

The implantable cardioverter-defibrillator: From Mirowski to its current use

Sudden cardiac death can be prevented in two broad categories of patients—those who have survived a life-threatening ventricular arrhythmia or who have sustained ventricular tachycardia, and those who have not experienced sudden cardiac arrest but are known to be at increased risk.

ABSTRACT: Sudden cardiac death is the initial presentation for many patients with cardiac disease. Dr Michel Mirowski was a pioneering cardiologist who recognized the public health importance of this fact. In the 1970s his efforts led to the development of the implantable cardioverter-defibrillator that has revolutionized the ability to prevent and treat sudden cardiac arrest. However, in the first decade of the 2000s these devices remain underutilized in British Columbia and Canada. Increased physician awareness is needed regarding which patients are at high risk of sudden cardiac death and would benefit from this potentially lifesaving therapy.

By the mid-20th century it was well known that ventricular arrhythmias were the mechanism of death in a large proportion of patients with cardiac disease. The 1960s brought with them the advent of electronic monitoring, cardiopulmonary resuscitation, and synchronized cardioversion.¹⁻³ Once clinicians had tools at their disposal for the treatment of ventricular arrhythmias, it was not surprising to see the first coronary care units opened in 1962.²

While considerable attention was being paid to the treatment of arrhythmias among hospitalized patients, little attention was being paid to the major public health problem of sudden cardiac death (SCD) outside the coronary care unit.⁴ SCD is the initial presentation of cardiac disease in 15% of patients⁵ and more than 50% of all such deaths occur out of hospital.⁶ Michel Mirowski was one of the few clinicians in the 1960s to recognize the scope of the problem of SCD. It was his perseverance that ultimately led to the development of the first successful therapy for out-of-hospital cardiac arrest—the implantable cardioverter-defibrillator (ICD).

Michel Mirowski

Mieczyslaw (Michel) Mirowski was born 14 October 1924 in Warsaw, Poland.⁴ The story of his early life is nothing short of incredible. He grew up in a middle-class family among the large Jewish population of Warsaw at that time, but his relatively comfortable life changed dramatically with the outbreak of the Second World War.

With the invasion of Poland by the Nazis in 1939, Michel knew he could not stay in Poland, but he was determined to continue his education. Therefore, at the age of 15, he made the decision to leave his family and flee to Russia along with a friend. He would be the only member of his family to survive the Second World War.

Mirowski spent the following 5 years of the war in the Soviet Union, fleeing the advancing Germans. Despite long odds, he continually evaded

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Russian authorities who were intent on sending refugees to labor camps in Siberia. Somehow, he always managed to find enough work to feed himself and to stave off the malnutrition and disease that was rampant in the Soviet Union at that time.

After the war ended, Mirowski briefly returned to Poland and began medical school in Gdansk before leaving to pursue his medical education in Western Europe. He eventually entered medical school in Lyon, France, in 1947, despite knowing almost no French or English. It was in Lyon where Mirowski was first attracted to cardiology and also where he met and fell in love with his wife, Anna.

Upon graduation from medical school in 1954, he worked initially in Tel Aviv, Israel, as a registrar and then pursued further training in Mexico City, Baltimore, and Staten Island. He returned to Israel in 1963 to set up a private practice in a small community hospital. His new boss, Professor Harry Heller, unwittingly became the inspiration for Mirowski's research. In 1966 Heller began having episodes of ventricular tachycardia and died soon after. It was with Heller's death that Mirowski first conceived the idea of an implantable defibrillator.

Development of the ICD

In 1968 Mirowski was recruited to the Sinai Hospital in Baltimore, where he became the director of the hospital's new coronary care unit and was given protected time for research. Fortunately for this research, the hospital had a division of biomedical engineering and an animal laboratory.⁷ At the Sinai, Mirowski joined with Morton Mower, a junior cardiologist on staff with extensive animal research experience, to begin work on an ICD in July 1969.⁸ Only a month later they successfully tested their first crude prototype, made from a broken exter-

nal defibrillator paddle, on a dog.⁹ The paper describing their work was eventually published after initial rejections,¹⁰ but there remained considerable antagonism in the cardiology community toward the concept of the ICD. The antagonism also meant that they faced significant difficulty in securing funding for their research.

