Canadian Cardiovascular Society/Canadian Heart Rhythm Society 2016 Implantable Cardioverter-Defibrillator Guidelines

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ABSTRACT
Sudden cardiac death is a major public health issue in Canada. However, despite the overwhelming evidence to support the use of implantable cardioverter defibrillators (ICDs) in the prevention of cardiac death there remains significant variability in implantation rates across Canada. Since the most recent Canadian Cardiovascular Society position statement on ICD use in Canada in 2005, there has been a plethora of new scientific information to assist physicians in their discussions with patients considered for ICD implantation to prevent sudden cardiac death due to ventricular arrhythmias. We have reviewed, critically appraised, and synthesized the pertinent evidence to develop recommendations regarding: (1) ICD implantation in the primary and secondary prevention of sudden cardiac death in patients with and without ischemic heart disease; (2) when it is reasonable to discuss with patients considered for ICD implantation to prevent sudden cardiac death due to ventricular arrhythmias. We have reviewed, critically appraised, and synthesized the pertinent evidence to develop recommendations regarding: (1) ICD implantation in the primary and secondary prevention of sudden cardiac death in patients with and without ischemic heart disease; (2) when it is reasonable to discuss with patients considered for ICD implantation to prevent sudden cardiac death due to ventricular arrhythmias. We have reviewed, critically appraised, and synthesized the pertinent evidence to develop recommendations regarding: (1) ICD implantation in the primary and secondary prevention of sudden cardiac death in patients with and without ischemic heart disease; (2) when it is reasonable to discuss with patients considered for ICD implantation to prevent sudden cardiac death due to ventricular arrhythmias.

RESUMÉ
La mort subite d’origine cardiaque constitue un important problème de santé publique au Canada. Cependant, en dépit des importantes preuves appuyant le recours aux défibrillateurs cardioverteurs implantables (DCI) pour prévenir ce type de décès, le taux d’implantation de ces dispositifs demeure très variable à l’échelle nationale. Depuis le dernier énoncé de position de la Société canadienne de cardiologie en 2005 concernant l’usage des DCI au pays, une pléthore de nouvelles données scientifiques se sont ajoutées pour aider les médecins à aborder avec leurs patients la question du DCI pour prévenir la mort subite d’origine cardiaque causée par l’arythmie ventriculaire. Nous avons procédé à la revue, à l’évaluation critique et à la synthèse des données pertinentes afin de formuler des recommandations concernant : 1) l’implantation d’un DCI dans la prévention primaire et...
ICD implantation to prevent SCD due to ventricular arrhythmias.

The intended audience for these guidelines includes specialist and generalist physicians and surgeons, medical trainees, allied professionals, and administrators involved in the care of patients who present with or are at risk of malignant ventricular arrhythmias.

These guidelines were developed through a critical evaluation of the existing literature, expert consensus, and use of the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system. The strength of the evidence was weighed, with full consideration for any risks of bias, including publication bias and any imprecision, inconsistency, and indirectness of the available data. The strength of each recommendation was categorized as “strong” or “weak (conditional),” and the quality of evidence as “high,” “moderate,” “low,” or “very low.” Valid systematic methods were used when possible, on the basis of published evidence similar to previous guidelines. These guidelines were externally reviewed by experts and modified, on the basis of those reviews.

We have intentionally not addressed specific populations that are not well represented in clinical trials and have been discussed by the Canadian Heart Rhythm Society (CHRS) and/or CCS or Heart Rhythm Society, in particular for ICD leads; (6) the role of subcutaneous ICDs; and (7) ICD implantation infection prevention strategies. We expect that this document, in combination with the companion article that addresses the implementation of these guidelines, will assist all medical professionals with the care of patients who have had or at risk of sudden cardiac death.

Secondary to the mortality of ICD therapy is the occurrence of adverse events such as device-related complications, lead dislodgement, and arrhythmia therapies.

**Patient Selection**

**Risk assessment of SCD**

Standard criteria for assessing the risk of ventricular tachycardia (VT)/ventricular fibrillation (VF) include left ventricular ejection fraction (LVEF) and the presence of reversible/treatable causes of VF or certain specific diseases (eg, hypertrophic cardiomyopathy, cardiac sarcoidosis); these are the cornerstones of indications for an ICD. Additional factors that have been associated with a higher risk of VT/VF include an elevated heart rate, frequent premature ventricular complexes or nonsustained VT, a myocardial aneurysm or extensive scarring, and prolonged QRS duration on the electrocardiogram.

Additionally, newer noninvasive predictors for SCD, such as estimates of autonomic function and cardiac repolarization that include heart rate variability, baroreflex sensitivity, heart rate turbulence, and microvolt T-wave alternans, along with neurohormonal markers such as B-type natriuretic peptide. Although ongoing research is investigating the utility of these tools to guide ICD therapy, they are not presently used for this purpose in clinical practice because of their lack of predictive value in individuals and a lack of evidence that their use alters clinical outcome.

