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REVIEW

Clinical update

Exercise and competitive sports in patients with an implantable cardioverter-defibrillator

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Implantable cardioverter-defibrillators (ICDs) prevent sudden arrhythmic death in patients with different arrhythmogenic cardiac diseases. Because intense physical activity may trigger ventricular arrhythmias and may favour inappropriate shock delivery that impacts quality of life, current international recommendations only give clearance for moderate leisure-time physical activity to patients with an ICD. Hence, athletes are deemed non-eligible to compete with their ICD. The rationale for the current restriction from competitive sports is discussed in this review, as well as new insights that may alter these recommendations for certain sports participants in the foreseeable future. This review provides guidance for the choice of a durable lead and device system, careful programming tailored to the characteristics of the patient's physiological and pathological heart rhythms, instalment of preventive bradycardic medication, and guided rehabilitation with psychological counselling, allowing a maximum of benefit and a minimum of harm for physically active ICD patients.

Keywords Athlete • Implantable cardioverter-defibrillator • Ventricular arrhythmia • Sports

Sudden cardiac death (SCD) accounts for up to 50% of all cardiovascular mortality worldwide, and is mainly due to malignant ventricular arrhythmias. The implantable cardioverter-defibrillator (ICD) is a proven effective therapy to prevent SCD in high-risk cardiac patients and is considered standard therapy for primary and secondary prophylaxis of SCD in many indications.[1] Such patients may be athletic and/or physically active people. This review discusses some specific considerations about ICD therapy in such a population.

This paper was an invited review, requested by the Editor of the *European Heart Journal* after a pro-contra debate between the authors during the ESC Meeting 2013 (Amsterdam). This text refers to the existing recommendations, both European and American, and puts those into context with new information. Both authors are members of the ESC/EACPR Section on Sports Cardiology (and H.H. was Chair of that Section from 2010 to 2012) that issued the European recommendations. Moreover, H.H. was the first author of the Section's Recommendations on ICDs in athletes, and he was the European coordinator of the US/EU ICD Registry in Athletes. That Registry was endorsed by both the Section on Sports Cardiology of EACPR and by the Scientific Committee of EHRA.

Indications for implantable cardioverter-defibrillator therapy in athletes

Indications for ICD therapy in athletes are similar to those for the general population.[1] They are more specifically outlined in North American and European guidelines for competitive sport and leisure-time physical activity.[2–4]

Secondary ICD indications are obvious in case an athlete has developed a life-threatening arrhythmia and underlying pathology is evident. The group of young and physically active patients eligible for primary ICD implantation is rapidly growing. This is due to more widespread screening in family members with inherited arrhythmogenic conditions, channelopathies or cardiomyopathies, and to the rapid progress in genotypic identification of silent mutation carriers. The rationale for primary ICD implantation in some of them is that the first symptomatic manifestation of these diseases may be (exercise-related) SCD.[5] Moreover, asymptomatic athletes are increasingly evaluated by pre-participation screening,[6] which may

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unmask not only cardiac disease, but also a high risk for unexpected sudden death.[5,7,8] Whatever the circumstances of the cardiac disease diagnosis, when no causal therapy is available to prevent arrhythmia recurrences and when the risk of a potentially life-threatening arrhythmia is estimated to be high, the decision can be made to implant an ICD in an otherwise healthy and physically active patient.

The rationale behind current US and European recommendations on sports participation of implantable cardioverter-defibrillator patients

Current recommendations concerning ICDs in athletic populations emphasize that implantation of an ICD does not allow for any competitive or for intensive recreational sport participation.[2–4,9] The rationale behind these recommendations is based on six considerations, albeit largely indirect.

