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Use of implantable cardioverter defibrillators: From trials to practice

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Patients with sustained ventricular tachycardia or ventricular fibrillation are at high risk of sudden cardiac death. Recent clinical trials have suggested a benefit of implantable converter defibrillators (ICDs) over conventional drug therapy in selected patients who are at high risk of fatal ventricular tachyarrhythmia. Despite promising results from these trials, more studies are needed to better define those patients who would benefit most from ICD therapy.

Introduction

The potential benefit of ICDs in the management of malignant ventricular arrhythmia has long been recognized. Nonrandomized trials have suggested ICDs to be effective in preventing sudden cardiac death (SCD) in patients at risk.[1] Yet until recently, the criteria for selection of patients for ICD implantation remained unclear and the benefit of ICDs in reducing overall mortality (rather than SCD alone), was unproven. Recent large-scale clinical trials on the use of ICDs, however, have provided evidence to support their selective use. The goals of this review are to briefly discuss markers for predicting arrhythmic events, recent clinical trials of ICDs, pitfalls in interpreting ICD trial data, and clinical implications of ICD trial results.

Predicting arrhythmic events

Patients with sustained ventricular arrhythmias are at high risk of SCD. Up to 80% of SCDs are due to ventricular tachycardia (VT) or ventricular fibrillation (VF).[2] Implantation of an ICD in these patients may therefore be of benefit in preventing SCD. As it is not financially feasible to implant an ICD in all patients at risk of SCD, many studies have attempted to define predictors for significant arrhythmic events in order to select patients at highest risk for SCD who may benefit most from ICD therapy. Predictors that have been identified for SCD are shown in Table 1.

Age[15] greater than 45 and male gender[16] are also independently associated with SCD. Not surprisingly, a prior history of spontaneous sustained VT or VF confers a very high risk of recurrent sustained arrhythmia and SCD.[17]

Clinical trials of ICD

Trials evaluating the benefits of ICD therapy can be broadly divided into two types: secondary prophylaxis trials, in which the study population consists of cardiac arrest survivors or patients with

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Table 1: Predictors of sudden cardiac death

- A history of coronary artery disease (CAD)[3]
- A complicated in-hospital clinical course post-acute MI[4]
- Presence of frequent premature ventricular beats (including nonsustained VT) on Holter monitoring[5]
- Left ventricular ejection fraction ≤40%[6,7]
- Diminished heart rate variability[8,9]
- Positive late potentials on signal-averaged ECG (SAECG)[10,11,12]
- Inducibility of sustained VT or VF at electrophysiology study (EPS)[13,14]

spontaneous and hemodynamically unstable ventricular tachyarrhythmia; and primary prophylaxis trials, in which the study population is identified to be at high risk for significant arrhythmic events, but without a prior history of spontaneous sustained ventricular tachyarrhythmia.

Secondary prophylactic trials of ICDs

The Antiarrhythmic versus Implantable Defibrillator (AVID) study[18] compared ICDs with drug therapy in patients resuscitated from VF or those with hemodynamically unstable sustained VT. Of the 1016 patients enrolled, 507 were assigned to ICD and 509 to drug therapy with either amiodarone or sotalol. Ultimately, 95.8% of the drug therapy patients received amiodarone. VF was the index arrhythmia in 44.8% of cases, with the remainder being hemodynamically unstable VT. The primary endpoint was overall mortality. Over a mean follow-up of 18.2 months, the crude death rates were 15.8% in the ICD group and 24.0% in the drug group ($p<0.02$). This represented a 31% relative risk reduction at three years, and an average unadjusted extension of life conferred by an ICD of 2.7 months at three years. Multivariate analysis showed the benefit of ICDs to persist despite adjustment for co-variates, including the concomitant use of beta-blockers. Economic analysis from AVID showed the incremental cost of ICD over drug therapy to be substantial at $114,917 (US) per year of life saved.[19]

The Canadian Implantable Defibrillator Study (CIDS) [20,,21] compared ICD therapy to amiodarone in patients with resuscitated VT or VF, as well as with unmonitored syncope presumed to be secondary to ventricular tachyarrhythmia. Of 659 patients enrolled, 328 were randomized to receive an ICD and 331 to receive amiodarone. The primary endpoint was all-cause mortality. After five years of follow-up, there was a trend to reduction of all-cause mortality in the ICD compared to the amiodarone arm (8.3% vs. 10.2%, respectively). There was, however, a statistically significant 32.8% reduction in arrhythmic death with the ICD (from 4.5% to 3.0% per year) when compared to amiodarone. The confidence intervals for mortality reduction in CIDS and AVID overlap substantially. In conclusion, CIDS suggests a possible benefit of ICD therapy over amiodarone in patients with resuscitated VT or VF, or with unmonitored syncope presumed secondary to ventricular tachyarrhythmia, primarily due to a reduction in arrhythmic death.