Mirowski and Mower eventually obtained support from a major pacemaker company in 1970 to further develop the ICD, but after 2 years the company decided there was no market for the device. In 1972 Mirowski was introduced to Stephen Heilman, a physician and engineer who had formed a small medical equipment company called Medrad. Heilman was excited by the concept of the ICD and immediately put the company's engineers at Mirowski and Mower's disposal. The partnership was fruitful and resulted in the production of the first ICD prototype small enough to be completely implanted in a dog in 1975. A film of the first successful defibrillation of a dog implanted with the prototype ICD was released and the now-famous footage catapulted the ICD from relative obscurity to the forefront of cardiac research overnight.

Mirowski and the group at Medrad further refined the prototype to make it suitable for human implantation and eventually received approval for such an implant from the FDA. After Mirowski and Mower enlisted the aid of colleagues at Johns Hopkins Hospital, cardiac surgeon Myron Weisfeldt and electrophysiologist Philip Reed, the first successful human implant of an ICD was performed in February 1980.¹¹

Though the first ICD model was a success, it weighed 225 g, required a thoracotomy for implantation of the electrode patches, and was only capable of defibrillation. In the years that followed, numerous advances in ICD design have been made. Mirowski and

Mower were involved in many of the early refinements, including the development of the capacity of synchronized cardioversion for ventricular tachycardia.⁹ True to Mirowski's original vision, a catheter-electrode-based model developed in the late 1980s could be implanted without a thoracotomy, in a similar manner to the standard pacemaker.

In the late 1980s Mirowski was diagnosed with multiple myeloma and he succumbed to the disease in 1990. While his invention of the ICD was an enormous advance for cardiac medicine, perhaps his greatest legacy was the attention he drew to the problem of SCD as a whole.

ICDs in 2010

Unlike the early prototypes, modern devices are much smaller, with the newest models weighing as little as 90 g and measuring less than a centimetre thick. In addition to having full pacemaker capabilities, all modern ICDs are capable of overdrive pacing (antitachycardia pacing), which can often terminate ventricular tachycardia without resorting to shock therapy. ICDs are also available with biventricular pacing (cardiac resynchronization therapy) to improve symptoms in selected patients with advanced heart failure.

The use of ICDs in Canada and around the world has grown considerably since 1980. In 2008, 593 ICDs were implanted in British Columbia and 5811 were implanted across Canada. Although these numbers are expected to rise in the years to come, ICDs currently remain underutilized in Canada, even among survivors of cardiac arrest.¹²

Patient selection

Whether to implant an ICD in a particular patient is a complex decision and involves careful discussion among

the health care providers and the patient. The ultimate decision to implant an ICD rests with the cardiac electrophysiologist, who will be responsible for appropriate programming and long-term follow-up of the device. It is important for the other treating physicians to know which patients should be referred to a cardiologist or electrophysiologist and considered for an ICD.

There are two broad categories of patients who can benefit from an ICD. First are patients who have survived a life-threatening ventricular arrhythmia or who have sustained ventricular tachycardia (VT). In this instance, the ICD would be implanted for the secondary prevention of sudden cardiac arrest (SCA). The definition of “sustained” VT differs greatly in the literature, but is usually defined as VT resulting in hemodynamic symptoms (syncope, pre-syncope, chest pain) or lasting greater than 30 seconds. Second are patients who have not yet experienced SCA but are at increased risk. Here an ICD would be implanted for primary prevention of SCA.

ICDs for secondary prevention

Not surprisingly, patients who have survived SCA due to ventricular fibrillation (VF) or hemodynamically unstable VT have the highest rate of recurrence and would therefore stand to benefit most from an ICD. Similarly, patients who have sustained VT and are highly symptomatic or have underlying structural heart disease are also at high risk of recurrence.