Firstly, intense exercise increases the risk of SCD in people with underlying arrhythmogenic cardiac diseases, on average 2.5-fold.[10] Intense and prolonged exercise leads to physiological adaptations. Among these, increased catecholamine levels are predominant and is associated with acidosis, dehydration, electrolyte disturbances and potential ischaemic conditions induced by exercise. All these changes may promote both development and perpetuation of arrhythmias.[11] Secondly, these arrhythmias and/or their appropriately delivered ICD shocks may lead to transient loss of consciousness which may be dangerous for the athlete or spectators. Thirdly, shock effectiveness under metabolic conditions associated with intense exercise is not really known.[12] Limits have been reported on the effectiveness of automated external defibrillators in these conditions.[13] Moreover, regular intensive exercise can promote worsening the course of some underlying cardiac diseases such as arrhythmogenic right ventricular cardiomyopathy (ARVC) and dilated cardiolaminopathies.[14,15] There is also concern that extensive arm movements could promote lead problems, or that direct hits to the generator pocket during practice could cause damage to the device. Finally, the potential for inappropriate ICD interventions may be increased during physical activity. They can be caused by a multitude of aetiologies such as sinus tachycardia, rapid conduction of other supraventricular arrhythmias, T-wave oversensing during exercise (with double counting), or noise due to lead failure (insulation defect, abrasion, or fracture). Other extrinsic causes include detection of diaphragmatic potentials, bad connections due to lose setscrews or lead pins that are not fitted correctly within the defibrillator header, and electromagnetic interference.[5] Inappropriate shocks can have a negative psychological impact on the ICD carrier, and could even be dangerous by promoting induction of ventricular arrhythmias when delivered on the T-wave. These potential negative effects of exercise explain why available recommendations concerning ICDs are restrictive for intensive sports participation.[2–4,9]

The flip side of the physical activity coin, also in implantable cardioverter-defibrillator carriers

On the other hand, it is well known that physical activity reduces cardiovascular morbidity and mortality through a wide variety of mechanisms,[16,17] although it is unclear whether the intensity of physical activity in competitive athletes promotes health benefits beyond those of moderate activities.[18] Physical activity also contributes to psychological well-being in those affected by cardiovascular disease. It has been demonstrated that ICD patients experience fear for occurrence of shocks but also depression about reduction of sporting activities, especially among adolescents.[19,20] Re-enabling them to participate, if this could proof safe, would be desirable. Moreover, studies have shown that exercise training of ICD patients during cardiac rehabilitation seems safe, without increased risk of shocks, and improves aerobic capacity.[21]

These seemingly contradictory elements explain why the appropriateness of sports participation with an ICD is so debated and still largely unclear.[22–25]

'Current' recommendations and their contestation

Current recommendations disqualify an athlete with an ICD for most competitive sports,[2–4,9] except those with a low cardiovascular demand, such as golf, billiard, or bowling.[26] In accordance with European recommendations, ICD patients may, however, be encouraged to participate to leisure-time physical activities with low-to-moderate dynamic or static demand and without risk of bodily collision.[4] This recommendation thus guarantees the health-promoting effects on physical and psychological well-being of moderate exercise conditioning, while preventing the (presumed) risks of competitive and intensive sports. The distinction between 'competitive' and 'recreational' serves as crude guidance rather than a strict separator, since it is well recognized that some recreational athletes push themselves to the limits, just like competitive athletes might do. The US and European recommendations, published from 2004 to 2006, are based on many unproven or indirect arguments, as summarized above. They appear too restrictive for patients and some physicians, especially in young physically active patients. This applies of course in the first place to asymptomatic and primary ICD implantation patients.

Therefore, in contradiction to current recommendations, cardiologists tend to allow competitive sports in particular cases. A study showed that 40–60% of queried American electrophysiologists had allowed athletes with ICDs to participate in competitive and contact sports. In that survey, ICD shocks were reported as common during sports, but injury to the patient and to the ICD system were relatively rare (respectively, <1 and 5%). However, two deaths were reported, one because of head injuries due to fall.[22]