**Ischemic cardiomyopathy.** The ability of an ICD to reduce the risk of death in patients with chronic ischemic cardiomyopathy, mostly a previous myocardial infarction (MI), is well established. Several large randomized trials, the first Multicenter Automatic Defibrillator Implantation Trial (MADIT), the Multicenter UnSustained Tachycardia Trial (MUSTT), the second Multicenter Automatic Defibrillator Implantation Trial (MADIT-II), and the Sudden Cardiac Death in Heart Failure Trial (SCD-HeFT), have shown a reduction in total mortality with ICD implantation in addition to optimal medical therapy (OMT) in patients with a remote MI and a reduced LVEF. The MADIT-II study, which included patients with an LVEF ≤ 30%, at least 1 month after MI, reported a 5.6% (14.2% vs 19.8%; P = 0.016) reduction in mortality over 20 months of average follow-up, with an ICD vs OMT alone. The MADIT study included patients with LVEF up to 35%, and the MUSTT trial included patients with LVEF up to 40% and only included patients with spontaneous, nonsustained VT before enrollment and VT or VF induction at electrophysiology study (EPS). ICD use was not randomized in the MUSTT study. Both trials showed a decrease in mortality in patients treated with an ICD (MADIT: 15.8% vs 38.6%; P = 0.009; MUSTT: 21.7% vs 44.8%; P < 0.001). SCD-HeFT included ischemic and nonischemic patients with an LVEF ≤ 35%. The ischemic...
Nonischemic cardiomyopathy. The data for ICD benefit in nonischemic cardiomyopathy (NICM) is less clear-cut. Before the widespread use of OMT for heart failure, the 5-year mortality for NICM was estimated to be 50%. Observational studies suggest that up to 30% of these deaths are sudden.\textsuperscript{10,15} Five randomized studies have evaluated the use of ICDs in patients with NICM. The Amiodarone Versus Implantable Cardioverter-Defibrillator (AMIOVIRT) trial and Cardiomyopathy Trial (CAT) did not show benefit from ICD therapy but were small and likely underpowered to do so.\textsuperscript{16,17} Two large, older trials, the SCD-HeFT and the Defibrillators in Nonischemic Cardiomyopathy Treatment Evaluation (DEFINITE) trials, showed a decrease in arrhythmia-related death associated with ICD use.\textsuperscript{10,11,15,18}

The DEFINITE trial randomized patients with NICM, New York Heart Association (NYHA) class I-III limitation, an LVEF ≤ 35%, and more than 10 premature ventricular complexes per hour or nonsustained VT to OMT alone or OMT with an ICD. Although the primary end point of all-cause mortality was not significantly different in the 2 groups (OMT with ICD 7.9% vs OMT alone 14.1%; \( P = 0.08 \)), the risk of SCD was significantly lower in the ICD group (OMT with ICD 1.3% vs OMT alone 6.1%; \( P = 0.006 \)). The large, more recent Defibrillator Implantation in Patients With Nonischemic Systolic Heart Failure (DANISH) trial enrolled 1116 patients to either ICD or usual therapy with OMT and cardiac resynchronization therapy (CRT) if indicated.\textsuperscript{19} Again, there was no difference in overall mortality (relative risk [RR], 0.87 for ICD vs control; \( P = 0.28 \)), however, SCD was significantly decreased by 50% (\( P = 0.005 \)). Subgroup analysis suggested an overall mortality benefit to patients younger than age 68 years (RR, 0.64; \( P = 0.01 \)). This study differed from the earlier studies with extensive CRT use in both arms (58% in DANISH vs 0% in SCD-HeFT and DEFINITE) and the use of mineralocorticoid antagonists in 58%. It is possible that these more advanced therapies could have tempered the benefit of ICDs in these patients. With the exception of the DEFINITE trial, ICD therapy in primary prophylaxis in NICM has not generally included patients with NYHA functional class I limitation; therefore, the efficacy of ICDs in this population is less certain.

Figure 1. Aid in decision-making for primary prevention ICD. ICD, implantable cardioverter defibrillator; LVEF, left ventricular ejection fraction; MI, myocardial infarction; OMT, optimal medical therapy.
One important aspect of ICD therapy in the NICM population is the appropriate timing for ICD implantation and trying to predict which patient’s LVEF might recover. Although the CAT study showed no benefit to ICD implantation in patients with NICM within 9 months of diagnosis, it included only 10% of the originally planned patients and was underpowered to show a difference. In the DEFINITE study the average duration of NICM before randomization was almost 3 years. In a subanalysis in which outcomes from duration of NICM diagnosis vs ICD implantation were compared similar risk reduction with ICD therapy was reported when patients were stratified by ≤ 3 vs > 3 months or ≤ 9 vs > 9 months. Similarly, a single-centre study of patients with NICM implanted with an ICD reported similar rates of appropriate ICD therapies in patients diagnosed at < 9 (27%) vs ≥ 9 months (27%).

A significant proportion of patients with newly diagnosed NICM will have improvement in their LVEF with OMT and are unlikely to derive benefit from an ICD implantation. Thus, an ICD is not recommended within the first 3 months after the initial NICM diagnosis unless other potential reasons for ICD implantation are present (indication for pacing, sustained or hemodynamically significant ventricular arrhythmia, and syncope likely due to a ventricular tachyarrhythmia).

Optimal medical management of these patients is crucial; for details, we refer readers to recent CCS guidelines.

**RECOMMENDATION**

1. We recommend that patients with persistent left ventricular dysfunction due to either ischemic or NICM and ejection fraction ≤ 30% receive an ICD, when persistent refers to at least 3 months of OMT in all patients and, in patients with ischemic heart disease, at least 3 months after revascularization and at least 40 days after an MI (Strong Recommendation; High-Quality Evidence).

2. We suggest an ICD be considered for patients with persistent left ventricular dysfunction due to either ischemic or NICM and ejection fraction 31%-35% when persistent refers to at least 3 months of OMT in all patients and, in patients with ischemic heart disease, at least 3 months after revascularization and at least 40 days after an MI (Weak Recommendation; Moderate-Quality Evidence).

3. We recommend that patients likely to have left ventricular dysfunction 3 months after revascularization for MI or 40 days after MI without revascularization or 3 months following OMT in NICM undergo an assessment of ejection fraction at those time points (Strong Recommendation; Low-Quality Evidence).

**Practical tip.** Because the LVEF might worsen in the first 3 months after an MI, we recommend repeat assessment of LVEF (40 days or 3 months after MI depending on the clinical circumstances) for patients with an ejection fraction ≤ 45% at the time of or immediately after an MI. The method of ejection fraction assessment depends on local expertise and the reliability and accuracy of available assessment methods.

