





# Module 4. Conduction disorders, bradycardia, and management of athletes with a cardiac device



Exercise leads to morphological and functional adaptations that cause a wide variety of changes in the athlete's electrocardiogram (ECG). Among the rhythm and heart rate disorders, sinus bradycardia is the most common. Non specific intraventricular conduction disturbances may also be seen. However, fascicular and trunk blocks are rare, and while the PR interval may be prolonged, the presence of advanced second degree blocks and third-degree blocks is exceptional and should always point to an underlying organic pathology.

In this chapter, we will describe the different types of bradycardia and conduction disorders, as well as their management in athletes.

-  1. Types of bradycardia and conduction disorders
-  2. Management of athletes with bradycardia or conduction disorders
-  3 Definitions and concepts
-  4 Implantable cardioverter defibrillator

5. Specific considerations in athletes with pacemakers

6. Considerations regarding the implantation of devices in athletes

7 Follow-up for athletes with a device

8 Conclusions

References

# 1. Types of bradycardia and conduction disorders

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Below, we describe the main conduction abnormalities and bradycardia relevant in athletes.

## 1.2 Sinus bradycardia, sinus pauses and junctional rhythm

The presence of sinus bradycardia, defined as sinus rhythm with a heart rate <60 bpm, sinus pauses lasting 2-3 seconds, or junctional rhythm (QRS without P waves), is highly prevalent in young athletes and can be considered a physiological response to training. This occurs due to an increased vagal/sympathetic balance that slows the rate of the sinus node. Additionally, it has been described that sports practice also causes an intrinsic slowing of the sinus node (Stein et al., 2002).

## 1.3 Atrioventricular conduction disorders

The adaptive response to regular physical training also leads to a slowing of atrioventricular (AV) conduction. There are several types of atrioventricular block based on their electrocardiographic characteristics. In the cardiac pacing guidelines, electrocardiographic criteria are defined for each of them (Glikson et al., 2021):

**First degree atrioventricular block:** Athletes have a high prevalence of first-degree atrioventricular block (defined as PR interval lengthening  $>200$  ms with 1:1 atrioventricular conduction).

**Second-degree atrioventricular block:** There is atrioventricular conduction, but it is not 1:1; P waves are observed at a frequency of  $<100$  bpm that are not conducted to the ventricle.

There are several types of second-degree atrioventricular block that carry different prognoses depending on the block degree.

- **Second-degree atrioventricular block, Wenckebach or Mobitz type I:** Defined as a single non conducted P wave associated with progressive lengthening of the PR interval before the blocked impulse. This type of block is documented in 3% of athletes. It usually occurs at rest or during sleep, and it resolves during exercise or sympathetic stimulation (Zeppilli et al., 1980; Hanne-Paparo & Kellermann, 1981).

- **Second-degree atrioventricular block, Mobitz type II:** Defined as a non conducted P wave associated with a constant PR interval before the non blocked P wave. This type of block is often associated with more severe atrioventricular conduction disorders.
- **2:1 AV block:** P waves at a constant frequency <100 bpm, of which the second P wave is blocked and does not lead to the ventricle.
- **Advanced AV block:** Despite the presence of atrioventricular conduction, 2 or more P waves are observed at a constant heart rate <100 bpm that are not conducted to the ventricle.

**Complete or third degree AV block:** No evidence of conduction between the P and QRS waves.

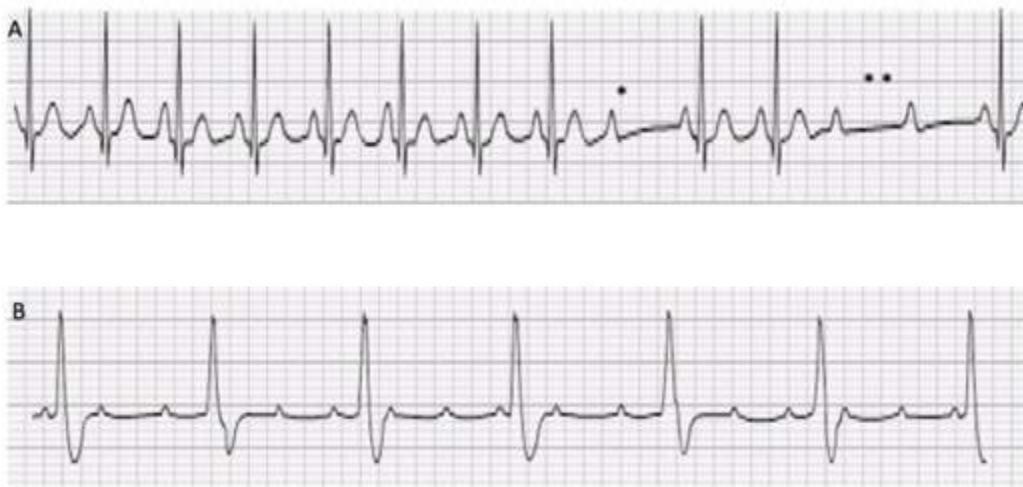
Figures 1 and 2 show examples of ECG strips with different types of AV block.

