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EHRA POSITION PAPER

Comprehensive multicomponent cardiac rehabilitation in cardiac implantable electronic devices recipients: a consensus document from the European Association of Preventive Cardiology (EAPC; Secondary prevention and rehabilitation section) and European Heart Rhythm Association (EHRA)

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Abstract Cardiac rehabilitation (CR) is a multidisciplinary intervention including patient assessment and medical actions to promote stabilization, management of cardiovascular risk factors, vocational support, psychosocial management,

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physical activity counselling, and prescription of exercise training. Millions of people with cardiac implantable electronic devices live in Europe and their numbers are progressively increasing, therefore, large subsets of patients admitted in CR facilities have a cardiac implantable electronic device. Patients who are cardiac implantable electronic devices recipients are considered eligible for a CR programme. This is not only related to the underlying heart disease but also to specific issues, such as psychological adaptation to living with an implanted device and, in implantable cardioverter-defibrillator patients, the risk of arrhythmia, syncope, and sudden cardiac death. Therefore, these patients should receive special attention, as their needs may differ from other patients participating in CR. As evidence from studies of CR in patients with cardiac implantable electronic devices is sparse, detailed clinical practice guidelines are lacking. Here, we aim to provide practical recommendations for CR in cardiac implantable electronic devices recipients in order to increase CR implementation, efficacy, and safety in this subset of patients.

Keywords Cardiac rehabilitation • Cardiac implantable electronic devices • Pacemaker • Implantable cardioverter-defibrillator • Cardiac resynchronization therapy • Prevention • Exercise training • Heart failure • Physical activity • Consensus document

Why should the heterogeneous group of cardiac implantable electronic device recipients perform cardiac rehabilitation?

Cardiac rehabilitation (CR) is a multidisciplinary intervention, which is recognized as integral to the comprehensive care of cardiac patients.[1] Core components of CR include patient assessment and medical actions to promote stabilization, management of cardiovascular risk factors, vocational support, psychosocial management, physical activity counselling, and prescription of exercise training (ET).

Currently, millions of people with cardiac implantable electronic device (CIED) live in Europe and hundreds of thousands join them every year: according to a 2017 report of the European Heart Rhythm Association (EHRA), a total of 547 586 pacemakers (PMs), 105 730 implantable cardioverter-defibrillators (ICDs), and 87 654 cardiac resynchronization therapy (CRT) devices were implanted in the ESC area in 2016.[2]

Hence, large subsets of patients participating in CR programmes have a PM, CRT, or ICD. Cardiac rehabilitation for patients with CIED is a unique opportunity not only to optimize medical treatment, to increase exercise capacity, and to improve their clinical condition but also to supervise the correct functioning of the device.

Patients who are CIED recipients are considered eligible for a CR programme.[1] This is not only related to the underlying heart disease but also to specific issues, such as psychological adaptation to living with an implanted device and, in ICD patients, the risk of arrhythmia, syncope, and sudden cardiac death. Therefore, these patients should receive special attention, as their needs may differ from other patients participating in CR.

Patients with CIEDs, as the other cardiac patients who are potentially eligible for CR, may have barriers that limit their participation, patient- or system-related.[1] It should be noted, however, that nearly all patients with CVD,[1] including those with CIEDs, could benefit from at least some components of a CR programme.

Cardiac implantable electronic devices are usually programmed at rest but their assessment during exercise may provide important clinical information, particularly in, those patients with chronotropic incompetence or in those with rate response programming devices. Stimulation therapy is aimed at reducing symptoms, improving quality of life (QoL), and increasing survival. Exercise training is a key component of a CR programme: together with CIED functions like rate stabilization, chronotropic support, and resynchronization, it may provide a significant synergistic effect on heart function.[3]

In ICD recipients, fear of shocks often leads to fear of exercise and self-limitation of everyday activities. In addition, referral from hospitals to CR centres is often negatively impacted by the fear of inappropriate shock delivery during exercise. These aspects can therefore deprive ICD recipients of the well-established beneficial effects of CR in terms of secondary prevention, physiological, and psychosocial functioning.

As evidence from studies of CR in patients with CIED is sparse, detailed clinical practice guidelines are lacking. Here, we aim to provide practical recommendations for CR in CIED recipients in order to increase CR implementation, efficacy, and safety in this subset of patients.

Summary box 1

- Patients who are CIED recipients are considered eligible for a CR programme. This is not only related to the underlying heart disease but also to specific issues, such as psychological adaptation to living with an implanted device and, in ICD patients, the risk of arrhythmia, syncope, and sudden cardiac death. Therefore, these patients should receive special attention, as their needs may differ from other patients participating in CR.
- The present paper is aimed to provide practical recommendations for CR in CIED recipients in order to increase CR implementation, efficacy, and safety in this subset of patients.

Clinical and technical evaluation in cardiac implantable electronic devices recipients presenting for cardiac rehabilitation

The history of the CIED implantation should be investigated: indication for the implantation, including the index event, and underlying

heart disease. Also, comorbidities that may complicate ET or might impose an additional risk should be described.[4]

Symptoms should be sought after, particularly sudden onset of dizziness or fatigue during exercise. Syncope and palpitations could be a sign of malcapture or uncontrolled arrhythmia. Hiccups (suggestive of phrenic nerve stimulation) should be specifically addressed.

The patient's mental status also deserves attention: psychological stress is a known predictor of worse outcomes in CIED patients.[5,6] ICD-specific measures, evaluating shock anxiety, device acceptance, behavioural avoidance, and ICD-specific patient concerns are available.[5]

The physical examination includes a standard cardiovascular assessment. Additionally, device position, signs of potential infection (redness, hotness, and pain), and presence of arm oedema or collateral circulation suggestive of central vein stenosis should be evaluated.[7]

An ECG at rest and during exercise testing shows the device at work. This can help to fine-tune the settings to prevent undesired pacing[8,9] or to initiate optimization of a CRT device in the absence of a narrowing of the QRS, or in the case of pseudofusion pacing.[10]

Device interrogation in CR is not different from what is generally performed (settings, sensing, pacing threshold, impedance, battery longevity, and arrhythmia log) since, during CR, some challenges may arise (*Table 1*). Characteristics of an appropriate programming of CIED during a CR programme are reported in the sections below; however, it is important to mention here that both the patient and the CR team need to be aware of device settings, especially the rate cut-off for therapy in patients with defibrillator.[11] Patients should be instructed to keep the heart rate (HR) at least 10–20 b.p.m. below the rate cut-off during exercise (see below, 'Safety issues').[4]

Another important observation is pacing percentage, dependent on the type of CIED. In patients with a PM or an ICD, a right ventricular pacing percentage near 0% is desirable[12,13] owing to its unfavourable effects on regional myocardial perfusion, myocardial metabolism, and contraction synchronism. Negative effects of right ventricular pacing are particularly evident in patients with preserved ejection fraction heart failure (HF) or asymptomatic left ventricular dysfunction. In CRT recipients, a percentage near 100% is aimed for, as the percentage of ventricular pacing correlates strongly with survival and morbidity.[14,15] Rate response histograms need to be analysed for frequency distribution.

Table 1 Challenges in patients with cardiac implantable electronic device during cardiac rehabilitation

- Chronotropic incompetence, inappropriate sensor function for rate-adaptive pacing (under- or overresponsive).
- Sinus tachycardia above the upper tracking limit (dual-chamber and CRT devices).
- Under- and oversensing (pacemaker and ICD).
- Arrhythmias (ventricular or supraventricular extrabeats, junctional rhythm, supraventricular, and ventricular tachyarrhythmias).
- Changes in AV conduction.