It was precisely these groups that were studied in the earliest randomized trials of ICD use.¹³⁻¹⁵ The largest of these trials was the AVID trial, where the ICD was compared with amiodarone or sotalol. There was a significant reduction in mortality over 18 months of follow-up favoring the device (24%

vs 16% for ICD vs placebo). The number needed to treat to prevent one death over 2 years was 12 patients and the cost per life-year saved by an ICD was estimated at US\$66 677 in 2002.¹⁶ Based on these trials, the 2005 Canadian Cardiovascular Society/Canadian Heart Rhythm Society guidelines¹⁷ and the more recent 2008 American College of Cardiology/American Heart Association/Heart Rhythm Society guidelines¹⁸ give their strongest level of support for ICD use in these groups. It is important to note that patients with potentially reversible causes of their VT or VF were excluded from these trials.

A less clear-cut situation arises when a patient who is at high risk for ventricular arrhythmias, usually because of an impaired left ventricular ejection fraction (EF), presents with syncope of unknown cause. Here, an electrophysiology study can be of value in deciding which patients might benefit from an ICD. If sustained VT or VF is induced during the study, implantation of an ICD should be considered.¹⁵

Less commonly, patients present with sustained VT but have no evidence of structural heart disease on evaluation. An ICD should be strongly considered in this population, particularly if the VT is associated with severe symptoms (pre-syncope, angina, or heart failure). However, some individuals with better-tolerated VT may be amenable to antiarrhythmic therapy or to ablation without the need for an ICD.¹⁹

The recommendations for ICD use for secondary prevention are presented in **Table 1**.

ICDs for primary prevention

The issue of which patients should receive an ICD for the primary prevention of SCD is considerably more

complex. Implantation is not without risk, including inappropriate shocks, device recall or malfunction, and increased hospitalization. Devices also remain expensive and require long-term follow-up at specialized centres experienced in their management. Considerable research has therefore centred on attempting to identify patients at highest risk for SCD and cases where the potential benefits of ICD use outweigh the risks and the cost.

The most important risk factor for SCD in the primary prevention population is an impaired left ventricular EF, with the risk of VT and VF increasing markedly as the EF drops below 30% to 35%.²⁰ The risk of SCD is also dependent on the cause of the reduced ejection fraction. Patients with ischemic heart disease due to a previous MI or severe coronary artery disease are at greater risk than those with non-ischemic cardiomyopathies.

The major clinical trials of ICDs for primary prevention in patients with ischemic heart disease and low EF were almost uniformly positive, with relative reductions of overall mortality of 30% to 50% at over 2 years of follow-up.²¹⁻²³ The majority of benefit was seen in patients with ejection fractions less than 30%. In the SCD-HeFT trial of patients with EF less than 30%, the number needed to treat to save one life over almost 4 years of follow-up was 14 patients,²⁴ and the cost per quality-adjusted life-year saved by an ICD has ranged between US\$34 000 and US\$70 200.²⁵ Certain patients with ejection fractions between 30% and 35% also appeared to benefit in some trials, but only if they had other high-risk markers of either nonsustained VT on monitoring or inducible VT or VF.^{21,23} These findings form the basis of the recommendations for ICD implantation in the ischemic heart disease population.

Importantly, most of these trials enrolled patients at least 1 month after MI in an effort to exclude any patient whose ejection fraction was likely to improve with recovery of stunned myocardium. In fact, implantation of an ICD immediately after MI in those with depressed ejection fractions conferred no benefit in two recent trials.^{26,27} Similarly, EF can improve significantly after coronary artery bypass grafting (CABG), thereby reducing the risk of SCD. Routine implantation of ICDs at the time of surgery conferred no benefit to patients with EF less than 35% in the CABG-PATCH trial.²⁸ Therefore, any consideration for an ICD should be delayed until 1 to 3 months after surgery.

The trials of ICD for primary prevention in patients with nonischemic cardiomyopathies were less conclusive. The two earliest trials showed no benefit with ICD use, but they were small and likely underpowered.^{29,30} Two larger subsequent trials showed a reduction in SCD and overall mortality, albeit a smaller reduction than that seen in the ischemic heart disease population.^{24,31} Again, those with ejection fractions less than 30% were most likely to benefit.

Some patients with recently diagnosed nonischemic cardiomyopathy will be expected to have significant recovery of their EF with medical therapy. Therefore, it is recommended that these patients be on maximal medical therapy for at least 9 months before assessing their candidacy for an ICD.