**Figure 1. ECG strips showing different types of conduction disorders:**  
**A) sinus pause >2 seconds (blue arrow); B) first-degree atrioventricular block (red PR arrow >200 ms); C) second degree AV block, Mobitz I or Wenckebach**



Source: own source.

**Figure 2. ECG strips: A) *second-degree AV block, type 2 and \* advanced AV block*; B) *complete AV block with ventricular escape rhythm***



Source: own source.

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## 2. Management of athletes with bradycardia or conduction disorders

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### 2.1 Sinus bradycardia, sinus pauses and atrioventricular junctional rhythm

Sinus bradycardia, sinus pauses of less than 3 seconds or first degree atrioventricular block, type Wenckebach, are highly prevalent in athletes and, to some extent, can be considered physiological as part of cardiac adaptation to exercise (Bjørnstad et al., 1994; Sharma et al., 1999). Heart rate can drop to 30-40 bpm in highly trained athletes, and even be lower than 30 bpm during sleep. All of this usually occurs asymptotically, has a benign prognosis, and there are no contraindications for sports participation.

Evaluation of these athletes includes a careful medical history to assess for symptoms related to bradycardia along with an appropriate clinical examination and a 12 lead ECG. In symptomatic athletes (dizziness, syncope, or exercise intolerance), as well as in cases of extreme bradycardia (<30 bpm on the ECG), it is recommended to perform long-term ECG monitoring and an exercise stress test to rule

out more advanced conduction disorders and confirm appropriate heart rate behavior in response to exercise. It is also recommended to complete the study with an echocardiogram to rule out underlying structural heart disease (Glikson et al., 2021).

Intense exercise or training can also cause an aggravation of sinus dysfunction due to previous heart disease or cause sinus dysfunction per se, and the athlete may start with symptoms (dizziness, syncope or presyncope). In these cases, symptoms typically occur during rest and not during exercise. Special attention should be given to athletes with sinus pauses longer than 4 seconds, and symptoms should be actively investigated in these individuals:

- In cases of **symptoms associated with bradycardia or sinus pauses**, cessation of sporting activity for 1 or 2 months may lead to clinical improvement or resolution of the condition. If this occurs, resuming training at a lower intensity can be considered, with follow up recommended at 6 months, and advising the athlete to consult earlier if symptoms reappear. Rarely, a pacemaker needs to be implanted in these patients (Baldesberger et al., 2008; Heidbuchel et al., 2021).
- In patients **with extreme bradycardia at rest** (<30 bpm on ECG):

- If they are **asymptomatic**, annual follow up is sufficient.
- In **symptomatic** patients, cessation of sporting activity is recommended for 1 or 2 months to assess whether there is clinical improvement or resolution of symptoms. If so, resuming training at a lower intensity can be considered, with follow up recommended at 6 months and advising the athlete to consult earlier if symptoms reappear. If symptoms do not resolve, the need for a pacemaker should be evaluated by a specialized physician.

## **2.2 First-degree atrioventricular block or second-degree Wenckebach (Mobitz I) block**

Slowing of AV node conduction is part of the physiological adaptations to exercise (Glikson et al., 2021; Zeppilli et al., 1980; Bjørnstad et al., 1994). Like sinus bradycardia, asymptomatic first degree AV block or second degree Wenckebach (Mobitz type I) block is highly prevalent in athletes and is usually asymptomatic. This type of block is typically seen at rest or during sleep and resolves with exercise, when the athlete's sympathetic tone increases (Zeppilli et al., 1980; Bjørnstad et al., 1994; Zehender et al., 1990). Most first-degree

AV blocks show moderate prolongation (around 280 ms) (Ector et al., 1984). In these cases, there is no contraindication for sports practice. However, it is important to confirm that the abnormalities correct themselves through sympathetic stimulation or exercise (Zeppilli et al., 1980). If this is the case, no further testing or treatment is necessary.

