achieved by additional leads but also by repositioning the active can to the abdominal position [13]. A similar idea but a different approach comes from Winter et al. [14] who practice repositioning of the RV lead to achieve optimal DFT.

In former studies, patches played the major role for DFT lowering. Interestingly, subcutaneous patch leads decreased DFT by 35% compared with epicardial patch placement in an animal model [15]. Usui et al. [16] found in an experimental setting, that even in cases of ‘malpositioned’ transvenous leads, which means the RV coil position away from the apex towards the tricuspid valve, a reversal of DFT increases if subcutaneous arrays are additionally placed in the left thorax.

The higher the number of fingers the lower the effects summarizes a randomized study from Gruada et al. [17], who omitted one of the three finger leads; however, the authors did not use a single-coil subcutaneous lead which would have been potentially even more effective.

Kettering et al. [18] suggested regular DFT testing in patients receiving subcutaneous leads; however, they did not report about regular impedance measurements during follow-up which may indicate major long-term complications such as lead fracture. A limitation of our study is the lack of information about the long-term results.

In conclusion, for DFT lowering the subcutaneous finger lead seems to represent a very effective method with a minor risk of insertion-related injury.

References

array electrode versus an “active can” implantable cardioverter defibrillator and a subcutaneous array electrode in addition to an “active can” implantable cardioverter defibrillator: results from active can versus array trials I and II. J Cardiovasc Electrophysiol 2001;12:921–7.