AV, atrioventricular; CRT, cardiac resynchronization therapy; ICD, implantable cardioverter-defibrillator.

A symptom-limited exercise test, preferably a cardiopulmonary exercise test (CPET), should be performed before the start of a CR and ET programme, also for safety and reassurance of patient and physician.[1,16] Enabling device telemetry during the exercise test allows simultaneous recording of surface ECG, marker annotations, and intracardiac electrograms, which can provide additional information.

Analysis of standard CPET parameters (peak oxygen uptake [VO_2], ventilatory thresholds, O_2 pulse, VE/VCO_2 slope) in patients with a CIED is not different than in other patients with cardiovascular disease and has been reviewed elsewhere.[17–20] Nevertheless, a CPET in CIED recipients provides a unique opportunity to test device settings and the evaluation of exercise response allows to establish some crucial points, apart from ischaemia and exercise capacity[21]:

(1) heart rate at rest, chronotropic response to exercise and during recovery;
(2) presence of exercise-induced arrhythmias;
(3) HR in case of onset of arrhythmia;
(4) effectiveness of pharmacological HR control;
(5) risk of reaching an exercise HR in the ICD intervention zone; and
(6) evaluation of maximum tracking rate and continuous biventricular stimulation.

First, not only the HR response to exercise should be evaluated. Optimally, if ventricular pacing is needed or desired, the PM should be programmed to at least track the maximum sinus rate reached during exercise. A different matter is rate response: there is still much controversy on its effectiveness, especially in HF patients.[22–24] As no deleterious effects have been described, this feature can probably be programmed 'ON' safely. Cardiopulmonary exercise test can be used to optimize rate response [and rate-adaptive atrioventricular (AV)-delay] by the device.[25] Of note, cyclergometer-based rate response may not always be indicative of rate response during other forms of exercise. Treadmill exercise testing should be preferentially used in patients with rate response programming devices since exercise on a treadmill is closer to physical activity performed during daily life.

In CRT, the exercise ECG allows to evaluate the delivery of actual resynchronization and its persistence during exercise, based on the QRS morphology.[10]

Of final note, in patients with continuous ventricular pacing, the evaluation of exercise-induced ischaemia based on the ECG is impossible and cardiac memory may be a source of repolarization abnormalities in those patients with discontinuous pacing. Other modalities may be needed,[9] and cardiac imaging techniques are recommended to evaluate the presence and extension of myocardial ischaemia[26]; nevertheless, gas analysis can detect myocardial ischaemia during exercise with reduced pulse volume and cardiac out-put before the development of ST-segment changes or chest pain.[27]

During follow-up of CIED patients, a chest X-ray can be useful to detect lead fracture, dislocation, or perforation if the electrical pacing parameters (threshold, impedance, and sensing) have changed. Lead perforation may be better detected with computed tomography.[28]

Before starting CR, a recent echocardiogram should be available to evaluate cardiac structure and function. Presence of low left

ventricular ejection fraction (LVEF), elevated left ventricular filling pressures, pulmonary artery pressures, or congestion require further investigation.[4] The tricuspid valve deserves special focus, as implantation of a right ventricular lead may induce or aggravate tricuspid regurgitation, especially if atrial fibrillation is present.[29]

In CRT, routine echocardiographic AV and interventricular optimization are not recommended.[9,10] However, it can be of benefit in CRT non-responders.[30] Exercise itself may alter ventricular synchrony, but only limited data exist on optimizing CRT during exercise.[31,32] Again, this may provide an additional tool in non-responders, whether performed during CPET or during exercise echocardiography.

Although modern CIEDs have an in-built Holter providing arrhythmia detection and summaries of pacing percentages, there is still a use for Holter monitoring, especially in the context of unexplained symptoms.[33]

Chronotropic response or chronotropic (in)competence during everyday life can be evaluated with a 24-h Holter, potentially prompting adjustments to device settings.

In CRT, the device-declared percentage pacing can overestimate the percentage of effective resynchronization, especially in atrial fibrillation.[34] Holter monitoring can help to objectivize this, facilitating optimization of device settings.[34,35] Some companies have built-in algorithms to address this issue.[36]

Summary box 2

- Clinical and laboratory evaluation is the first step in evaluating CIED patients in the setting of comprehensive CR. Minimally, history and clinical examination, device interrogation, chest X-ray, echocardiogram, CPET, and Holter should be performed before starting exercise-based CR. Key points are summarized in *Table 2*.

Table 2 Key points in the clinical and technical evaluation of patients with cardiac implantable electronic device in the setting of cardiac rehabilitation

History
Disease tolerance: physical complaints (angina, palpitations, (pre)-syncope, psychological coping with being a 'cardiac patient')
Exercise intolerance, with special attention to sudden decrease in exercise capacity (suggestive of ischaemia, sudden onset of conduction disturbances, or arrhythmias)
Comorbidities that may interfere with exercise training
Device tolerance: physical discomfort, phrenic nerve stimulation, and psychological coping
Clinical examination
Device position and aspect of pocket
Presence of arm oedema, collateral circulation (suggestive of subclavian thrombosis)
BP control
ECG
Non-paced/inhibited
Underlying rhythm
Resting HR
Intrinsic conduction (PR interval)
Device settings
Capture and sensing
Arrhythmias
Effectiveness of CRT
Device interrogation
Algorithms to minimize ventricular pacing
Rate responsiveness/sensor programming
Automatic CRT-optimization algorithms
In ICD: arrhythmia detection cut-offs
Exercise test, preferably CPET
Upper rate behaviour
Chronotropic competence or appropriateness of rate response
Exercise induced tachyarrhythmias, conduction disturbances including rate dependent branch block
Appropriate AV interval adaptation to ensure resynchronization
Imaging
Chest X-ray
Lead position(s)
Complications (lead fracture, dislocation, perforation)
Echocardiography
Left ventricular ejection fraction
Lead related tricuspid regurgitation
Exercise echocardiography: evaluation of exercise induced dyssynchony with CRT optimization
Holter monitoring
Chronotropic competence or appropriateness of rate response
Occurrence of arrhythmias undetected by CIED
Effectiveness of pacing in CRT

CIED, cardiac implantable electronic device; CPET, cardiopulmonary exercise test; CRT, cardiac resynchronization therapy; ECG, electrocardiogram; HR, heart rate; ICD, implantable cardioverter-defibrillator; MRI, magnetic resonance imaging.

Specificities of a comprehensive cardiac rehabilitation programme in specific cardiac implantable electronic devices recipients

Implantable cardioverter-defibrillator

ICD patients still have low referral rates and poor adherence to CR. This observation might be attributed to the high incidence of anxiety and depression (18–38% and 28–32%, respectively) and to the fear of ICD discharges,[37] highlighting the importance of psychoeducational component of CR.

Patients with ICD are recommended to participate in a CR programme in the context of[21]:

(1) primary cardiac disease multidisciplinary management, including medical treatments, cardiovascular risk factors control, return to work; and
(2) after ICD implantation in primary arrhythmogenic cardiopathies, mostly for exercise, physical activity, and psychoeducational components.

Centre-based, with professional supervision and individualized monitoring, as well as home-based CR, allow these patients to improve their exercise capacity safely.[21,38] If both centre-based and home-based CR programmes are available, centre-based CR could be recommended early after implantation, then home-based CR could definitively be an option. A multidisciplinary team directed by a cardiologist with competence in secondary prevention and CR has to be involved in the care of CIED recipients.[1] Among consultant professionals, an electrophysiologist should be available for consultation.