**RECOMMENDATION**

4. We suggest that an ICD be considered in patients with an acute indication for cardiac pacing within 3 months after revascularization or 40 days of MI and before achieving OMT when there is a high probability that the ejection fraction will remain < 35% (Weak Recommendation; Low-Quality Evidence). (OMT refers to evidenced-based heart failure therapies at their maximally tolerated doses.)

**Practical tip.** There is a high probability that the ejection fraction will remain < 35% if there is a high burden of scar on magnetic resonance imaging, minimal myocardial viability, the ejection fraction is significantly low despite a minor biomarker level increase at the time of an MI, or when revascularization addressed only a small amount of myocardium.

**Prediction of the degree of benefit from ICD implantation**

The benefit of an ICD is highly dependent on a patient’s individual risk of death due to ventricular arrhythmias, death due to other causes, and the acute and chronic complications of an ICD. It is important to consider that there is risk to ICD implantation, including periprocedural risks, inappropriate shocks, and device infection. The level of risk is known to be higher in patients who are frail or have significant comorbidities (eg, chronic kidney disease).

**Age.** As people age, they are increasingly more likely to develop diseases that put them at risk for SCD and, as such, be considered for an ICD. So too, they are more likely to become frail and develop comorbidities that reduce their life expectancy from nonsudden death and limit the benefit from an ICD. At present, health care providers face the dilemma of whether the outcomes achieved by ICDs in younger and fit people enrolled in clinical trials can be generalized to older or frail patients. A meta-analysis on the survival benefit of primary prevention ICDs in older patients, using pooled data from 5 randomized clinical trials reported an attenuated benefit in patients older than 75 years of age because of competing causes of death. There are limited clinical trial data, because there were fewer than 400 patients eligible for analysis in this age group.

Age alone should not be a deterrent to ICD implantation because, although older patients (older than 75 years) exhibit higher mortality and complications after ICD implantation, they still receive similar rates of appropriate therapies and derive a significant mortality benefit.

**Sex differences in ICD therapy and complication rates.** The results of studies that examined the effect of sex on the rate of appropriate ICD therapies and the effect of ICDs on mortality have been conflicting. Subgroup analyses performed on data from the MUSTT and MADIT-II trials suggested that there was no sex difference in mortality, whereas analysis from SCD-HeFT reported a statistically significant improvement in mortality for men only. Further subgroup analyses, meta-analyses, and a number of
population-based studies have also shown discrepant effects of sex on ICD benefit in primary and/or secondary prevention populations. Whereas some studies reported an increased incidence of appropriate therapy in men, others suggest that sex has no effect on the likelihood of appropriate therapy. With relatively low numbers of women in these trials (8%-32%) and registries, many studies were not powered to detect a mortality benefit in women. The National Cardiovascular Data Registry (NCDR) ICD Registry reported that women had a higher rate of peri-procedural complications than men (7.2% vs 4.8%); 95% confidence interval [CI], 1.25-1.53; \( P < 0.001 \). Using the available data, we conclude that women and men have similar benefit from ICDs, particularly at an older age. However, women appear to have an increased rate of device-related complications.

Comorbidity. Comorbidities can increase the risk of SCD and, as such, the derived benefit of an ICD, and also increase the risk of nonarrhythmic death resulting in lesser benefit. Those shown to increase nonarrhythmic death in ICD recipients are diuretic use, older age, increased NYHA class, hypertension, atrial fibrillation, increased QRS duration, LVEF < 30%, nonprescription use of a β-blocker, reduced heart rate variability, low serum sodium, chronic lung disease, peripheral vascular disease, diabetes, and chronic kidney disease. These must be balanced with the factors that increase the risk of SCD such as reduced LVEF, increased NYHA class, and inducible VT.

Use of risk scores to assist with decision-making. Many risk scores have been developed that combine individual markers in an attempt to provide greater ability to discriminate those who would from those who would not benefit from an ICD. The ideal risk score that would assist with decision-making in a potential ICD recipient would identify patients with high risk of nonarrhythmic death and those with a very low risk of arrhythmic death. In both of these groups the benefit from ICD would be limited.

There have been risk scores derived to predict mortality in the chronic heart failure population and in populations eligible for primary prevention ICD therapy. The scores with some validation and most frequently cited include the Seattle Heart Failure Model, and the SHOCKED, and MADIT risk scores. All have modest predictive abilities. In one study of patients in a heart function clinic, the Charlson Comorbidity Index (CCI) (Table 1) was potently associated with SC death, and had an even stronger association with nonsudden death, as the index increased. The CCI, as well as other measures of comorbidity and frailty, have the advantage of being easily derived at the bedside.

Frailty. There are many methods of estimating frailty. Table 2 shows a global assessment tool in which the clinician makes a gestalt judgement about the patient’s frailty on the basis of a 7-point ordinal scale. This method shows predictive validity for estimating outcomes such as death and institutionalization that is comparable with other methods, and is feasible in a clinical setting.

<table>
<thead>
<tr>
<th>Table 1. List of comorbidities to consider in assessment of ICD benefit</th>
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<tr>
<td><strong>Components of Charlson Comorbidity Index:</strong> myocardial infarction, congestive heart failure, peripheral vascular disease, dementia, chronic pulmonary disease, connective tissue disease, peptic ulcer disease, liver disease, diabetes, hemiplegia, renal disease, leukemia/lymphoma, metastatic tumour</td>
</tr>
<tr>
<td><strong>Age</strong></td>
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<tr>
<td><strong>Atrial fibrillation</strong></td>
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<tr>
<td><strong>New York Heart Association class</strong></td>
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<td><strong>Serum sodium</strong></td>
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<td><strong>Heart Rate Variability</strong></td>
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<td><strong>ICD, implantable cardioverter defibrillator.</strong></td>
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long-term, limited generalizability, assessment of only quantity and not quality of life, and that the studies from which these scores were derived assessed risk as a static, not dynamic variable. However, estimating the ICD benefit using risk scores promotes honest communication and evidence-based decision-making between patients and physicians to achieve the most appropriate therapy that is consistent with the patient’s values and preferences regarding their quantity and quality of life.