Recently, a prospective international Registry has evaluated the risks associated with intensive sports participation for ICD patients.[27] It included 372 ICD-athletes (median age 33 years, 62% with beta-blockers, and median follow-up 31 months) who had made the

decision to participate in organized sports activities (i.e. regular practice and competition) in disregard of the standing recommendations. Forty-two per cent of the ICDs were implanted for secondary prevention. No death or resuscitated arrest and no arrhythmia- or shock-related injury during sports were reported. There were no generator malfunctions, and the freedom from lead malfunction was not lower than in contemporary lead survival series. On the other hand, the majority of shocks, both appropriate and inappropriate, occurred during sports or physical activity. Moreover, seven out of eight ventricular arrhythmia storms occurred during exercise. Nevertheless, the efficacy of shocks when appropriate was good. Apart from some limitations (patients were self-selected; no control group was studied; and antitachycardia pacing terminated ventricular arrhythmia episodes have not been evaluated), the Registry provides arguments that a blanket recommendation against competitive sports for all patients with ICDs is not really warranted. At least, the Registry provides some data that inform both physicians and athletes. They may enable balanced recommendations, in light of the six considerations about sports participation with an ICD as outlined above. For example, in a recreationally jogging asymptomatic LQT3 carrier, induction of arrhythmias or progression of the substrate are no concerns. If we rely on the Registry data on the effectiveness of shocks if needed and the low risk for lead damage, one could argue for participation. That is in contrast with a competitively active soccer player with ARVC, in whom arrhythmias may be promoted and the underlying substrate may progress.

We have to note that this Registry, albeit large, does not provide answers on many questions, like patients with substrates in which exercise is a more profound trigger (e.g. ischaemia or catecholaminergic polymorphic VT), or with a low ejection fraction, and whether any shocks alter the prognosis. Last but not least, the Registry showed that 30% of the patients who received a shock stopped their sport practice, indicating that the psychological impact of shocks (appropriate or inappropriate) is not negligible, and should be taken into consideration to play or not to play. This long-term effect is hardly studied.

Apart from the purely medical considerations, some answers will remain open, even with a much longer follow-up of the Registry, since they relate to philosophical and ethical aspects: in how far is a competitive athlete really free to decide based on information provided to him/her? Could a blanket allowance for (competitive) sports participation from the medical side reduce the opportunity for an athlete and his surrounding to find valid alternatives for continuation of competition, and hence making a free choice? There is an ethical ground that in instances where personal freedom may be lacking, society may supersede the right of a personal choice and take the decision to participate or not (like the mandatory obligation to wear seat belts). And in how far do we rely on our technical arsenal to send athletes in the arena and let them be resurrected if they succumb, rather than to prevent them from developing arrhythmias in the first place by restricting the intensity of their sports participation? These questions may have answers that are different in different countries, regions, sports federations, and between physicians. There is no wrong or right: this is about values and preferences . . . Therefore, counselling of patients and involved third-parties in light of local societal and cultural backgrounds will become of paramount importance in each individual case.

Taking individual athlete factors into account

Definitions of sport intensity and competition level also deserve consideration when giving clearance for sports participation in ICD patients. Classically, exercise intensity level is based on catecholamine blood levels[28] or oxygen consumption. From a physiological point of view, exercise can be defined as low or moderate when its intensity is lower than the individual anaerobic or ventilatory threshold. Intense exercise corresponds then to exercise intensity higher than this threshold.[29] Also duration of exercise is involved in the physiological alterations due to exercise, even it is moderate. Dehydration is more pronounced in long duration exercise than in short one.[30] Finally, environmental factors like extreme weather conditions also determine the physiological stress. According to current recommendations, a 'competitive' athlete is defined as a subject following a structured training programme in order to improve his/her performance or ranking. However, also a large number of 'recreational' subjects aim for the same goal and participate occasionally to competitions, mostly for individual sports, for pleasure and not necessarily for performance. One has to judge in how far their preparation and participation poses a potential risk as ICD carrier along the questions outlined above. This may impact the recommendation to participate or not. Thus, instead of systematically prohibiting all competitive sports in ICD patients, and allow all recreational mild-to-moderate sports, a broader and individualized evaluation is warranted. The risk to ICD patients should be graded, taking factors such as underlying cardiac disease, history, environmental factors, and personal attitude during sports into account. However, even 'low-risk' patients, in whom a more lenient exercise participation may be warranted, must be clearly informed of the potential risks and their potential psychological impact, and of the possibility that the risk level can change over time (e.g. after a cardiac event and/or worsening of the disease). It needs to be seen how future updates of the recommendations will be adapted along these lines. And, as mentioned, this may be region-specific.