Strategies targeted to support an active lifestyle for individuals who receive an ICD shock before, during, or after exercise need to be implemented, including psychological techniques to reduce fear and anxiety and convincing individuals with ICD to undertake exercise.

The risk of arrhythmias during exercise (ventricular and supraventricular) might be increased by several factors: i.e. acute exercise by an excessive adrenergic stimulation, myocardial ischaemia, or the presence of some specific underlying cardiac diseases (long QT syndrome, hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, and catecholaminergic polymorphic ventricular tachycardia (VT)).[21]

The risks of severe ventricular arrhythmias [VT or ventricular fibrillation [VF]) during exercise testing depend also on the underlying cardiac disease and the previous history of VT/VF.[21] Supraventricular arrhythmias may trigger an inappropriate shock and should therefore be prevented.[21]

In order to prevent inappropriate shocks, the following measures are recommended[21]:

(1) stop the exercise testing and training 10–20 b.p.m. below the programmed zones of ICD therapies;
(2) continuously monitor CIED recipients during ET sessions, at least during the first session at every increase of exercise intensity; and
(3) use beta-blockers, when clinically indicated for the patient's disease, and monitor their effects on maximal HR.

Wearables, such as smartwatches and HR monitors, are recommended to patients at home, during daily life, physical, and sport activities.

Theoretically, pronounced arm–shoulder movements or intense mechanical strain of the ICD pouch could also trigger inappropriate ICD shocks, particularly in the case of subcutaneous-ICD,[39] but in giving advice, this should not be presented as a reason for patients to avoid exercise.

The CR staff should be confident, expressing understanding of the purpose of the device and that this increases the safety of the patient. In case of any device intervention (appropriate or inappropriate), the cardiologist should assess the causes, and any changes in device programming, medications, or exercise regime should be considered. Exercise should be started again swiftly after the device interrogation to avoid that the ICD discharge can become a psychological block of future activity.[21]

Cardiac resynchronization therapy

In patients with reduced ejection fraction HF (HFrEF), CRT has been shown to reduce symptoms, hospitalizations, and mortality, while increasing exercise capacity, cardiac performance, and QoL;[40–42] nevertheless in one-third of CRT recipients, a lack of symptoms improvement still remains.[43]

As most CRT recipients are HFrEF patients, it is suggested that the exercise prescription may follow guidelines suggested for people with HFrEF,[44,45] with specific adaptations.

The CRT population includes individuals with a CRT-P or a CRT-D device, and specificities reported for ICD recipients should be taken into account for those who have an implanted CRT-D. The programming parameters of the CRT device in terms of AV delay and optimization protocols may contribute significantly to this therapy benefits and could improve exercise performance if standardized.[46]

Some points need specific attention during ET in CRT recipients:

(1) exercise can induce sinus tachycardia above upper tracking limit (UTL), causing inadequate tracking of sinus rhythm (PM Wenckebach or 2:1 block). This is particularly important in patients with CRT, as device settings are optimized for 100% (biventricular) pacing, also during exercise. This subject is described in detail in the section below on programming of CIED during a CR programme.
(2) Exercise can induce changes in AV conduction leading to loss of resynchronization.
(3) The CR team should pay attention to possible limiting factors associated with pacing therapy. If the patient's atrial rate is paced, then the CR team should be especially mindful of a blunted or delayed HR response to exercise.

Daily activity at lower intensities should supplement the exercise programme to sustain secondary prevention and morbidity benefits, per guideline recommendations.[47]

Summary box 3

ICD

- Centre-based, with professional supervision and individualized monitoring, as well as home-based CR, allow ICD patients to improve their exercise capacity safely.
- The risks of severe ventricular arrhythmias during exercise testing depend of the underlying cardiac disease and the previous history of life-threatening ventricular arrhythmias. Supraventricular arrhythmias may trigger an inappropriate shock and should therefore be prevented
- In order to prevent inappropriate shocks, the following measures are recommended:
  - stop the exercise testing and training 10–20 b.p.m. below the programmed zones of ICD therapies;
  - continuously monitor CIED recipients during ET sessions, at least during the first session at every increase of exercise intensity;
  - use beta-blockers and monitor their effects on maximal HR; and
  - wearables, such as smartwatches and HR monitors, are recommended to patients at home, during daily life, physical, and sport activities.

CRT

- The CRT population includes individuals with a CRT-P or a CRT-D device, and specificities reported for ICD recipients should be taken into account for those who have an implanted CRT-D.

- The programming parameters of the CRT device in terms of atrial ventricular delay and optimization protocols may contribute significantly to this therapy benefits and could improve exercise performance if standardized.
- Some points need specific attention during ET in CRT recipients:
  - exercise can induce sinus tachycardia above UTL, causing inadequate tracking of sinus rhythm (PM Wenckebach or 2:1 block);
  - exercise can induce changes in AV conduction leading to loss of resynchronization; and
  - the CR team should pay attention to possible limiting factors associated with pacing therapy.

Prescribing exercise training in cardiac implantable electronic device recipients

Different exercise protocols including moderate intensity continuous training, high-intensity interval training, resistance/strength training, or combinations of these modalities have been evaluated in CIED patients (*Table 3*).[46] Structured ET results in similar improvements in exercise capacity, both in ICD and CRT patients.[48] Most often ET was prescribed supervised as single intervention or integrated in a comprehensive CR programme.[49–60]

In the largest supervised ET study in HFrEF patients (HF-ACTION), the relationship between outcomes and randomized treatment according to ventricular pacing status was examined.[51,61] Of 2331 patients, 1118 (48%) had an ICD: 683 with right ventricular and 435 with biventricular pacing.[61] Patients with devices were older, and had a lower absolute peak VO_2; ET similarly improved absolute peak VO_2 in groups with and without pacing devices.[61] However, the primary composite endpoint (all-cause death or hospitalization) was reduced only in patients randomized to ET without a CIED.[61] Therefore, the authors concluded that ET may improve exercise capacity in patients with implanted cardiac devices, but the apparent beneficial effects of exercise on hospitalization or death may be attenuated in patients with CIEDs, requiring further study.[61]

In another study from HF-ACTION patients, a history of sustained VT/VF, previous atrial fibrillation/flutter, exercise-induced dysrhythmia, lower diastolic blood pressure, and non-white race, but not ET, were associated with an increased risk of ICD shocks.[51]

A recent systematic review and meta-analysis (1730 participants, 8 trials, mean ET duration 12 weeks, and follow-up 8–24 weeks) showed that ICD patients, following exercise-based CR, achieved a

Table 3 Exercise training studies in cardiac implantable electronic device patients