How should we use risk scores? Inclusion of appropriate risk scoring should be encouraged as part of the assessment not only before implantation but also at the time of replacement. This could improve recognition of patients likely to benefit and those at very high risk of mortality despite ICD therapy who likely will not benefit or might forgo ICD therapy on the basis of personal values.

Physicians should use a combination of a statistical predictive model and clinical impression including a multidisciplinary approach (heart failure clinics, primary care physician, geriatric evaluation) to guide the appropriate discussion with the patient and family about the absolute risk reduction in the overall context of life expectancy and quality of life of each ICD candidate.

Because of the very dynamic status of some patients, one should not hesitate to delay decisions regarding device implantation or replacement to reassess their appropriateness. Risk scores are tools to improve assessment and inform discussion and should complement, not supplant, clinical expertise.

**RECOMMENDATION**

5. We recommend that an ICD not be offered to patients in whom comorbidities make it unlikely that an ICD will substantially increase a patient’s life expectancy (Strong Recommendation; Moderate-Quality Evidence).

6. We recommend that an ICD be replaced by a pacing system, removed, or abandoned at the time of ICD generator end of life/service in patients with life-threatening comorbidities, at the request of the patient, or when an ICD is unlikely to increase life expectancy (Strong Recommendation; Low-Quality Evidence).

**Practical tip.** Validated risk calculators/risk assessment tools such as the CCI, the Seattle Heart Failure Model, or the SHOCKED or MADIT risk scores can be of aid in the
estimation of each patient’s benefit/risk of an ICD implantation.

Secondary prevention

The basis for ICD use in secondary prevention assumes the exclusion of all reversible causes (Fig. 2). Three randomized trials have studied ICD use vs antiarrhythmic drug therapy (mainly amiodarone) in patients after cardiac arrest in the absence of a reversible cause (Antiarrhythmics Versus Implantable Defibrillators [AVID], Canadian Implantable Defibrillator Study [CIDS], Cardiac Arrest Study Hamburg [CASH]). A meta-analysis that included these 3 trials showed a 28% reduction in the relative risk of death with an ICD that is almost entirely due to a 50% reduction in arrhythmic death. Most of the benefit was seen in the population with an LVEF ≤ 35%.50

**Table 2. Frailty scale**

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
<th>Details</th>
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<tbody>
<tr>
<td>1</td>
<td>Very fit</td>
<td>Robust, active energetic, well-motivated, and fit. Commonly exercise regularly</td>
</tr>
<tr>
<td>2</td>
<td>Well</td>
<td>Without active disease but less fit than category 1</td>
</tr>
<tr>
<td>3</td>
<td>Well with treated comorbid disease</td>
<td>Disease symptoms are well controlled compared with those in category 4</td>
</tr>
<tr>
<td>4</td>
<td>Apparently vulnerable</td>
<td>Although not frankly dependent, commonly complain of being slowed or have disease symptoms</td>
</tr>
<tr>
<td>5</td>
<td>Mildly frail</td>
<td>Limited dependence on others for instrumental activities of daily living</td>
</tr>
<tr>
<td>6</td>
<td>Moderately frail</td>
<td>Help is needed with activities and instrumental activities of daily living</td>
</tr>
<tr>
<td>7</td>
<td>Severely frail</td>
<td>Completely dependent, or terminally ill</td>
</tr>
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</table>

**RECOMMENDATION**

7. We recommend use of an ICD for patients after cardiac arrest due to ventricular arrhythmias in the absence of a reversible cause (Strong Recommendation; High-Quality Evidence).

8. We suggest an ICD be considered after MI in the presence of sustained VT or VF > 48 hours after MI or > 48 hours after revascularization for MI in the absence of reversible causes (Weak Recommendation; Low-Quality Evidence). (Sustained VT refers to hemodynamically significant VT or VT > 30 seconds in duration.)

9. We recommend an ICD for patients with sustained VT in the presence of significant structural heart disease in the absence of reversible causes (Strong Recommendation; Moderate-Quality Evidence).

Significant structural heart disease pertains to conditions in which the risk of cardiac arrest in the presence of VT is high. These are conditions such as infiltrative cardiomyopathies or those associated with a reduced LVEF. This does not pertain to conditions in which the risk of cardiac arrest is low such as atrial septal defect, most valvulopathies, and atiopathies. Syncope of unknown origin that prompts consideration for an ICD should be symptomatically consistent with that due to a ventricular arrhythmia, associated with significant structural heart disease, and not due to a specific nontachyarrhythmic cause like vasovagal syncope. EPS should only be considered in conditions in which its result is known to be predictive (this pertains primarily to patients with ischemic heart disease). Furthermore, the VT induced during an EPS that prompts consideration of an ICD is not idiopathic VT in which ablation or medical therapy has a high efficacy of eliminating or suppressing the VT such as outflow tract VT, fascicular VT, or bundle branch reentry VT.

Table 3 shows a summary to help in decision-making for ICD implantation.

10. We suggest an ICD be considered in patients with significant structural heart disease and syncope of unknown origin for whom the cause of syncope is most likely VT/VF and in whom the risk of recurrent VT/VF is high (Weak Recommendation; Moderate-Quality Evidence).

11. We recommend an ICD for patients with syncope of unknown origin with inducible VT at the time of EPS and structural heart disease (Strong Recommendation; Moderate-Quality Evidence).