In case of symptomatology, it can be resolved with the temporary discontinuation of sports practice. If symptoms have resolved, sporting activity can be resumed under medical supervision after 6 months.

In asymptomatic cases, especially in athletes with extreme PR prolongation (>300 ms), annual reevaluation is recommended, since no data on natural progression in athletes are available.

### **2.3 Type 2 second-degree atrioventricular block, advanced atrioventricular block, or complete AV block**

Unlike sinus bradycardia or first-degree AV blocks or second-degree Mobitz type 1 (Wenckebach) blocks, second-degree Mobitz type 2 blocks, 2:1 AV block, advanced or complete AV block are rarely physiological, although these types of conduction disorders have occasionally been reported in athletes with high training volumes,

especially in endurance sports (Northcote et al., 1989; Viitasalo et al., 1982).

In such conduction disorders, a more comprehensive cardiological evaluation should be performed to exclude the presence of structural heart disease or ventricular arrhythmias (Heidbuchel et al., 2021). Cardiac imaging tests, stress test, prolonged ECG monitoring, and electrophysiological study (to assess the presence of infra-Hisian block) (Doutreleau et al., 2013) may be necessary to complete the evaluation in these patients. If conduction disturbances resolve during sympathetic stimulation or exercise, enhanced vagal tone is more likely the cause. However, ventricular pauses  $\rightarrow$ 3 seconds or a resting heart rate of 40 bpm due to conduction abnormalities are rarely seen in recreational athletes, although such abnormalities have been described in high level athletes (Bettini et al., 1990; Vidal et al., 2017).

In the absence of structural heart disease, a 2 month period of sports deconditioning can be considered, and a return to low-to-moderate intensity sporting activity can be evaluated if symptoms resolve. If symptoms persist (dizziness, syncope, or exercise intolerance), pacemaker implantation should be considered (Glikson et al., 2021; Heidbuchel et al., 2021).

In the absence of a reversible cause (including sports deconditioning), due to the risk of severe symptoms or possible progression to more

advanced or complete AV block, pacemaker implantation is recommended even in the absence of symptoms (Glikson et al., 2021; Heidbuchel et al., 2021).

## **2.4 Implantable cardiac devices: Pacemaker and implantable cardioverter defibrillator**

The first permanent pacemakers were implanted in the 1950s in patients with acquired complete heart block. Many years later, implantable cardioverter defibrillator (ICD) technology was developed, and the first devices were placed in humans in the mid-1980s.

Some athletes who have had a pacemaker or ICD implanted continue to participate in high intensity and competitive sports after implantation. More than 4% of electrophysiologists surveyed in a study published in 2006 had at least one patient who continued participating in more vigorous sports than golf after ICD implantation (Lampert et al., 2006). This finding was surprising given the sports eligibility recommendations in effect at the time (36th Bethesda Conference of 2005), which allowed only low intensity sports (e.g., bowling, billiards, golf, etc.) (Maron & Zipes, 2005). Subsequent studies have demonstrated a low incidence of adverse outcomes associated with participation in competitive sports in patients with implantable

cardiac electronic devices (ICEDs), despite the fact that sports can be arrhythmogenic in some athletes (Saarel et al., 2018).

In this section, we review the types of devices available and special considerations for athletes.

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## 3 Definitions and concepts

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### 3.1 Pacemaker

Indications for pacemakers include sinus node dysfunction, advanced atrioventricular block, refractory arrhythmias (e.g., bradycardia-tachycardia syndrome), and heart failure (Glikson et al., 2021). Unlike patients with ICDs, patients with pacemakers have not been restricted from participating in competitive sports, although there are few published data on the extent of participation or the safety of sports practice in this population (most are case reports or small series).