Exercise type	Studies	Patients	Setting	Exercise training characteristics	Outcome	Safety
Moderate intensity continuous training[49–51,53,63,64]	*N* = 7 (2 ICD, 2 ICD and CRT, 3 CRT) Exercise: 508 ICD, 298 CRT Control: 418 ICD, 281 CRT	HFrEF, NYHA II–IV (*N* = 6) ICD for prim. or sec. prevention of SCD (HFrEF 73%) (*N* = 1)	Supervised exercise training (*N* = 5) Telemonitoring (*N* = 2)	Frequency: 3–5 times/week for 8–16 weeks Intensity: 60% peak VO2, 60–80% HRR, 90% VT1, 80–90% peak HR Time: 5–120 min	Delta VO_2peak + 4.0–30%	No more shocks during exercise, no severe adverse events. No data on safety (*N* = 2)
High-intensity interval training[52,55]	*N* = 2 (1 ICD, 1 CRT) Exercise: 38 ICD, 34 CRT Control: 12 ICD, 29 CRT	HFrEF, NYHA I–III	Supervised exercise training	Frequency: 2–3 times/week for 2–24 weeks Intensity: 4 min 85–95% peak HR, 3 min 60–70% peak HR Time: 60–75 min	Delta peak VO_2 + 3.7–9.8%	No more shocks during exercise, no severe adverse events (*N* = 1). No data on safety (*N* = 1).
Moderate intensity continuous and resistance/strength training[56–60]	*N* = 5 (4 ICD, 1 CRT) Exercise: 272 ICD, 223 CRT Control: 142 ICD, 432 CRT, 515 no ICD	HFrEF, NYHA I–IV (*N* = 2) ICD for prim. or sec. prevention of SCD (HFrEF 24–73%) (*N* = 3)	Supervised exercise training (*N* = 1) Comprehensive CR (*N* = 4)	Frequency: 2–3/week for 2–24 weeks Intensity: 50–90% peak HR, 50–90% HRR, 50–80% 1-RM Time: 30–90 min	Delta peak VO_2 + 7.0–15%	No more shocks during exercise, no severe adverse events.

1-RM, one repetition maximum; HFrEF, heart failure with reduced ejection fraction; HRR, heart rate reserve; SCD, sudden cardiac death; VT1, first ventilator threshold.

better exercise capacity. The impact on all-cause mortality, serious adverse events, and health-related QoL remained unclear due to small numbers of events and enrolled patients.[62]

Telemonitored ET in HFrEF was used in one study with ICD patients [New York Heart Association (NYHA) II–III, $N = 111$],[63] and in one study with CRT-D patients (NYHA III, $N = 52$, following a hospital-based ET),[64] proving to be equally safe and effective as conventional centre-based training.

Two studies exposed stable, but still symptomatic HFrEF patients with ICD ($N = 38$)[55] or CRT ($N = 34$)[52] to supervised high-intensity interval training. Exercise training was safe and exercise capacity improved significantly in both studies. However, in CRT patients (more symptomatic, NYHA III) the dropout rate was nearly 41%, questioning the general applicability of HIIT programmes.[52]

In HFrEF patients with disynchrony, biventricular pacing mainly improves the central component of exercise capacity. ET has the potential to maximize the benefits from device therapy, by targeting also the peripheral component. A 12–14 weeks supervised ET programme further improved peak VO_2 by 16–24%, compared to CRT alone.[53,54]

The majority of exercise interventions contained an aerobic component in the form of walking, cycling, running, or a combination; resistance or strength training was also used in a population of ICD recipients, implementing 15–20-min sessions once to twice per week.[49–60] Training volumes were not reported in >50% of the studies and are difficult to quantify, but most were prescribed to progressively increase workloads over 2–3 months, as tolerated and the interventions were implemented in outpatient CR settings.[49–60] Training programmes varied in session frequency (3–5 per week), session duration (30–90 min), and intensity (50–90% of peak VO_2 or maximal HR).[49–60] In a review including 1889 patients, 834 of them with an ICD, the duration of CR programmes ranged from 4 to 12 weeks.[65]

Some studies used multicomponent interventions (support group, education, and psychological interventions).[66–68] The control condition was represented as 'usual care' or no exercise recommendation. Clinically meaningful effects were found between groups in peak VO_2, general health, and mental health in favour of the rehabilitation group, with a reduction in total attributable direct costs.

One study reported a yoga intervention in the ICD population.[69] Forty-six participants were randomized to a control group or an 8-week adapted yoga group. Total shock anxiety decreased for the yoga group and increased for the control group. Compared to the control, the yoga group had greater overall self-compassion and greater mindfulness. Exploratory analyses utilizing a linear model revealed that the yoga group had a 32% lower risk of experiencing device-related firings at end of follow-up.

Therefore, based on the knowledge of ET for HF patients, exercise prescription may include both endurance and resistance training.[70] Inspiratory exercise can be particularly valuable in most fragile and recently stabilized patients.[71] Endurance training may use continuous and/or interval or intermittent training models, 3–5 days/week, during 30–60 min, associated with dynamic exercises. Continuous aerobic training prescription may be similar to that used in HF patients,[3] keeping in mind upper limits of the device.

Resistance training sessions (2–3 sessions/week) may be tailored according to a preliminary evaluation of strength, but special attention is required with shoulder movement in order to avoid important strain in the side of implant, particularly in the early phase after device placement.[72] Upper body strength training may dislodge newly implanted leads, and therefore, resistance training is not recommended in the first 4–6 weeks post-implant. Any activities that could result in a direct impact with the CIED should be avoided.

Further, people with CRT may have considerable peripheral limitations with muscle weakness because of long-term inactivity. Thus, when resistance training is introduced, it should be of low to moderate intensity and completed twice weekly,[73] highly tailored on each single patient.

As example of a resistance training protocol[70]:

(1) intensity 2–3 sets with 10–12 repetitions per set at 40–70% 1 repetition maximum (RM) with full recovery (>1 min) between sets (if 1-RM evaluation is not available, rate perception exertion of 12–15, Borg Scale 6–20);
(2) warm-up and cool down 10–15 min; and
(3) at least 12 weeks duration, but preferably more.

Cardiac implantable electronic device recipients may experience deviations in cardiovascular risk factors (obesity, hypertension, dyslipidaemia, and diabetes). In this case, further refinement of exercise prescription can be recommended, within the above-mentioned safety margins, and based on current evidence[3]; to facilitate this process, digital decision support systems are available.[74]

Summary box 4

- Implantable cardioverter-defibrillator patients, following exercise-based CR, achieved a better exercise capacity. The impact on all-cause mortality, serious adverse events, and health-related QoL remained unclear.
- In small studies, telemonitored ET in HFrEF was used in one study with ICD patients and in another with CRT-D patients, proving to be equally safe and effective as conventional centre-based training.
- Two studies exposed stable, but still symptomatic HFrEF patients with ICD or CRT to supervised high-intensity interval training. ET was safe and exercise capacity improved significantly in both studies. However, the dropout rate was nearly high, questioning the general applicability of high-intensity interval training.
- Exercise prescription may include both endurance and resistance training. Inspiratory exercise can be particularly valuable in most fragile and recently stabilized patients. Endurance training may use continuous and/or interval or intermittent training models, 3–5 days/week, during 30–60 min, associated with dynamic exercises. For continuous aerobic training, prescription may be similar to that used in HF patients, keeping in mind upper limits of the device.
- Resistance training sessions (2–3 sessions/week) may be tailored according to a preliminary evaluation of strength, but special attention is required with shoulder movement in order to avoid important strain in the side of implant, particularly in the early phase after device placement.

Appropriate programming of cardiac implantable electronic device during a cardiac rehabilitation programme

As shown in *Table 1*, during CR, some challenges for patients with a CIED may arise.

Chronotropic incompetence is the patient lack of increased HR and it may limit exercise tolerance.[75] The reason for this phenomenon may reside in the sinus node, AV node, or a pacing response. Therefore, rate-adaptive pacing should be programmed 'ON'. Specific attention should be payed to potential insufficient or exaggerated sensor response to exercise, prompting reprogramming of the sensor (more or less reactive, see *Table 4*).