**Practical tip.** All patients with a history of VT or VF should undergo evaluation for reversible causes of ventricular arrhythmias. Depending on the clinical circumstances this will likely include, but not be limited to, evaluation for coronary artery anomalies, ischemia, or acute MI immediately preceding the arrhythmic arrest (angiogram or computed tomography coronary angiogram), structural heart disease (echocardiography, magnetic resonance imaging, or positron emission tomography), or risk of recurrent arrhythmias (electrophysiology testing).
Table 3. Checklist to help the clinician prescribe ICDs in various clinical contexts

<table>
<thead>
<tr>
<th>ICD implantation checklist (all indications)</th>
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<tbody>
<tr>
<td>□ ICD therapies and implantation wished by the patient and consistent with the patient’s goals of care</td>
<td></td>
</tr>
<tr>
<td>□ After an assessment of comorbidities, an ICD is expected to substantially increase the patient’s life expectancy</td>
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</tr>
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</table>

ICD implantation checklist (primary prevention)

| □ The left ventricular ejection fraction remains \( \leq 30\% \) (strong recommendation) or \( \leq 35\% \) (weak recommendation) |  |
| □ The patient has been receiving optimal medical therapy for at least 3 months |  |
| □ In patients with ischemic heart disease, revascularization has been considered |  |
| □ In patients with ischemic heart disease, it has been at least 3 months after revascularization or at least 40 days after a myocardial infarction |  |

ICD implantation checklist (secondary prevention)

| □ The patient has had a cardiac arrest due to ventricular tachycardia or ventricular fibrillation |  |
| □ All reversible causes of ventricular arrhythmias have been excluded (common reversible conditions include myocardial infarction within the preceding 48 hours, reversible hypokalemia, reversible hypomagnesemia, and QT-prolonging medications) |  |
| □ Sustained ventricular tachycardia in the presence of significant structural heart disease in the absence of reversible causes |  |

ICD, implantable cardioverter defibrillator.

Other Issues

Left ventricular assist devices and ICDs

The prevalence of advanced heart failure has continued to increase worldwide, and left ventricular assist devices (LVADs) are being implanted more frequently for the treatment of end-stage congestive heart failure. Ventricular arrhythmias are common in patients with LVADs, occurring in 20%-50% of patients with the most episodes arising in the first 30 days after implantation.\(^5\) Whereas some patients might experience hemodynamic compromise attributable to the deleterious effects of the arrhythmia on the right ventricular (RV) function, others tolerate extended episodes of ventricular arrhythmias without symptoms or significant change in LVAD output.\(^5\,\,^2\)

There are no prospective randomized controlled trials of primary prevention ICD after LVAD implantation. In an observational study of 478 patients from the Cleveland Clinic, of whom 90 patients had an ICD, one-third of patients had their first arrhythmic event beyond 30 days after LVAD implantation. Furthermore, survival was improved in ICD patients (\(P = 0.024\)) and they were more likely to survive to transplantation (\(P = 0.015\)). Survival curves in these studies separate early between ICD and non-ICD recipients, usually within the first 3 months.\(^5\) These benefits of an ICD in LVAD patients were confirmed in another study in which the addition of an ICD increased the likelihood of survival to transplantation (2.72 times more likely to survive to transplantation in a multivariable model). Although shock frequency tended to decrease after LVAD implantation, appropriate shocks for ventricular tachyarrhythmias still occurred in 21% of patients.\(^5\,\,^4\)

LVADs might interact with the ICD (lead parameters, ventricular tachyarrhythmias, and electromagnetic interference), ICD programming should take this into consideration and be tailored in this special population.\(^5\,\,^5\,\,^6\)

Patients listed for heart transplantation

Before the era of ICD implantation in patients awaiting heart transplantation, the expected 1-year mortality was 30%.\(^5\) Advances in heart transplantation candidate selection and in the medical and device treatment of listed patients explain, in part, the decline in ICD-related improvements in the waiting list mortality.\(^5\) Patients listed for heart transplantation are highly selected patients and have an expected 10-year survival of \(> 50\%\) after transplantation.\(^5\) In an analysis of 310 patients awaiting transplantation at the University of Minnesota, the survival to transplantation was more likely with than without an ICD and the survival benefit remained significant up to 4 years after ICD implantation (\(P = 0.0001\)).\(^5\) In an analysis of 854 patients awaiting transplantation in Europe with a median follow-up of 4.7 months, total mortality in ICD patients was 11.8% compared with 21.5% in non-ICD patients (\(P = 0.03\)).\(^5\) Therefore, heart failure patients listed for heart transplantation, who are expected to be discharged to wait as outpatients, should receive primary prevention ICD implantation.

RECOMMENDATION

12. We suggest that ICDs be considered in patients with an LVAD (Weak Recommendation; Low-Quality Evidence).
13. We recommend that an ICD be implanted in outpatients who have been listed for cardiac transplantation (Strong Recommendation; Moderate-Quality Evidence).

Device Selection

All patients referred for ICD implantation should undergo evaluation by a specialist in heart rhythm disorders to determine ICD eligibility and CRT criteria. Please refer to the CCS guidelines for CRT indications.\(^6\,\,^2\,\,^3\)