The Cardiac Arrest Study Hamburg (CASH) study compared ICDs to drug therapy in cardiac arrest survivors with documented VF. Although the final published result is not yet available, preliminary results have been presented in abstract form.[22] A total of 349 patients were randomized to ICD, metoprolol, amiodarone, or propafenone. The propafenone arm was prematurely terminated by the Safety Monitoring Board because of a significantly higher mortality in the propafenone compared to the ICD arm (28.6% vs. 13.6% at 11 months).[23] The primary endpoint was total mortality in the ICD group compared to the drug-treated group (metoprolol or amiodarone). There was a statistically significant 37% reduction in total all-cause mortality (19.1% in the drug group to 12.1% in the ICD group), and a reduction in SCD (11.0% in the drug group to 2.0% in the ICD group). Overall, CASH suggests a benefit of ICD over drug therapy in patients with previous cardiac arrest.

Primary prophylactic trials of ICDs

The Multicenter Automatic Defibrillator Implantation Trial (MADIT)[24] studied whether prophylactic ICD implantation improves survival over conventional medical therapy in a subgroup of patients with unsustained VT, previous MI, and left ventricular ejection fraction ≤35%. Unlike those enrolled in CASH or AVID, these patients had no prior history of cardiac arrest or spontaneous sustained ventricular tachyarrhythmia. To be eligible for MADIT, sustained VT or VF, inducible during EPS, could not be suppressed by intravenous

procainamide. It was believed that the use of EPS would be helpful in selecting patients at particularly high risk for SCD from an asymptomatic population, who might benefit from ICD therapy. Of 196 patients enrolled, 95 were assigned to ICD and 101 to conventional drug therapy. The primary endpoint was all-cause mortality. The five-year overall mortality rate was 15.8% in the ICD group and 38.6% in the drug group, representing a hazard ratio of 0.46 in favor of ICDs (p=0.009). There appeared to be a reduction in both arrhythmic- (3.2% vs. 12.9%) and nonarrhythmic- (7.4% vs. 12.9%) related deaths from ICDs over drug therapy. Furthermore, regression analysis revealed no evidence that antiarrhythmics, including amiodarone and beta-blockers, had any meaningful influence on the benefit of ICDs. Although MADIT may provide evidence for using ICDs over drug therapy in selected asymptomatic patients at high risk of SCD, the magnitude of such benefit remains uncertain due to the lack of standardization in the drug therapy group, and the fact that only 45% of this group were receiving amiodarone at the end of the study.

The Coronary Artery Bypass Graft Patch (CABG Patch) trial[25] evaluated the benefit of prophylactic ICD implantation at the time of coronary bypass surgery in patients at increased risk of SCD. Patients were enrolled if their left ventricular ejection fraction was < 0.36 and they had late potentials on preoperative SAECG. Of 900 patients randomized, 446 received an ICD and 454 were assigned to control. The primary endpoint was overall mortality. During a mean follow-up of 32 months, there was no statistical difference in overall mortality in the ICD compared to control group (22.6% vs.20.9%, respectively) and in cardiac death (15.9% vs.15.8%, respectively). Secondary analysis also failed to identify subgroups who might benefit from ICD therapy. Therefore, the CABG Patch trial appears to refute the benefit of ICDs in patients at high risk of SCD who are undergoing coronary bypass surgery.

Pitfalls in interpreting trial data

At first glance, there appears to be a discrepancy between the results of the above trials. The magnitude of true benefit provided by the ICD over drug therapy is also unclear.[26,27]

One reason for the apparent discrepancy between trial results is the differences in patient selection for ICD implantation. In AVID, CIDS, and CASH, patients had a history of either near-fatal ventricular tachyarrhythmia or spontaneous hemodynamically unstable VT. This is in contrast to patients studied in MADIT and CABG Patch who had identifiable risk factors for SCD, but no prior history of spontaneous sustained ventricular tachyarrhythmia.