In patients with AV block, the UTL should be programmed higher than the maximum sinus rate to maintain 1:1 conduction during (higher-level) exercise. The UTL should be lower than the HR at 2:1 block which depends on the total atrial refractory period (TARP), equalling programmed sensed AV (SAV) delay plus the post-ventricular atrial refractory period (PVARP): TARP = SAV + PVARP. For example, if SAV is 200 ms and PVARP 300 ms, TARP equals 500 ms, so that sinus rhythm >120 b.p.m. in patients with complete heart block will result in a 2:1 block with a sudden drop in HR from 120 to 60 b.p.m. during exercise, independent of the programmed UTL. Tracking of high sinus rates can be facilitated by programming a rate-adaptive SAV delay (e.g. shortest 100 ms at UTL) and a rate-adaptive PVARP (e.g. shortest 250 ms at UTL: this allows 1:1 conduction up to 350 ms = 171 b.p.m.).

Considerations on UTL and 2:1 block are particularly important in patients with CRT. If 1:1 tracking is not ensured, resynchronization may be interrupted. This potentially causes non-response to CRT. If patients develop angina during exercise, the HR at the onset of angina should be recorded and the UTL should be reduced in patients with AV block, typically to 110 b.p.m. in dual-chamber devices and 130 b.p.m. in CRT.

During exercise, biological signals, such as the P wave, demonstrate a shift in frequency content and depending on the filters of the device may be sensed at lower amplitudes. Therefore, the P-wave amplitude should be checked during exercise and atrial sensitivity should be adjusted if necessary (e.g. 0.1–0.25 mV). Physical activity can cause myopotential oversensing of the pectoral muscle (only in unipolar sensing) or the diaphragm in ICDs with integrated bipolar sensing.[76,77] It should be checked if sensing is programmed to bipolar in PMs and if ventricular oversensing occurs during exercise or deep respiration (or coughing) in ICDs with integrated bipolar sensing. Rarely, electrical devices used in CR can cause oversensing. Transcutaneous electrical neuromuscular stimulation (TENS) and other electrical or magnetic resources should be avoided.

Exercise may trigger premature beats and tachyarrhythmias. To terminate endless loop tachycardia after ventricular or supraventricular premature beats, algorithms (usually called 'PM mediated

Table 4 Challenges for patients with a cardiac implantable electronic device during a CR programme

Problem	Programming solution
Chronotropic incompetence	Activate sensor
Insufficient heart rate increase despite sensor	Increase sensor reactivity (threshold of activity detection, rate increase, duration of rate increase, etc.)
Excessive pacing rate increase	Decrease sensor reactivity (threshold of activity detection, rate increase, duration of rate increase, etc.)
Sinus rate above the upper tracking limit	Increase upper tracking limit
2:1 block during exercise	Shorten sensed AV delay and/or PVARP, consider rate-adaptive AV delay and rate-adaptive PVARP
Angina pectoris during exercise	Limit upper tracking rate to 110 b.p.m. in patients with coronary artery disease
Undersensing during exercise	Increase sensitivity (atrium: up to 0.1–0.2 mV)
Oversensing during exercise	Check sensing polarity (bipolar!), reduce sensitivity in pacemakers, avoid TENS
Multiple supraventricular or ventricular premature beats, endless loop tachycardia	Activate 'PMT intervention' in dual-chamber and CRT devices, activate 'PVC reaction' in dual-chamber devices, in individual cases increase the lower rate limit
Non-sustained ventricular tachycardia	Prolong tachycardia detection in ICDs (≥ 40 intervals)
Supraventricular tachycardia during CR	Prolong tachycardia detection in ICDs (≥ 40 intervals in VT zones, ≥30/40 intervals in VF zone), activate enhanced detection criteria or VT/SVT discrimination criteria, in individual patients increase tachycardia detection rate (e.g. to 200 b.p.m.) with a monitoring zone (e.g. 180–200 b.p.m.)
Accelerated junctional rhythm during exercise	Increase the lower rate limit in dual-chamber and CRT devices (e.g. to 70 b.p.m.), activate overdrive algorithms
Shortening of intrinsic AV delay	In CRT: Shorten the sensed AV delay or (better) activate rate-adaptive AV delay; if available activate negative AV hysteresis

AV, atrioventricular; CR, cardiac rehabilitation; CRT, cardiac resynchronization therapy; ICD, implantable cardiac-defibrillator; PMT, pacemaker tachycardia; PVARP, post-ventricular atrial refractory period; PVC, premature ventricular complex; SVT, supraventricular tachycardia; TENS, transcutaneous electrical nerve stimulation; VF, ventricular fibrillation; VT, ventricular tachycardia.

tachycardia intervention') should be activated in dual-chamber and CRT devices. Algorithms that start a long PVARP or force atrial pacing after a premature ventricular beat [(PVC) reaction] should be activated at least in dual-chamber devices. In CRT, PVC reaction algorithms should rather not be activated since the associated long PVARP may stop atrial triggering and interrupt CRT. Non-sustained VT and supraventricular tachycardias during CR should not trigger ICD therapies. To avoid unnecessary or inappropriate ICD therapy, tachycardia detection should be programmed to long values (e.g. ≥ 30/40 intervals in the VF, >40 intervals in the VT zone).[78] Algorithms for discrimination of ventricular and supraventricular tachycardia should be activated. The use of very high tachycardia detection zones (e.g. ≥ 200 b.p.m.) can be used on an individual basis if the risk of VT <200 b.p.m. is low. In this case, a monitoring zone without ICD therapies should be programmed to make sure those tachycardias below 200 b.p.m. which may cause symptoms, such as dizziness during CR are detected.

Accelerated junctional rhythms can occur during CR, particularly in HF. This terminates AV synchrony in dual-chamber devices and also ventricular resynchronization in CRT. In these patients, the lower rate limit should be increased (e.g. 70 b.p.m.) and overdrive algorithms (e.g. atrial preventive pacing) should be activated.

High adrenergic tone during CR can shorten intrinsic AV conduction and thus interrupt CRT. To avoid this, a shorter or (better) rate-responsive AV delay, and a negative AV hysteresis (automatic shortening of the AV delay upon ventricular sensing) can be programmed.

Summary box 5

- In case of chronotropic incompetence, rate-adaptive pacing should be programmed 'ON'.
- In patients with AV block, the UTL should be programmed higher than the maximum sinus rate to maintain 1:1 conduction during (higher-level) exercise; the UTL should be lower than the HR at 2:1 block.
- Considerations on UTL and 2:1 block are particularly important in patients with CRT. If 1:1 tracking is not ensured, resynchronization may be interrupted.
- Physical activity can cause myopotential oversensing of the pectoral muscle (only in unipolar sensing) or the diaphragm in ICDs with integrated bipolar sensing. It should be checked if sensing is programmed to bipolar in PMs and if ventricular oversensing occurs during exercise or deep respiration (or coughing) in ICDs with integrated bipolar sensing.
- Rarely, electrical devices used in CR can cause oversensing, TENS, and other electrical or magnetic resources should be avoided.
- Non-sustained VT and supraventricular tachycardias during CR should not trigger ICD therapies. To avoid unnecessary or inappropriate ICD therapy, tachycardia detection should be programmed to long values (e.g. ≥ 30/40 intervals in the VF, > 40 intervals in the VT zone).
- Algorithms for discrimination of ventricular and supraventricular tachycardia should be activated. The use of very high tachycardia detection zones (e.g. ≥ 200 b.p.m.) can be used on an individual basis if the risk of VT <200 b.p.m. is low.