Single vs dual-chamber devices

In ICD candidates, the decision to proceed with a single chamber ICD (with only a RV lead) vs dual-chamber ICD (with a right atrial and RV lead) device (Fig. 3A) is primarily dependent on whether there is an indication for permanent pacing. The implantation of a dual-chamber ICD is reasonable in patients who require pacing because of sinus node dysfunction. However, there are limited data to support the use of dual-chamber devices to improve arrhythmia discrimination. The Dual Chamber and Atrial Tachyarrhythmias Adverse Events Study (DATAS) randomized 335 patients eligible for a primary prevention ICD to receive a single or dual-chamber device.\(^6\) During the mean 16-month follow-up period, the primary outcome was a composite, which included: (1) all-cause mortality; (2) invasive intervention because of a cardiovascular cause; (3) hospitalization or prolongation of hospitalization because of cardiovascular cause; (4) inappropriate shocks (2 or more episodes with inappropriate shocks); and (5) sustained symptomatic atrial tachyarrhythmias. The
incidence of the composite outcome was 33% lower in the dual-chamber ICD group (odds ratio, 0.31; 95% CI, 0.14-0.67; \( P = 0.0028 \)). However, there were no statistically significant reductions in any individual component. This study has important limitations including a small sample size, high crossover rate (10%), and the use of previous-era ICD programming. ICD programming trials have shown that reductions in appropriate and inappropriate ICD therapies can be achieved with no worsening in the syncope or mortality rates. The ICD programming in the Use of Dual-chamber ICD with Special Programmed Features to Lower the Risk of Inappropriate Shock (RAPTURE) study randomized 100 subjects to either single or dual-chamber ICDs with contemporary arrhythmia discrimination programming.\(^{65}\) The incidence of inappropriate therapies was the same (2%) in both groups. One hypothesis for the findings was that the magnitude of shock reduction through programming was so substantial that the ability to differentiate between the dual-chamber and single-chamber discrimination was not possible. However, there might be specific subgroups in which the implantation of dual-chamber ICDs is reasonable (eg, previously documented slow VT or subjects with supraventricular tachycardia and VT with similar heart rates.

Importantly, most of the patients enrolled in the multicentre trials that established the survival benefit of ICDs received single-chamber devices.\(^{10,65,66}\) Furthermore, it is established that there is a higher rate of early complications with the use of dual- vs single-chamber ICDs. Prospective data from the Ontario ICD database on 3340 patients showed an increased risk of major complications in subjects who received a dual-chamber defibrillator compared with subjects who received single-chamber devices (adjusted hazard ratio, 1.82; 95% CI, 1.19-2.79; \( P = 0.006 \)).\(^{67}\) Using data from the NCDR, Peterson et al. reported that among 32,034 patients who received an ICD for primary prevention without indications for pacing, the use of a dual-chamber device compared with a single-chamber device was associated with a higher risk (4.7% vs 3.5%; \( P < 0.001 \)) of device-related complications.\(^{68}\) In a larger study Dewland et al. also reported NCDR data from 104,049 subjects who underwent first-time ICD implantation. Adverse events were more frequent with dual- than with single-chamber ICDs (3.17% vs 2.11%; \( P < 0.001 \)), as was the rate of in-hospital mortality (0.40% vs 0.23%; \( P < 0.001 \)). These differences were maintained after adjusting for demographic characteristics, medical comorbidities, and ICD indication. In these studies, only 40% of the patients with a dual-chamber ICD had a fulfilled indication for a dual-chamber device.\(^{69}\)

On the basis of current data, we recommend the implantation of a single-chamber ICD in all patients who undergo ICD insertion for primary prevention. Dual-chamber devices should only be implanted in patients who fulfil
guideline recommendation for pacing (eg, sinus node dysfunction or atrioventricular block) and who are not candidates for CRT.

**ICD lead selection**

Up until recently, most implanted ICD leads were dual-coil leads with a coil in the RV and superior vena cava (SVC) (Fig. 3A). ICDs with dual-coil leads coordinate ICD shocks between these coils and the ICD generator. It was previously thought that the use of an SVC coil was necessary to achieve a satisfactory defibrillation threshold (DFT). The improvement in DFTs with newer ICDs and concern regarding an increased risk of complications at the time of lead extraction associated with the SVC coil has decreased the use of dual-coil leads in favour of single-coil (RV only) leads.

There have been no randomized trials to address the superiority of a dual-coil compared with a single-coil system. Although early, small studies reported superior defibrillation efficacy with dual-coil leads, several recent reports have shown that the use of dual-coil leads is unlikely to have any clinical effect on the likelihood of a successful shock. A sub-study of SCD-HeFT in which 811 subjects were evaluated showed no difference in mean DFT ($12.1 \pm 4.7$ J vs $12.8 \pm 4.8$ J; $P = 0.087$), and similar first shock efficacy (82.2% vs 91.9%, dual vs single coil; odds ratio, 0.41; $P = 0.085$). The addition of an SVC coil was not associated with improved outcomes in this study.

Epstein et al. performed a retrospective analysis of patient and lead characteristics, procedural outcomes, and complications of 2201 consecutive patients who underwent transvenous ICD lead extraction at 9 high-volume centres. Data were available on 2176 extracted leads (385 single-coil and 1791 dual-coil). Eighteen major complications were observed, all in patients with dual-coil leads.

Because of the abundance of data showing no benefit of dual-coil over single-coil leads and a higher associated complication rate during lead extraction, single-coil leads should be regarded as the standard of care for ICDs. Therefore, we recommend the implantation of single-coil ICD leads in most patients who undergo ICD implantation. Dual-coil leads might be considered in populations in which the DFT threshold might be higher and/or when DFT safety margin fails with a single-coil lead. Because active fixation leads can be implanted in different RV positions (apical, septal, outflow tract) and because most lead extractors agree that the extraction procedure is less complicated compared with passive fixation high-voltage (HV) RV leads, we suggest the use of active fixation high-voltage (HV) RV leads.

**RECOMMENDATION**

14. We suggest a single-chamber ICD instead of a dual chamber ICD in patients with no indication for atrial pacing and in whom the indication for ICD implantation is for the primary prevention of SCD due to ventricular arrhythmias (Weak Recommendation; Moderate-Quality Evidence).

**RECOMMENDATION**

15. We suggest a single-coil HV ICD lead is preferred over a dual-coil HV ICD lead at the time of implantation (Weak Recommendation; Moderate-Quality Evidence).

**Site of ICD implantation**

Decisions regarding the location of device implantation are heavily influenced by the fact that the likelihood of a successful defibrillation is influenced by the location of the ICD generator in an active can configuration. There are no randomized studies that compared the clinical efficacy of left- vs right-sided ICD systems. However, observational data support improved ICD shock efficacy of a left pectoral implantation, consistent with the hypothesis that more of the ventricular myocardium is within the shock vector created between an RV coil and ICD generator when the ICD generator is on the left compared with the right pectoral region. Contraindications to ICD implantation on a specific side include chronic intravenous indwelling catheters, mastectomy with lymph node resection, previous infection, and subclavian vein thrombosis of the ipsilateral side.