There is also a role for ICDs in the primary prevention of SCD in patients who have preserved ejection fractions but conditions that predispose them to ventricular arrhythmias (such as hypertrophic cardiomyopathy, long QT syndrome, arrhythmogenic right ventricular cardiomyopathy, or Brugada syndrome). An evaluation by

Table 1. Who should receive an ICD* for secondary prevention?

Patient category	Remarks
Should definitely receive an ICD	
Survivors of cardiac arrest due to VF or hemodynamically unstable VT	This excludes patients with a transient or reversible cause, including <ul style="list-style-type: none"> • Recent acute MI (within 48 hours) • Drug use • Electrolyte abnormalities
Patients with known structural heart disease and sustained VT	Ablation may be an alternative in some patients
Patients with syncope of uncertain origin but inducible VF or hemodynamically significant VT at EPS	EPS can be especially helpful in evaluating syncope in patients with structural heart disease
Should be strongly considered for an ICD	
Patients with no structural heart disease but sustained VT	Treatment with pharmacotherapy or ablation may be more appropriate initial therapy

* See box for abbreviations used in table

Table 2. Who should receive an ICD* for primary prevention?

Patient category	Remarks
Should definitely receive an ICD	
Patients with ischemic heart disease and EF ≤ 30%	Must be at least <ul style="list-style-type: none"> • 1 month since MI • 3 months since revascularization (CABG or PCI)
Should be strongly considered for an ICD	
Patients with nonischemic cardiomyopathy and EF ≤ 30%	Should be NYHA class II or III (little evidence of benefit in NYHA class I)
Patients with ischemic heart disease and EF 31%–35% with inducible VT/VF at EPS	Must be at least <ul style="list-style-type: none"> • 1 month since MI • 3 months since revascularization (CABG or PCI)
Patients with inherited or acquired conditions predisposing them to ventricular arrhythmias with high-risk features	Including (but not exclusive to) HCM, Brugada syndrome, long QT syndrome, and ARVC
May be considered for an ICD	
Patients with ischemic heart disease and EF 31%–35% without inducible VT/VF at EPS	An EPS is useful in risk stratifying patients with ischemic heart disease and EF 31%–35%
Patients with nonischemic cardiomyopathy and EF 31%–35%	Should be NYHA class II or III

* See box for abbreviations used in table

an electrophysiologist is essential for identifying high-risk patients who would benefit from an ICD.

The recommendations for ICD use for primary prevention of SCD are summarized in **Table 2**. The Canadian and American guidelines differ somewhat in their recommendations and we have emphasized the Canadian recommendations where conflicts arise.^{17,18}

Abbreviations

- ARVC: arrhythmogenic right ventricular cardiomyopathy
- CABG: coronary artery bypass grafting
- CHF: congestive heart failure
- EF: ejection fraction
- EPS: electrophysiology study
- HCM: hypertrophic cardiomyopathy
- ICD: implantable cardioverter-defibrillator
- MI: myocardial infarction
- NYHA: New York Heart Association
- PCI: percutaneous coronary intervention
- VF: ventricular fibrillation
- VT: ventricular tachycardia

When not to implant

As well as knowing who might benefit from ICD therapy, it is important for treating physicians to know who is not an appropriate candidate (see **Table 3**). Patients with VT or VF due to reversible causes should not receive an ICD. This includes patients with VT or VF within the first 48 hours of an acute MI due to electrolyte abnormalities or due to the effects of drug use or intoxication. Patients with incessant VT or VF are also not candidates for an ICD until their arrhythmia is brought under control with antiarrhythmic or ablation therapies. Severe psychiatric conditions are also relative contraindications for an ICD, especially if follow-up will be difficult or if ICD discharges would exacerbate the psychiatric condition. Patients with severe symptomatic heart failure (NYHA class IV) or with frequent hospitalizations are more likely to die from cardiac pump failure than VT or VF and should not have an ICD implanted unless their clinical status improves.³² Similarly, patients whose life expectancy is less than 1 year due to cardiac or noncardiac disease are not likely to survive to benefit from an ICD.

Summary

Sudden cardiac death remains an important public health problem today.

The most important risk factor for SCD in the primary prevention population is an impaired left ventricular EF, with the risk of VT and VF increasing markedly as the EF drops below 30% to 35%.