Secondly, in AVID, CIDS, and MADIT, there was significantly greater use of beta-blockers in the ICD group compared to the control group, and it is difficult to exclude the possibility that some of the apparent benefit of ICDs may instead be due to beta-blockade.[28] The effect of concomitant drug therapy is especially important given the only modest absolute risk reduction and the wide 95% confidence interval in the relative risk reduction of ICDs over drug therapy. Although a subgroup of patients who could receive particular benefit from an ICD could not be defined in AVID, patients with EF < 30% appeared to derive the greatest benefit from ICD therapy in CIDS.[29]

Care is also needed when interpreting the discrepancy in the results between the primary prophylaxis ICD trials. One factor is the difference in the indicator used for predicting patients at high risk for SCD. Whereas MADIT required inducible VT or VF on EPS, CABG Patch used only SAECG to define high risk groups. Thus, differences in the results of these trials may merely reflect the fact that inducible ventricular tachyarrhythmia is a better marker than abnormalities on SAECG for predicting SCD.[25]

A second factor is the effect of the treatment of ischemia on the benefit incurred by ICD therapy. All patients in the CABG Patch trial underwent complete coronary revascularization compared to only 46% in MADIT. Previous studies[30,31] have suggested that coronary bypass surgery decreases the risk of SCD, presumably by removing any ischemic trigger in the genesis of lethal ventricular arrhythmia, or by favorably altering the autonomic nervous input to the heart.[32] Therefore, it is possible that revascularization reduced the risk of SCD sufficiently to preclude any potential benefit of ICD to be seen.[27]

Clinical implications of trial results

In patients with identifiable risk factors for significant arrhythmic events, all possible precipitating causes such as cardiac ischemia and left ventricular dysfunction should be fully investigated and optimally treated with proven medical therapy. In patients with previous near-fatal ventricular tachyarrhythmia or hemodynamically unstable sustained VT, ICDs

appear to be superior over antiarrhythmic therapy in reducing overall mortality. The magnitude of the benefit, however, is unclear and may be lower than anticipated from historical or uncontrolled studies. Furthermore, in patients with CAD and left ventricular dysfunction who have ongoing cardiac ischemia and are candidates for coronary bypass surgery, revascularization likely reduces the risk of SCD. For those who have CAD, left ventricular dysfunction, and nonsustained VT, EPS may be useful in identifying which patients are at highest risk of SCD.

For the moment, we believe ICDs should be considered only for patients with a prior history of cardiac arrest or unstable sustained VT, or in those whose estimated risk of SCD is extremely high. In patients with well-tolerated sustained ventricular tachyarrhythmia, there is no clear evidence to support ICD therapy and amiodarone remains a reasonable alternative.

Summary

The role of ICDs in the management of ventricular tachyarrhythmia remains complex. Patients with sustained ventricular tachyarrhythmia are at high risk of SCD. Clinical predictors are now available to select subgroups who are at highest risk of SCD who may benefit from ICD over conventional drug therapy. Recent clinical trials with ICDs have provided evidence to support their selective use. Results of AVID, CIDS, and CASH, taken together, suggest a benefit of ICD over conventional drug therapy in patients with a history of near-fatal ventricular tachyarrhythmia or hemodynamically unstable VT. In contrast, MADIT showed a benefit of ICD over drug therapy in selected asymptomatic patients with CAD, left ventricular dysfunction, and nonsustained VT. On the other hand, CABG Patch failed to show any benefit of ICD implantation in prolonging survival in patients undergoing coronary artery bypass surgery. Care, however, must be taken in interpreting the results of these trials. Differences in patient selection prohibit meaningful comparison between some of the trial results. Furthermore, it is still unclear whether the magnitude of benefit incurred by ICD therapy justifies its high cost.

Several ongoing trials that may help to clarify the role of ICDs in patients at risk of SCD are shown in Table 2. Until the publication of these new trials, clinicians must evaluate the benefits and risks of ICD therapy on an individual basis.

Table 2: Ongoing trials defining the role of ICD therapy in patients at risk of SCD.

- The Defibrillation In Acute Myocardial Infarction Trial (DINAMIT), a Canadian-German collaboration
- The German Dilated Cardiomyopathy Study (GDCMS)[33]
- The Multicenter Unsustained Tachycardia Trial (MUSTT)[34]
- The Sudden Cardiac Death in Heart Failure Trial (SCD-HeFT)
- MADIT-2 (A comparison of ICDs to either drug or no therapy in different subgroups of patients at risk of SCD)

The decision to implant an ICD in many patients with ventricular tachyarrhythmia is difficult. While recent published clinical trials suggest a benefit of ICD over conventional drug therapy in only selected groups of patients at high risk of SCD, until the publication of ongoing ICD trials, there is no compelling evidence to recommend ICD therapy for all patients with ventricular tachyarrhythmia. Continued research is needed to define the population that will most benefit from ICD therapy.

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Abstracts of Interest

Worldwide clinical experience with a new dual-chamber implantable cardioverter defibrillator (ICD)

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A total of 300 patients were implanted at 55 centers worldwide with a 62 cc DDDR ICD in a multicenter, prospective study to evaluate safety and effectiveness. This ICD uses a PR Logic™ algorithm to discriminate supraventricular from ventricular arrhythmias (GEM™ DR, Model 7271).