There are several types of pacemakers:

- **Endocardial pacemakers:** Endocardial pacemakers consist of a system composed of: a) a generator (pacemaker), which is usually implanted subcutaneously (typically) or sub-muscularly in the pectoral region; b) electrodes that are typically

implanted through the axillary/cephalic or subclavian vein into the myocardium (right atrium or ventricle) and connected on the other end to the pacemaker generator. Pacemakers have the ability to detect cardiac activity and stimulate the myocardium. Depending on the type of pacemaker, they are classified as single chamber (only stimulating or sensing one cardiac cavity, usually the right ventricle) or dual chamber (typically with two electrodes, one in the right atrium and one in the right ventricle), which sense and stimulate the myocardium in both cardiac cavities, thus coordinating the electrical activity between the atrium and ventricle.

**Figure 3. Types of endocardial pacemakers. A) single-chamber; B) dual-chamber; C) triple-chamber or cardiac resynchronization device, and D) leadless or transcatheter pacemaker in the septo-apical portion of the right ventricle**



**Electrode in the right ventricle; electrode in the right atrial; \*  
electrode for left ventricular pacing in a cardiac resynchronization  
device**

- **Epicardial pacemaker:** In some patients with congenital anomalies, either in venous or cardiac anatomy, or with poor venous access, the electrodes are implanted in the chamber to be sensed and stimulated via the epicardium, through a thoracotomy during cardiac surgery or through a small thoracotomy or robotic surgery. These electrodes, like the endocardial electrodes, detect cardiac activity and are capable of stimulating the myocardium. They are connected to a pacemaker generator, which is sometimes implanted in the pectoral region like endocardial pacemakers, and in other cases, located sub-muscularly in the abdominal area.
- **Cardiac resynchronization pacemaker:** It has the ability to stimulate both ventricles (right and left), resulting in a more synchronous contraction of the left ventricle. These devices are implanted in patients with dilated heart disease with ventricular

dysfunction (left ventricular ejection fraction [LVEF] <35%) and wide QRS type left bundle branch block (LBBB) or ventricular dysfunction and in patients with complete atrioventricular block and ejection fraction (EF) <40%. Cardiac resynchronization therapy, by improving the electrical and mechanical asynchrony in these patients, enhances their quality of life and cardiac function (Glikson et al., 2021). The system consists of a generator, typically implanted in the pectoral region like endocardial pacemakers, and up to 3 electrodes: one implanted in the right atrial endocardium, another in the right ventricular endocardium (as in a conventional endocardial pacemaker), and one for stimulating the left ventricle, implanted in the lateral epicardial veins of the heart through coronary sinus cannulation.

- **Leadless or transcatheter pacemakers:** Recently, to address the issues related to pacemaker electrodes and the surgical wounds required for the implantation and replacement of conventional pacemakers, a special type of pacemaker that functions without leads has been developed. These are intracardiac pacemakers, which are very small (like a tiny capsule) and are implanted directly into the right ventricle, where they can sense and stimulate the myocardium of the right ventricle. Unlike conventional pacemakers, these devices are small in size and are implanted using a specific

cannulation device via the femoral vein. They do not require surgical wound in the pectoral area and drastically reduce complications related to the generator and electrodes (Seriwala et al., 2016).

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## 4 Implantable cardioverter defibrillator

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There are heart diseases that increase the patient's risk of sudden death due to ventricular arrhythmias. In these patients, implantation of an implantable cardioverter defibrillator (ICD) improves survival and decreases the risk of sudden death (Zeppenfeld et al., 2022).

Unlike pacemakers, which only solve the problem of bradycardia or cardiac pauses, the ICD is also capable of detecting and treating malignant ventricular arrhythmias that can cause sudden death in the patient.

At present, there are 2 main types:

- **Endovenous ICD (single-chamber, dual-chamber, triple-chamber):** It consists of a system with a generator (located in the pectoral area, either subcutaneously or, sometimes, sub-muscularly) and an electrode that is positioned in the right ventricle endocardium. These devices sense cardiac electrical activity and have the ability to stimulate the

myocardium as pacemakers do in case of pauses or slow heart rates. In addition, they have a high-energy circuit capable of delivering an electric shock to treat malignant ventricular arrhythmias, thus treating or preventing sudden arrhythmic death in our patients.