Thanks to the pioneering work of Michel Mirowski and colleagues, patients at high risk for SCD can be treated effectively with an ICD. Increasing physician awareness in British Columbia regarding the appropriate indications for device implantation will enhance the delivery of this potentially lifesaving therapy to those patients who need it most.

Competing interests

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References

1. Kouwenhoven WB, Jude JR, Knickerbocker GG. Closed-chest cardiac massage. *JAMA* 1960;173:1064-1067.

2. Lee TH, Goldman L. The coronary care unit turns 25: Historical trends and future directions. *Ann Intern Med* 1988;108: 887-894.
3. Lown B, Fakhro AM, Hood WB Jr, et al. The coronary care unit. New perspectives and directions. *JAMA* 1967;199: 188-198.
4. Kastor JA. Michel Mirowski and the automatic implantable defibrillator. *Am J Cardiol* 1989;63:977-982 contd.
5. Kannel WB, Doyle JT, McNamara PM, et al. Precursors of sudden coronary death. Factors related to the incidence of sudden death. *Circulation* 1975;51:606-613.
6. Gillum RF. Sudden coronary death in the United States: 1980-1985. *Circulation* 1989;79:756-765.
7. Mendeloff AI. Michel Mirowski and the Department of Medicine at the Sinai Hospital of Baltimore. *Pacing Clin Electrophysiol* 1991;14(5 Pt 2):873-874.

Table 3. Who should not be considered for ICD* therapy?

Patients with VT/VF with a reversible cause
Patients with incessant VT/VF
Patients not expected to survive for at least 1 year
Patients with severely symptomatic CHF <ul style="list-style-type: none"> • Symptoms at rest (NYHA class IV) or • Multiple hospitalizations
Patients with severe psychiatric illness where <ul style="list-style-type: none"> • ICD implantation would aggravate the illness/symptoms or • ICD follow-up would be compromised

Abbreviations

ARVC: arrhythmogenic right ventricular cardiomyopathy
 CABG: coronary artery bypass grafting
 CHF: congestive heart failure
 EF: ejection fraction
 EPS: electrophysiology study
 HCM: hypertrophic cardiomyopathy
 ICD: implantable cardioverter-defibrillator
 MI: myocardial infarction
 NYHA: New York Heart Association
 PCI: percutaneous coronary intervention
 VF: ventricular fibrillation
 VT: ventricular tachycardia