Physical activity, sports counselling, and sexual activity

General recommendations for physical activity are consistent with the underlying pathology, such as HF, dilated cardiomyopathy, and arrhythmogenic cardiomyopathy.[79]

Physical activity was associated with a decreased risk of cardiac events: it is considered safe and is applicable in all stable individuals, including cardiac patients, who are on optimal medical therapy, regardless of the LVEF value.[47]

Thus, all asymptomatic patients, regardless of the LVEF, without exercise-induced ventricular arrhythmias should be advised to participate in low to moderate intensity leisure-time exercise activities. Instead, symptomatic individuals for exercise-induced arrhythmias should abstain from competitive and leisure sports or recreational exercise associated with moderate or high exercise intensity.

In arrhythmogenic cardiomyopathy, regular exercise programmes may be associated with acceleration of the disease process and worsen outcomes.[80] Reducing exercise intensity was associated with a substantial decrease in the risk of ventricular tachyarrhythmias or death, to the same level as inactive patients. Therefore, while regular low-moderate intensity physical activity, i.e. the usually recommended 150 min weekly, should be considered in all patients, high-intensity exercises should be denied in this clinical condition.

In patients with hypertrophic cardiomyopathy, the risk of exercise-induced ischaemia should be considered.[81,82] A recent study found that 50% of patients with hypertrophic cardiomyopathy experienced myocardial ischaemia at rest.[83] Ischaemic events were confirmed by positive results from high-sensitivity troponin tests. Therefore, patients with hypertrophic cardiomyopathy should be monitored as regard of high-sensitivity troponin positivity or negativity for safety exercise.[81]

For all patients with CIEDs, physical activities associated with a risk of chest trauma (e.g. rugby, boxing, martial arts) should be avoided. Other sports (like soccer, basketball, baseball) can be possible while wearing appropriate padding. It is noteworthy that sports with pronounced arm movements (such as volleyball, basketball, tennis, golf, climbing) may increase the risk for late lead damage due to subclavian crush (with insulation or conductor failure). Implantation on the contralateral side of the dominant arm (e.g. at the left side in a right-handed tennis player), fixation within the pocket, or submuscular placement, may improve durability of the system. It is not known whether subcostal or epicardial implant techniques provide long-term benefit.

Electromagnetic interference (EMI) is unlikely with modern devices and no cases have been reported, however, it should always be suspected and evaluated in specific athletic environments with electronic equipment (e.g. fencing). As discussed in other sections of this paper, myopotential inhibition may result in inhibition of pacing, a problem that is more common with unipolar electrodes, although it usually can be corrected with appropriate reprogramming of the device.

The patients must be aware of the programmed detection rate cut-offs, avoiding to reach them during exercise. Conversely, detection zones need to be programmed sufficiently high to allow for high (enough) HRs during the desired exercise levels. This practice proved

safe and reduced the occurrence of shocks in the ICD Sports Safety Database.[84] The most common cause of inappropriate shocks in ICD patients is the occurrence of sinus tachycardia and supraventricular arrhythmias.[85]

Underlying heart disease and endurance sports 'per se' carries a higher risk for developing atrial fibrillation. Implantation of a dual system ICD for the sole reason of atrial arrhythmia detection and discrimination is generally not warranted because usually not effective.[86]

Similar to other cardiovascular patients, ICD patients often experience fear about the perceived strain of sexual activity on the heart and the subsequent potential for ICD shock. However, the absolute risk caused by sexual activity is considered to be extremely low, because sex for most patients represents only a moderate stress on the heart.[87] A specific and dedicated counselling has been advocated to face this issue.[88]

Summary box 6

- Asymptomatic patients, regardless of the LVEF, without exercise-induced ventricular arrhythmias should be advised to participate in low to moderate intensity leisure-time exercise activities.
- Symptomatic patients for exercise-induced arrhythmias should abstain from competitive and leisure sports or recreational exercise associated with moderate or high exercise intensity.
- In arrhythmogenic cardiomyopathy, regular exercise programmes may be associated with acceleration of the disease process and worsen outcomes.
- For all patients with CIEDs, physical activities associated with a risk of chest trauma (e.g. rugby, boxing, martial arts) should be avoided. Other sports (like soccer, basketball, baseball) can be possible while wearing appropriate padding. It is noteworthy that sports with pronounced arm movements (volleyball, basketball, tennis, golf, climbing) may increase the risk for late lead damage due to subclavian crush.
- The absolute risk caused by sexual activity is considered to be extremely low, because sex for most patients represents only a moderate stress on the heart. A specific and dedicated counselling has been advocated to face this issue in patients with CIEDs.

Psychological support and education

Psychosocial management directed by a psychologist is one of the core components of comprehensive secondary prevention and CR,[1] assessment and intervention modalities are described elsewhere.[89] Specific objectives are identification and correction of psychosocial and/or behavioural risk factors, optimization of the patient's awareness and acceptance of the disease, provision of psychological support to the patients and their caregivers, promotion of adherence and of disease management, activation of positive affectivity and of personal/sociofamilial resources.[89] In addition, assessment of occupational problems, reduction in occupational distress, family and social reintegration may be included among objectives.[89]

Pacemaker implantation for conventional reasons induces a clear improvement in QoL not only at several months or 1 year after implantation but also after long-term follow-up (7.5-year follow-up period) as shown in 881 bradycardia PM recipients included in the large scale nationwide Dutch FOLLOWPACE study.[90]

Quality of life is preserved for ICD patients, comparable to PM recipients,[91] however, ICD shocks lead to psychological distress.[92] Moreover, there is discordance between patients and clinicians on information requirements, in particular, the potential consequences of implantation on psychological well-being and QoL in the short and long term, as well as the care pathway at which to discuss ICD deactivation.[93]

Data on perceptions, experience, and QoL of patients living with ICDs are controversial. In a systematic review, 5 randomized controlled trials with a total of 5138 patients and 10 observational studies with a total of 1513 patients were analysed.[94] Patients were implanted for primary prevention purposes in three studies, secondary prevention in four, primary and secondary prevention in one, in the remaining studies indications were not reported. Nine studies found comparable QoL for ICD recipients and patients in the control groups, three studies found an increased QoL for ICD patients, and three studies found a decreased QoL for ICD patients.[94] Controversial results were found also comparing QoL of ICD patients with that of distinct control groups: medical treatment in six, PM in five, other typical cardiac procedures in the remaining studies.[94] Nevertheless, lower QoL was apparent among ICD patients who experienced device discharges, with a possible relation with the number of received shocks and the time from shock.[94] Number of received shocks seems to be an important variable: MADIT-RIT included 1500 patients from 98 hospital centres who received an ICD with or without concomitant CRT for primary prevention.[95] In this study, ≥2 appropriate or inappropriate ICD shocks and ≥2 appropriate ATPs were associated with more anxiety at 9-month follow-up despite no significant changes in the assessment of global QoL by the EQ-5D questionnaire.[95]

Although it is not clear if QoL of ICD recipients is worse than that of cardiac patients without an ICD, a proportion of them may suffer of anxiety and depression, like other patients with heart disease.