Results: Mean age was 64 ± 13 years (79% male). Primary ICD indications were VT only (45%), and both sudden cardiac death and VT (36%). Mean EF was 37% ± 16% and 79% of the patients were in NYHA class I/II. All but 2 patients (99%) had a successful implant of the Model 7271 system (2 patients were implanted without an atrial lead because atrial pacing/sensing could not be measured, 1 due to chronic AF). The median defibrillation threshold was 9 joules. The average follow-up time was 1.7 months. The relative sensitivity for the detection of VT/VF episodes was 99.8%. Sixty-four patients experienced a total of 1153 appropriately detected spontaneous episodes (752 in VT zone, 225 in FVT zone, and 176 in VF zone). All but 6 (5 VT and 1 VF) of the spontaneous episodes (3 patients) were successfully terminated. The 1 episode of VF that was not successfully terminated occurred in a patient who had 28 episodes of VF. Six therapies were delivered for this episode before it spontaneously terminated. Two hundred twelve out of 295 supraventricular tachycardia (SVT) episodes had therapy appropriately withheld. No serious unanticipated device-related effects have been reported out to 3 months post-implant. Thirteen patients died (4%), but no death was considered device-related by the investigator or an independent safety review committee.

Conclusions: Early experience with the new DDDR ICD demonstrates safe and effective performance. The discrimination algorithm used in this device substantially reduces inappropriate treatment of SVT.

The electrogram width criterion: A new detection algorithm to reduce the incidence of inappropriate therapies in implantable cardioverter-defibrillator recipients

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Enhanced detection algorithm such as rate stability and sudden onset have been introduced for discrimination of ventricular (VT) from supraventricular tachycardia (SVT) in tiered-therapy implantable cardioverter-defibrillators (ICDs). The electrogram (EGM) width measurement is a new morphology criterion used in the Medtronic 7218 and 7223 ICD and is designed to discriminate between SVT and true VTs by measuring the width of the QRS complex of the intraventricular electrogram. The aim of this study was to evaluate the specificity and the sensitivity of the new criterion by reviewing spontaneous tachyarrhythmia episodes and evaluating the accuracy of arrhythmia detection.

Patients and methods: In 85 patients with a Medtronic 7218 or 7223 ICD, the EGM width was programmed passly after selecting a proper EGM source and slew threshold, measuring QRS width during sinus rhythm (SR) and defining the width threshold. A minimum of 8 QRS-snapshots of the last 8 QRS complexes had to be classified as wide to detect VT.

Results: During a mean follow up period of 18.5 months, 209 stored Episodes (E) of VT could be discriminated from 66E of SVT in 24P, 37E of SVT in 5P were not appropriately discriminated by the new detection algorithm. Those 5P had either a right or left bundle brunch block which caused widths measurements during SR and VT in the same range. The mean QRS width during SR was 80 ± 12ms and during VT 131 ± 28ms with a mean Delta-QRS of 62 ± 19.9ms.

Conclusion: 1. The new EGM width criterion is able to significantly reduce inappropriate ICD therapy and thereby improving specificity without sacrificing sensitivity. 2. The new criterion should not routinely be enabled in patients with a right or left bundle brunch block or QRS widths > 100ms during SR.

The effect of myocardial revascularization in patients with VT/VF and coronary artery disease: Relationship to outcome in the antiarrhythmics versus implantable defibrillators (AVID) registry

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Revascularization (REVASC), including CABG/PTCA, is often considered to improve the survival(-SURV) of VT/VF patients with coronary artery disease (CAD). To characterize REVASC effects on AVID therapy, we reviewed the SURV of 2311 AVID registry patients with CAD.

Results: REVASC after VT/VF was associated with an improved SURV ($p<0.01$) when restricted to patients without prior REVASC (n = 399). Adjustment for baseline characteristics (BASE: age, LVEF, MI, and CHF) eliminated this apparent survival advantage. ICD therapy imparted a substantial benefit in CAD patients who did not undergo REVASC ($p <0.001$). No improvement in SURV was seen with ICD therapy ($p = 0.14$) in patients undergoing REVASC after the index event.

Conclusions: VT/VF patients undergoing REVASC are healthier, as evidenced by BASE, which accounts for an improved outcome. The benefit of ICD therapy in VT/VF survivors with CAD is greater in those patients with a higher mortality who are not REVASC. Residual myocardial ischemia may render drug therapy less effective or perhaps proarrhythmic.

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