* See box for abbreviations used in table

8. Mower MM. Building the AICD with Michel Mirowski. *Pacing Clin Electrophysiol* 1991;14(5 Pt 2):928-934.
9. Kastor JA. Michel Mirowski and the automatic implantable defibrillator. *Am J Cardiol* 1989;63:1121-1126.
10. Mirowski M, Mower MM, Staewen WS, et al. Standby automatic defibrillator. An approach to prevention of sudden coronary death. *Arch Intern Med* 1970;126:158-161.
11. Mirowski M, Reid PR, Mower MM, et al. Termination of malignant ventricular arrhythmias with an implanted automatic defibrillator in human beings. *N Engl J Med* 1980;303:322-324.
12. Birnie DH, Sambell C, Johansen H, et al. Use of implantable cardioverter defibrillators in Canadian and US survivors of out-of-hospital cardiac arrest. *CMAJ* 2007;177:41-46.
13. Kuck KH, Cappato R, Siebels J, et al. Randomized comparison of antiarrhythmic drug therapy with implantable defibrillators in patients resuscitated from cardiac arrest: The Cardiac Arrest Study Hamburg (CASH). *Circulation* 2000;102:748-754.
14. The Antiarrhythmics Versus Implantable Defibrillators (AVID) Investigators. A comparison of antiarrhythmic-drug therapy with implantable defibrillators in patients resuscitated from near-fatal ventricular arrhythmias. *N Engl J Med* 1997;337:1576-1583.
15. Connolly SJ, Gent M, Roberts RS, et al. Canadian implantable defibrillator study (CIDS): A randomized trial of the implantable cardioverter defibrillator against amiodarone. *Circulation* 2000;101:1297-1302.
16. Larsen G, Hallstrom A, McAnulty J, et al. Cost-effectiveness of the implantable cardioverter-defibrillator versus antiarrhythmic drugs in survivors of serious ventricular tachyarrhythmias: Results of the Antiarrhythmics Versus Implantable Defibrillators (AVID) economic analysis substudy. *Circulation* 2002;105:2049-2057.
17. Tang AS, Ross H, Simpson CS, et al. Canadian Cardiovascular Society/Canadian Heart Rhythm Society position paper on implantable cardioverter defibrillator use in Canada. *Can J Cardiol* 2005;21(suppl A):11A-18A.
18. Epstein AE, DiMarco JP, Ellenbogen KA, et al. ACC/AHA/HRS 2008 Guidelines for Device-Based Therapy of Cardiac Rhythm Abnormalities: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the ACC/AHA/NASPE 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices) developed in collaboration with the American Association for Thoracic Surgery and Society of Thoracic Surgeons. *J Am Coll Cardiol* 2008;51:e1-62.
19. Simpson CS, O'Neill BJ, Sholdice MM, et al. Canadian Cardiovascular Society commentary on implantable cardioverter defibrillators in Canada: Waiting times and access to care issues. *Can J Cardiol* 2005;21(suppl A):19A-24A.
20. Burns RJ, Gibbons RJ, Yi Q, et al. The relationships of left ventricular ejection fraction, end-systolic volume index and infarct size to six-month mortality after hospital discharge following myocardial infarction treated by thrombolysis. *J Am Coll Cardiol* 2002;39:30-36.
21. Buxton AE, Lee KL, Fisher JD, et al. A randomized study of the prevention of sudden death in patients with coronary artery disease. Multicenter Unsustained Tachycardia Trial Investigators. *N Engl J Med* 1999;341:1882-1890.
22. Moss AJ, Zareba W, Hall WJ, et al. Prophylactic implantation of a defibrillator in patients with myocardial infarction and reduced ejection fraction. *N Engl J Med* 2002;346:877-883.
23. Moss AJ, Hall WJ, Cannom DS, et al. Improved survival with an implanted defibrillator in patients with coronary disease at high risk for ventricular arrhythmia. Multicenter Automatic Defibrillator Implantation Trial Investigators. *N Engl J Med* 1996;335:1933-1940.
24. Bardy GH, Lee KL, Mark DB, et al. Amiodarone or an implantable cardioverter-defibrillator for congestive heart failure. *N Engl J Med* 2005;352:225-237.
25. Sanders GD, Hlatky MA, Owens DK. Cost-effectiveness of implantable cardioverter-defibrillators. *N Engl J Med* 2005;353:1471-1480.
26. Hohnloser SH, Kuck KH, Dorian P, et al. Prophylactic use of an implantable cardioverter-defibrillator after acute myocardial infarction. *N Engl J Med* 2004;351:2481-2488.
27. Steinbeck G, Andresen D, Seidl K, et al. Defibrillator implantation early after myocardial infarction. *N Engl J Med* 2009;361:1427-1436.
28. Bigger JT Jr. Prophylactic use of implanted cardiac defibrillators in patients at high risk for ventricular arrhythmias after coronary-artery bypass graft surgery. Coronary Artery Bypass Graft (CABG) Patch Trial Investigators. *N Engl J Med* 1997;337:1569-1575.
29. Strickberger SA, Hummel JD, Bartlett TG, et al. Amiodarone versus implantable cardioverter-defibrillator: Randomized trial in patients with nonischemic dilated cardiomyopathy and asymptomatic nonsustained ventricular tachycardia—AMIOVIRT. *J Am Coll Cardiol* 2003;41:1707-1712.
30. Bansch D, Antz M, Boczor S, et al. Primary prevention of sudden cardiac death in idiopathic dilated cardiomyopathy: The Cardiomyopathy Trial (CAT). *Circulation* 2002;105:1453-1458.
31. Kadish A, Dyer A, Daubert JP, et al. Prophylactic defibrillator implantation in patients with nonischemic dilated cardiomyopathy. *N Engl J Med* 2004;350:2151-2158.
32. Setoguchi S, Nohria A, Rassen JA, et al. Maximum potential benefit of implantable defibrillators in preventing sudden death after hospital admission because of heart failure. *CMAJ* 2009;180:611-616. **BWMJ**