Data from the Cross-Sectional National CopenHeartICD Survey showed that patients with primary prevention ICD had lower levels of perceived health, QoL, and more fatigue. Anxiety, poor perceived health, fatigue, and low QoL were all predictors of mortality.[96]

All adults listed in the Swedish ICD and PM Registry in 2012, with an ICD implanted for at least 1 year (2658), were included in a study about multi-morbidity burden, psychological distress, and QoL.[97] Of

them, 8.5% showed depressive and 15.9% anxiety symptoms, 16.6% had type D personality.[97] Greater multi-morbidity burden, female sex, not working outside the home, history of ICD shocks, negative ICD experience, higher levels of ICD-related concerns, and the presence of anxiety, depression, or Type D personality were associated with worse QoL in ICD recipients. Multi-morbidity burden and psychological distress are essential factors related to QoL.[97] This issue should be discussed with potential ICD recipients prior to implant.[97]

Adjustment to life with an ICD may be challenging not only for some patients but also for their partners, with disease and individual characteristics likely influencing the process.[98] A cohort of 286 consecutively implanted patients, 21% women, and their partners completed questionnaires on social support and symptoms of anxiety and depression, prior to ICD implantation and 12 months later.[98] Higher ratings of perceived social support prior to ICD implantation were associated with greater reductions in couples' symptoms of anxiety and depression, whereas having received an ICD shock was associated with less improvement.[98] Secondary prevention indication for ICD implantation and symptomatic HF were associated with less improvement in anxiety symptoms and these associations applied to both patients' and partners' levels of distress.[98]

Cognitive behavioural therapy (CBT) is an effective tool in managing stress and symptoms related to anxiety, as well as for the minimization of catastrophic thoughts related to depressive symptoms in patients with ICDs.[99] An integrative review indicated that CBT has been effective in the treatment of ICD patients with depressive and anxiety symptoms. Research also showed that young women represented a risk group.[99] Lewin *et al.*[38] evaluated a brief home-based CBT rehabilitation programme for patients undergoing implantation of an ICD in a prospective multicentre, intention-to-treat, cluster-randomized controlled trial recruiting 192 patients. At 6 months, the intervention significantly improved QoL, reduced the incidence of clinically significant psychological distress, and significantly reduced unplanned readmissions.[38]

Finally, elderly individuals are increasingly represented among patients with ICDs, but data describing life with an ICD are scarce among octo- and non-agenarians. Moreover, few studies have reported elderly patients' perspective on discussions concerning what shock deactivation involves, preferences on battery replacement, and their attitudes about turning off the ICD nearing end-of-life. In a survey, participants were identified via the Swedish PM- and ICD-registry, with 229 octo- and non-agenarians (82.0 ± 2.2 years, 12% female).[100] About one-third (34%) had discussed their illness trajectory with their physician, with those octo- and non-agenarians being more decisive about a future deactivation (67% vs. 43%, $P < 0.01$).[100] A minority (13%) had discussed what turning off shocks would involve with their physician, and just 7% had told their family their wishes about a possible deactivation in the future.[100] Therefore, a significant majority of patients have not discussed possible future deactivation with their physician or family. Misunderstandings regarding withdrawing the ICD treatment in the end-of-life were evident, which may result in a potentially painful end-of-death with the ICD not being deactivated.

Summary box 7

- Pacemaker implantation for conventional reasons induces a clear improvement in QoL. Quality of life is preserved for ICD patients, comparable to PM recipients, however, ICD shocks lead to psychological distress.
- Lower QoL was apparent among ICD patients who experienced device discharges, with a possible relation with the number of received shocks and the time from shock. Although it is not clear if QoL of ICD recipients is worse than that of cardiac patients without an ICD, a proportion of them may suffer of anxiety and depression.
- Adjustment to life with an ICD may be challenging not only for some patients but also for their partners.
- Cognitive behavioural therapy is an effective tool in managing stress and symptoms related to anxiety, as well as for the minimization of catastrophic thoughts related to depressive symptoms in patients with ICDs.
- Elderly individuals are increasingly represented among patients with ICDs, but data describing life with an ICD are scarce among octo- and non-agenarians. Few studies have reported elderly patients' perspective on discussions concerning what shock deactivation involves, preferences on battery replacement, and their attitudes about turning off the ICD nearing end-of-life.

External electrotherapy in cardiac implantable electronic device recipients during cardiac rehabilitation

The term external electrotherapy (electrostimulation) describes the medical application of electric current generated by a special electrotherapy device and supplied to the patient via electrodes or via water as a guide medium. Electrotherapeutic procedures may be used for improvement of circulation, reduction of tissue swelling, warming of skin and deeper tissue layers, regulation of muscle tone, and pain reduction.

Electrotherapeutic applications are associated with the risk of electromagnetic interaction between the ICD or PM and the current-applying device (EMI).[101–103] The effect on implantable devices is complex and not surely predictable (temporary false inhibition/triggering, switching to asynchronous pacing rate, inappropriate energy delivery, programme restart, and complete destruction of electronics).

Electromagnetic interference is frequently encountered in electrosurgery, magnetic resonance imaging, or personal electromagnetic

equipment,[104–107] but has also been described in the physiotherapeutic environment.[107–110]

The data situation regarding the optimal management of CIED patients in CR needing electrotherapeutic procedures is currently still insufficient. Until now, there are no European guidelines or recommendations regarding the use of electrotherapeutic procedures in CR. Australia is the only country with definite guidelines for clinical use of electro-physical agents.[111] Available data are predominantly represented as case reports. More systematically, Digby *et al.*[112] performed a comprehensive review of the literature based on an own 2-year retrospective analysis including all physiotherapeutic treatments in a local physiotherapy practice facility. However, international physiotherapy societies and CIED manufacturers have not yet agreed on a consistent recommendation.

In the management of CIED patients, the following points should be considered during CR:

- avoid electrotherapeutic applications with high risk of EMI;
- consult with the implanting centre in case of doubt;
- provide a magnet for deactivating the anti-tachycardia function of an ICD in the context of a malfunction and ensure asynchronous stimulation;
- be especially cautious in stimulation-dependent and freshly operated patients;
- interrogate the device after application of electrotherapy with possible interaction; and
- in case of inadequate infrastructure of the rehabilitation clinic (no options of CIED programming, insufficient information about the underlying arrhythmias status), abstain from electrotherapy and use manual therapeutic procedures.

Except for the safe application of ultrasound, all types of electrostimulation are limited or contraindicated and should be performed under continuous ECG monitoring if necessary (*Table 5*).

Particularly the use of transcutaneous electrical nerve stimulation, diathermy, and interference current therapy usually regarded as contraindicated in CIED patients, and should be avoided within 3 months of electrode implantation.[113]

Return to work and fitness to drive

For patients with CIED, special barriers may arise in occupational reintegration, especially in industrial professions. Exposure to electrical fields are associated with the risk of electromagnetic interaction between CIED and the EMI by superimposing intrinsic biosignals or inputting noise signals.[105,114] The effect on implantable devices is complex and not surely predictable. External fields may influence electrical circuit, the internal memory or the leads/CIED case and surrounding tissue, inducing various malfunctions (thermal damage, electrode dislocation, temporary false inhibition/triggering, switching to asynchronous pacing rate, inappropriate energy delivery, programme restart, and complete destruction of electronics).[115]

Given a risk of EMI, the implantation of CIED may be a contraindication for the resumption of work in certain areas.[116]

Table 5 Application limitations of physiotherapeutic procedures in patients with cardiac implantable electronic devices[101,111,112]

Type of electrotherapy	Recommendation
DC application	
Constant DC	
Stable galvanization 1-, 2-, 3-, or 4 cells-bath Stangerbad (full hydrogalvanic bath)	Out of the CIED/electrode field no restrictions
Iontophoresis	
Pulsed DC (constant DC + low frequency AC)	
Impulse galvanization	Should be avoided
Diadynamic currents	Should be avoided
AC application	
High-frequency therapy (over 100 kHz)	
Shortwave diathermy	Should be avoided
Decimeter wave	At extremities possible with ECG monitoring, otherwise should be avoided
Microwave	At extremities and head possible, At thoracal and lumbal with ECG monitoring possible
Ultrasound	No restrictions
Medium frequency therapy (2000–36 000 Hz)	
Interference current	Should be avoided
Low-frequency therapy (up to 1000 Hz)	
TENS	Should be avoided
Stimulation current	Stimulation at extremities and head possible, at thoracal and lumbal area should be avoided

CIED, cardiac implantable electrical device; ECG, electrocardiogram; TENS, transcutaneous electrical nerve stimulation.