The DFT is affected by the shock vector and impedance. Left-sided ICD systems are associated with lower DFTs because of the vector formed by the active device can and the lead system compared with the vector formed by only the lead (between the 2 coils). This difference was not reproducible on the right side. Although some right-sided ICD systems have a satisfactory DFT because of a low shock impedance, this impedance is not predictable or consistently low resulting in an unpredictable DFT with right-sided ICD systems. Gold et al. reported that among 627 patients, 5.9% received a right-sided implant. This group had higher DFTs at the time of implantation ($10.6 \pm 3.8$ J) than those who received a left pectoral implant ($8.9 \pm 4.2$ J; $P = 0.014$) despite similar shock impedances. Of note, the conversion efficacy for induced VF was similar at 99% on the right vs 98% on the left ($P = 0.18$). In addition, there was no difference in the efficacy for converting spontaneous arrhythmias among patients who received right and left pectoral implants (100% vs 97%, respectively; $P = 0.31$). However, the all-cause mortality rate was higher for patients who received right-sided implants (hazard ratio, 1.93; $P < 0.004$). This might have been because of the association of comorbidities (eg, dialysis for chronic kidney disease, previous infection) and implantation site.

In summary, we recommend routine left-sided ICD systems. Right-sided ICD implantation should only be considered in subjects with contraindications to a left-sided ICD implantation.
Subcutaneous ICDs

A number of subjects at risk for SCD are not suitable candidates for transvenous ICD leads or are at high risk of developing complications associated with transvenous leads. The development of new technology such as the subcutaneous ICD (S-ICD; Fig. 3B) allows for the implantation of a defibrillator system without transvenous ICD leads.74 This provides life-saving therapy to patients who would otherwise require more extensive procedures such as epicardial lead placement via thoracotomy with or without subcutaneous array. Recently published data showed that S-ICDs are effective in preventing SCD.74 To date, however, the number of patients studied is relatively small (approximately 10,000 patients worldwide) and data on the system’s long-term performance are limited. The inability to provide pacing (including antitachycardia pacing) is an important limitation of S-ICD systems. Noteworthy, although no lead failures were reported in a nonrandomized multicentre trial,75 the annual incidence of inappropriate shocks due to T-wave oversensing or supraventricular arrhythmias was 13%,75 significantly higher than the reported 2%-5% rate of inappropriate shocks with a transvenous system using modern programming strategies.76 Pooled data from patients enrolled in the initial S-ICD approval study75 and the EFFORTLESS registry77 were similar. The rate of device-related complications was 11.1% at 3 years, predominantly driven by infection (1.7%) and erosion (1.2%).78

The ongoing Prospective, Randomized Comparison of Subcutaneous And Transvenous Implantable Cardioverter Defibrillator Therapy Trial (PRAETORIAN; NCT01296022) might help to identify the best candidates for this technology.

**RECOMMENDATION**

16. We recommend that transvenous ICDs be implanted on the left side as the first option for endovascular systems (Strong Recommendation; Moderate-Quality Evidence).

Practical tip. The implantation of an S-ICD might be considered in patients in whom an ICD is recommended who have 1 of the following conditions: (1) congenital heart disease with no access to the ventricles; (2) congenital heart disease with right to left shunt resulting in increased risk of thromboembolic complications with transvenous ICD system; and (3) absence of a pocket site due to either previous device-related infection and/or chronic indwelling catheters.

**RECOMMENDATION**

17. We recommend an S-ICD be considered in patients with limited vascular access or pocket sites in whom an ICD is recommended (Strong Recommendation; Low-Quality Evidence).

Practical tip. Although S-ICD systems have been shown to be effective at terminating life-threatening arrhythmias and might have some advantages compared with transvenous ICD systems, we believe that the use of S-ICDs should be limited because of concerns regarding the risk of inappropriate shocks with present devices and the lack of long-term studies and randomized trials that compared transvenous vs S-ICDs.

Other Considerations at the Time of Implant

Venous access

Many different venous access routes can be used for ICD implants. Most commonly, the cephalic, axillary, or subclavian veins are used.79 Lateral access strategies using the cephalic or axillary vein are preferred to prevent such complications as a pneumothorax or lead impingement by the costoclavicular ligament. Many techniques to visualize the axillary vein can be used including fluoroscopic landmarks, venography, or surface sonography.80-82 There is still controversy surrounding the benefit from the axillary vein or cephalic vein approach over the subclavian route to prevent lead failure, because no randomized trials exist, although registry data suggest a lower complication rate using the cephalic approach.83,84 Venous access during device revisions or upgrade to an ICD might be challenging because venous obstruction or stenosis might often be encountered. A simple venogram performed with contrast injection from a peripheral vein on the ipsilateral side of the device upgrade can identify these issues before skin incision. It is estimated that at the time of upgrade, 26% of patients will present with some degree of vein stenosis and 9% will have complete occlusion.85-87 Venoplasty or lead extraction can be performed in experienced centres to obtain vascular access instead of implanting on the contralateral side.88-91 Alternative nontraditional venous access (supraclavicular or innominate vein) can also be considered in selected cases.92,93 It should be remembered that lead extraction in patients with multiple leads is associated with an increase in the absolute major event rate. In such complex cases, discussion with or referral to a specialized centre should be considered before proceeding.