Practical aspects of implantable cardioverter-defibrillator implantation in physically active patients

Implantable cardioverter-defibrillator selection and implantation

Concerning the choice of the device, in most cases a single right ventricular (RV) lead ('single-chamber ICD' or 'VVI-ICD') implantation may suffice. Accurate detection of fast ventricular rates depends on good sensing signals, which are therefore of even more importance in this patient population and should be critically assessed during lead implantation. To improve specificity of arrhythmia detection, dual chamber ICDs (i.e. with an atrial + ventricular lead, 'DDD-ICD') have been advocated by some. However, studies have shown that DDD-ICDs do not lead to a significant decreased incidence of inappropriate ICD therapy vs. VVI-devices.[31,32]. Moreover, an extra

atrial lead to the defibrillator configuration adds complexity during implant and follow-up. Large trials have clearly shown a higher incidence of early and late post-operative complications in DDD-ICD.[33] Although the ICD Registry has shown comparable lead longevity in athletes compared with other populations, many of these young patients will require replacement of the original ICD lead(s) later in life. If less leads are implanted during the initial procedure at young age, extraction, and/or placement of additional leads will be less indicated and less complicated, thus likely reducing morbidity (and mortality) in the longer term. Those considerations indicate that in many young patients a simple VVI-device may suffice, or that a single-pass lead (including atrial sensing) could be considered, unless there are specific reasons for implantation of an atrial lead.[5]

Because the ICD housing ('can') acts as one of the electrodes to defibrillate the heart ICD implantation is usually performed at the left infraclavicular region so that the heart is located within the shock vector between the can and RV shock coil. In physically active patients with left arm dominance, there is concern for lead fracture due to costo-clavicular crush. Thus, extreme ipsilateral arm movements should be avoided with some sports restriction (racket sports, swimming, volleyball, . . .).[5] A right-sided implanted defibrillator can be considered. The defibrillation threshold with such a configuration can be higher however, and thus needs to be tested during implantation. Some will opt for an abdominal implantation and epicardial pacing/sensing electrodes and a subcutaneous array for shocks, or even for a fully subcutaneous ICD (S-ICD), but systematic data on long-term performance of such configurations are not available (especially not in athletes populations).

Given the concern for lead problems in the longer term, there is interest in the applicability of fully S-ICD devices in athletic patients. The S-ICD is no real option when there is clearly pace-terminable arrhythmia history, but could certainly be of value in primary prophylaxis patients. Initial experience with S-ICD shows a high efficacy but a potential lower specificity of such devices, which could lead to more inappropriate shocks.[34] Large prospective comparative trials will be needed to fully gauge S-ICD potential compared with classical ICD.

ICDs providing resynchronisation via an additional LV epicardial lead (CRT-ICDs) are implanted in heart failure patients, which are restricted to moderate levels of physical activity during cardiac rehabilitation.[21] Restriction from intense or competitive sports is related to the underlying condition, not to the ICD per se.

Implantable cardioverter-defibrillator programming

Because of the young age of the majority of the physically active patients and the large range of heart rate changes induced by their lifestyle, specific device settings are needed.

Detection of life-threatening ventricular arrhythmias by ICD is mainly based on the ventricular rate. Different rate zones can be programmed and therapies specified for these different zones. One has to be cautious to activate lower rate cut-offs, since they may lead to higher inappropriate shock rates. It may be helpful to program additional discriminatory parameters to improve specificity for detection of ventricular arrhythmias (like sudden onset, stability or sustainability of rate, morphology), but one has to consider that these may impact sensitivity (e.g. ventricular arrhythmias may develop during sinus tachycardia). Therefore, care should be taken in the programming of such additional discriminatory parameters. It may be desirable to activate these algorithms only as a second line, like after inappropriate shock delivery. Application of shocks in the 'ventricular fibrillation (VF)' rate zone should be preceded by at least one attempt of antitachypacing to stop arrhythmia during charging of the ICD in order to reduce the need for shocks.[35] In young active patients, the 'VF'-zone threshold may be elevated to $\geq$210–220 b.p.m. Recent data have shown that in ICD patients, extension of the detection time at these rates also reduces inappropriate shocks without impacting safety.[36] Again, this needs confirmation in athletic populations that may be more prone to earlier loss of consciousness when arrhythmia develops during sports.