ELECTROMAGNETIC interference can be expected especially by oversensing of the electric field at an AC frequency of 50/60 Hz, less covered from band filters for lower and higher frequencies.[117] The extent and likelihood for EMI depends on exposure-related parameters (distances from the EMI source, modulation, magnetic and electric field strengths, current frequency) and on CIED- and lead-related parameters (aggregate model, programming parameters, lead configuration, implantation site).[118]

The actual incidence of relevant malfunctions of the CIED due to electromagnetic fields is low (0.5%),[119] affecting high-risk individuals who work in an industrial environment and it may be lower for workers in non-industrial environment. If there is uncertainty about electrical, magnetic, or electromagnetic interferences, an exact workplace analysis must be performed to identify potential risks. This should be done by the technical personnel of the organization, the professional association or the Technical Control Board, based on field measurements, and should be coordinated with the representative of the ICD manufacturer.[120,121]

During or at the end of a CR programme, sometimes patients can ask information about their fitness to drive. It is important to emphasize that patients with an ICD have an ongoing risk of sudden incapacitation that might cause harm to others while driving a car.

An EHRA Task Force on 'ICD and driving' was formed in 2009 to assess the risk of driving for ICD patients based on the literature available and it remains the most recent European scientific document about this argument.[122] The reader is referred to the reading of this document to get an overview of the problem, taking into account that driving restrictions vary across different countries in Europe, have many medico legal considerations, and that this argument is authority of individual member states in Europe. The same considerations apply to high-risk workers, such as pilots, professional drivers, and persons who handle dangerous or heavy machines or substances.

Summary box 8

- Electrotherapeutic applications are associated with the risk of EMI between the ICD or PM and the current-applying device. For patients with CIED, special barriers may arise in occupational reintegration, especially in industrial professions. Exposure to electrical fields is associated with the risk of EMI by superimposing intrinsic biosignals or inputting noise signals.
- In the management of the EMI risk in case of electrotherapeutic applications during CR or EMI risk in the workplace:
- avoid electrotherapeutic applications with high risk of EMI, consult with the implanting centre in case of doubt;
- provide a magnet for deactivating the anti-tachycardia function of an ICD in the context of a malfunction and ensure asynchronous stimulation;
- be especially cautious in stimulation-dependent and freshly operated patients;
- interrogate the device after application of electrotherapy with possible interaction;
- in case of inadequate infrastructure of the rehabilitation clinic, abstain from electrotherapy;
- in the workplace, if there is uncertainty about electrical, magnetic, or electromagnetic interferences, an exact analysis must be performed to identify potential risks. This should be done by the technical personnel of the organization, the professional association or the Technical Control Board, and should be coordinated with the representative of the ICD manufacturer; and
- during or at the end of a CR programme, sometimes patients can ask information about their fitness to drive. An EHRA Task Force on 'ICD and driving' was formed in 2009 to assess the risk of driving for ICD patients based on the literature available. The reader is referred to the reading of this document to get an overview of the problem.

Summary

- Cardiac rehabilitation is a multidisciplinary intervention including patient assessment and medical actions to promote stabilization, management of cardiovascular risk factors, vocational support, psychosocial management, physical activity counselling, and prescription of ET.
- Millions of people with CIEDs live in Europe and their numbers are progressively increasing, therefore large subsets of patients admitted in CR facilities have a CIED. Cardiac rehabilitation is a unique opportunity, not only to optimize medical treatment, increase exercise capacity, and improve patient physical and mental condition but also to supervise the correct functioning of the device and to reassure the patient with the CIED about physical activity. These patients should receive special attention, as their needs may differ from other patients participating in CR. Clinical and technical evaluation is the first step in evaluating CIED patients in a CR setting. History and clinical examination, chest X-ray, echocardiogram, Holter monitoring, and CPET should be performed before starting exercise-based CR.
- As the basis for exercise advice and prescription, a symptom-limited exercise test, preferably CPET, is mandatory. Endurance training intensity zones can be determined on the ventilatory thresholds, peak VO_2, or, in absence of a CPET, on HR and HR reserve.
- Both the patient and the CR team need to be aware of device settings, especially the rate cut-off for therapy in patients with a defibrillator. Patients should be instructed to keep the HR at least 10–20 b.p.m. below the rate cut-off during exercise. The communication of the settings to the CR team is also essential.
- Regarding effects of ET on functional capacity in CIED recipients, most of the information relates to ICD patients, few data are available in patients with CRT. Exercise training seems to be safe, improves aerobic capacity and is not associated with a significant increased risk of ICD shocks or adverse events. As in patients with HF, ET should be based on aerobic activity combined with resistance exercise. Respiratory exercise can be also useful in most frail and recently stabilized patients.
- In right ventricle arrhythmogenic cardiomyopathy, regular exercise programmes are associated with acceleration of the disease process and worsen outcomes. In patients with hypertrophic cardiomyopathy, the risk of exercise-induced ischaemia should be considered they should be monitored as regard of high-sensitivity troponin positivity or negativity for safety exercise.
- Similar to other cardiovascular patients, CIED patients, in particular those with an ICD, often experience fear about the perceived strain of sexual activity on the heart and the subsequent potential

for ICD shock. However, the absolute risk caused by sexual activity is extremely low, because sexual activity for most patients represents only a moderate stress on the heart. A specific and dedicated counselling has been advocated to face this issue.

- Psychosocial management is one of the core components of secondary prevention and CR, QoL is a very important issue in CIED recipients, particularly in those with an ICD. CBT may be an effective tool in managing stress and symptoms related to anxiety and depression.
- Electrotherapeutic procedures are sometimes used in CR and are associated with the risk of EMI. It is important to avoid electrotherapeutic applications with high risk of EMI and consult with the implanting centre in case of doubt. After application of electrotherapy, the device should be interrogated.
- For patients with CIED, special barriers may arise in occupational reintegration, especially in industrial professions. Exposure to electrical fields is associated with the risk of electromagnetic interaction between CIED and EMI. The same considerations apply to high-risk workers, such as pilots, professional drivers, and persons who handle dangerous or heavy machines or substances.
- During or at the end of a CR programme, sometimes patients can ask information about their fitness to drive. An EHRA Task Force on 'ICD and driving' was formed in 2009 to assess the risk of driving for ICD patients based on the literature available. The reader is referred to the reading of this document to get an overview of the problem.
- This clinical consensus document is expected to improve the implementation of adequate comprehensive CR in patients with CIEDs, fulfilling a previous gap in recommendations and providing treatment optimization of these patients.

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