Prevention of infections

The cardiac implantable electronic devices (CIED) infection rate varies from 0.5%-1.8% for de novo implants to 2.1%-5.6% for complex procedures. Prevention of infection starts with proper surgical technique and skin preparation. It is recommended to shave the skin as close to the procedure area as possible with an electric shaver. Skin wash with soap or chlorhexidine before surgery is also recommended. Skin preparation with chlorhexidine 2% in 70% isopropyl alcohol is preferable over povidone-iodine solutions. Intravenous administration of antimicrobial agents 1 hour before skin incision has been shown to reduce the infection rate.94 The choice of antibiotics might vary according to local prevalence of methicillin-resistant staphylococcus (MRSA). In MRSA carriers, preoperative (3-5 days) nasal application of mupirocin might be considered. Cefazolin, clindamycin, or vancomycin might be used in most patients before skin incision. There is
no scientific evidence that additional antibiotic doses after skin closure, combining 2 antibiotics preoperatively (cefazolin and vancomycin), or washing the pocket with antibiotics before closure reduces the infection rate. The ongoing Prevention of Arrhythmia Device Infection Trial (PADIT; NCT01628666) is comparing one intravenous cefazolin dose preoperatively with an incremental antibiotic strategy (vancomycin with cefazolin preoperatively, pocket wash, and 48 hours of oral antibiotics). There is also no definitive value to perform a capsulectomy at the time of replacement to decrease the infection rate. The use of a resorbable antibiotic envelope is being evaluated in the World-Wide Randomized Antibiotic Envelope Infection Prevention Trial (WRAP-IT; NCT02277990).

It has been shown that the presence of hematomas significantly increases the infection rate. A subgroup of the Bridge or Continue Coumadin for Device Surgery Randomized Controlled Trial (BRUISE CONTROL) showed that the overall 1-year device-related infection rate was 2.4% (16 of 659). Infection occurred in 11% of patients (7 of 66) with previous hematomas and in 1.5% (9 of 593) without. Hematoma was the only independent predictor and was associated with a > sevenfold increased risk of infection (hazard ratio, 7.7; 95% CI, 2.9-20.5; P < 0.0001). A summary is presented in Table 4.

### Table 4. Checklist for the prevention of CIED infection

<table>
<thead>
<tr>
<th>Recommended infection reduction strategies</th>
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<tr>
<td>☐ Electrical shaving of hair at device insertion site close to procedure time</td>
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<tr>
<td>☐ Skin preparation with chlorhexidine 2% in 70% isopropyl alcohol</td>
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<tr>
<td>☐ Intravenous antibiotic administration that covers pertinent organisms (including MRSA if appropriate) and has been completed before skin incision (30 minutes to 1 hour)</td>
</tr>
<tr>
<td>☐ Rigorous hemostasis to prevent device pocket hematoma</td>
</tr>
</tbody>
</table>

CIED, cardiac implantable electronic devices; MRSA, methicillin-resistant staphylococcus.

Defibrillator Implantation (NORDIC) trials are 2 randomized trials that compared DT or no DT at the time of implantation. Both showed noninferiority of the no DT strategy.

There are no data to suggest that a no DT strategy is safe in the S-ICD population. Thus, at time of a S-ICD implantation, DT is required. Further, it should be recognized that certain populations are not well represented or studied in these trials (hypertrophic cardiomyopathy and channelopathies) and DT can be considered in these groups.

There are data to support that a small R wave detection in sinus rhythm (< 3 mV) can be associated with undersensing of VF.

### RECOMMENDATION

19. We recommend that defibrillation safety margin testing not be performed for endovascular left-sided devices that are implanted for prevention of SCD due to ventricular arrhythmias in the absence of conditions known to increase the DFT (right-sided implants, hypertrophic cardiomyopathy, channelopathies, at the time of generator replacement when a lead is on advisory) or if detection of VF could be impaired (such as an unusual lead position or small R wave detection) (Strong Recommendation; High-Quality Evidence).

20. We suggest that defibrillator safety margin testing be considered at the time of implantation for right-sided implants and for patients with hypertrophic cardiomyopathy or channelopathies (Weak Recommendation; Low-Quality Evidence).

21. We recommend defibrillation safety margin testing for all subcutaneous defibrillation systems (Strong Recommendation; Moderate-Quality Evidence).

### Practical tip.

Because the R waves in sinus rhythm correlate with the device’s ability to sense VF we recommend defibrillator safety margin testing in all patients whose R waves are ≤ 3 mV. In this group, the ICD shock can be at the device’s highest output but it is recommended that ICD R wave sensitivity be programmed to the least sensitive value during testing.

### Anticoagulation

In patients at risk of thromboembolism who are receiving a vitamin K antagonist (eg, warfarin), it has been reported that implantation with a therapeutic international normalized ratio (INR; INR of 2-3) was associated with a significant reduction in the risk of hematomas. We also refer the reader to the previous CCS/CHRS CRT guidelines where this topic was addressed.

There is less evidence for continuation of the direct-acting anticoagulants at the time of device implantation. The ongoing second BRUISE CONTROL (BRUISE CONTROL 2) trial (NCT01675076) will address this issue prospectively.
RECOMMENDATION

22. We recommend that ICD implantation should be performed with a therapeutic INR in patients who receive vitamin K antagonists with an estimated annual risk of embolic events ≥ 5%. For patients who receive vitamin K antagonists with an estimated annual risk of embolic events < 5%, we recommend ICD implantation be performed with a therapeutic INR or temporary discontinuation of a vitamin K antagonist (no bridging) (Strong Recommendation; High-Quality Evidence).

Practical tip. The risks of bleeding and stroke must be evaluated on a patient by patient basis. In the absence of higher than expected bleeding with CIED insertion, we recommend the continuation of vitamin K antagonists with a therapeutic INR in all patients with a mechanical valve (or valves), previous transient ischemic attack/stroke, recent thromboembolism, or atrial fibrillation with a higher risk of stroke (ie, Congestive Heart Failure, Hypertension, Age, Diabetes, Stroke/Transient Ischemic Attack [CHADS2] score ≥ 3).

References

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