Sometimes, chronotropic incompetence can be observed, or bradycardic drugs could lead to symptomatic bradycardia. In such cases, AV sequential pacing via a DDD-ICD may be preferable to reduce symptoms due to pure ventricular pacing. If rate responsiveness is required, appropriate rate acceleration during the athlete's particular sport activity needs to be evaluated. This can be done by performing long-term ECG recording while training. Conversely, inappropriate rate acceleration during sports participation needs to be excluded. Dual sensors (minute ventilation + activity) are able to better adapt to different physical activities and would be desirable in ICDs for physically active patients.[37] The upper rate limit of rate responsive pacing in ICD patients is usually restricted by the requirement to detect ventricular arrhythmias, preventing programming of high pacing rates. To further evaluate appropriateness of device programming an exercise test and/or long-term ECG recording during sport sessions may be warranted.

Other considerations concerning sports participation after implantable cardioverter-defibrillator implantation

Leisure-time physical activity resumption is allowed from 6 weeks after implant, preferably after a control (sub)maximal exercise test. In case of appropriate or inappropriate ICD interventions, a few weeks refraining from sports could be reconsidered, to evaluate the effect of changes in medical therapy or ICD programming.[5]

Sports participation with strong and obligatory bodily contact (rugby, American football, shooting, martial arts) is contra-indicated.[2–5,27] For other sports with a smaller collision risk (soccer, basketball, hockey, . . .), some have advocated padding of the ICD implantation site, although effectiveness of these protection systems has never been proved.

Given the fact that there is latency between arrhythmia onset and ICD intervention to terminate it, physical activities during which dizziness or (pre)syncope would expose the patient or others to additional risks are relatively contra-indicated.

Strong magnetic fields could, mostly temporarily, inhibit tachy-arrhythmia therapy or lead to inappropriate interventions.

Patients should be instructed about this potentiality if encountering any sports-related exposition to electro-magnetic fields.[5]

Implantable cardioverter-defibrillator devices monitor physiological heart rates, arrhythmias, and sinus rate at which potential ventricular arrhythmias occur. Thus, a specific 'monitoring zone', with detection but without therapies, can be specifically programmed to gain more information in this regard. After a few months without problems, level of sports participation could be tailored to an individualized target heart rate, which can be monitored by the patient on a wrist device. Such advice should always be balanced vs. risk of exercise-triggered arrhythmias.[5]

Delivery of inappropriate shocks is the most important clinical concern in athletic ICD patients. They may result in important psychological problems, from anxiety to aversion, and coping problems with the ICD therapy. Correct identification of the cause of the inappropriate shocks is key to preventing recurrences.[5] The patient should get extensive reassurance and counselling to support an active life style with carefully titrated physical activities. The most effective therapy for inappropriate shocks is prevention, by precautions mentioned above. In this respect, anticipation and prevention of sinus tachycardia may be important, by limiting the amount of maximal exercise, warning against sudden bursts of exercise, and by prophylactic administration of bradycardic drugs such as beta-blockers. Calcium antagonists will be less effective in this respect. The indication for beta-blocker therapy needs to be explained to the patient, and be balanced against the impact on physical performance. The dose can sometimes be titrated by making use of the ICD monitor capabilities, as outlined above.

Conclusions

The ICD is a very important tool to prevent sudden arrhythmic death in people with malignant ventricular arrhythmias. In athletes and physically active people, quality of life with an ICD and long-term acceptance of the therapy will be highly dependent on prevention of inappropriate shocks. In this population, as few and as simple leads as possible, devices with high longevity, careful programming tailored to characteristics of the patient's physiological and pathological heart rhythms, rehabilitation with psychological counselling, and sometimes preventive bradycardic medication are required to achieve this goal. Concerning sport activity itself, balanced advice seems appropriate, based on the intermediate findings of the international ICD Registry. Whereas current recommendations do not allow for intensive or competitive sports, more leniency may be considered in some competitive athletes and is often possible in those who want to perform mild-to-moderate recreational activities.

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