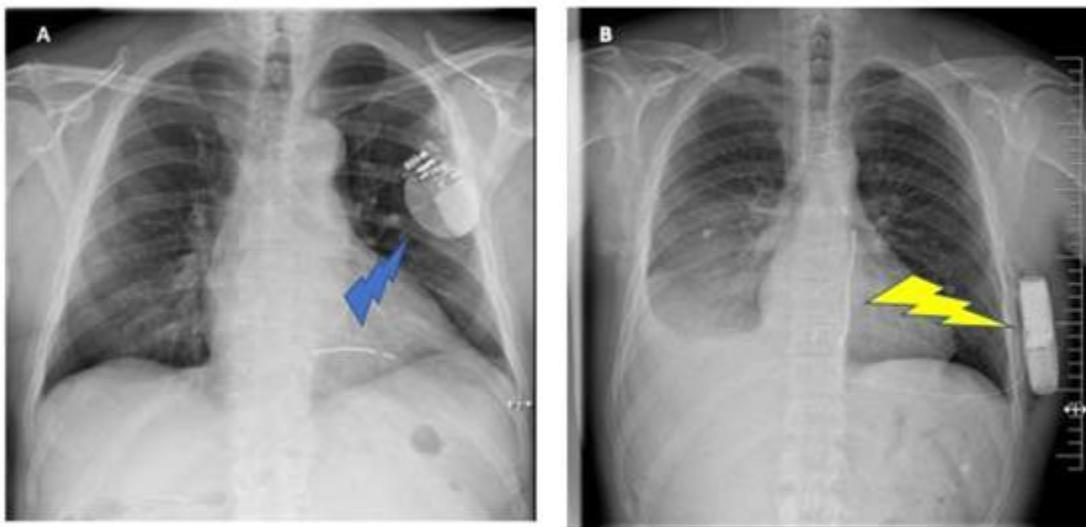
ICDs can be single-chamber (electrode in the right ventricle); dual-chamber (pacemaker-like electrode in the right atrium and a defibrillator electrode in the right ventricle); and triple chamber, like the previously described triple chamber pacemaker, but the right ventricular electrode is a defibrillation electrode instead of a pacemaker electrode.

- **Subcutaneous ICD:** Recently, defibrillators have been designed to treat malignant ventricular arrhythmias (ventricular fibrillation or tachycardia) without touching the heart.

One of the problems with defibrillators is electrode malfunction. By 8 years, around 25% of patients have required reinterventions due to electrode malfunction or fracture. This leads to a risk of device infection and a rate of inappropriate therapies. The subcutaneous ICD is as effective as a conventional endovenous ICD and is also associated with a lower rate of electrode related complications.

The device consists of a generator implanted on the lateral chest wall between the serratus anterior and latissimus dorsi muscles, and it also has an electrode that is tunneled subcutaneously over the sternum (Figure 4).

**Figure 4. A) transvenous ICD; blue lightning bolt, current during high-energy shock between right ventricle coil and defibrillator generator; B) subcutaneous ICD; yellow lightning bolt, current during high energy shock between parasternal coil and defibrillator generator**



Source: own source.

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One of the limitations of this device is that it cannot pace the heart, making it contraindicated in patients who require cardiac resynchronization therapy or need heart pacing, either due to bradycardia and cardiac pauses or slow ventricular tachycardias that could be treated with antitachycardia pacing instead of defibrillation, which is more painful (Knops et al., 2020).

#### **4.1 Recommendations for sports practice in individuals with an implantable cardiac device**

Sports practice can potentially have several unfavorable effects on athletes with cardiac devices:

- 1 Sports can increase ventricular arrhythmias dependent on adrenergic stimulation.
- 2 Sports can promote the phenotypic expression and progression of certain diseases (e.g., arrhythmogenic cardiomyopathy or mutations in lamin A/C).
- 3 Sports can promote the occurrence of inappropriate therapies in devices and the deterioration of electrodes.

Therefore, when assessing the risk of sports practice in individuals with ICDs, 2 considerations must be taken into account: one related to the **underlying pathology**, and the other related to the risks associated with potential **device malfunction**.

When making decisions about sports participation, it is important to engage in “shared decision-making” with the athlete, always considering the effect of sports on the underlying substrate, the fact that intensive sports may damage the device or trigger appropriate or inappropriate shocks, the psychological impact of shocks on the athlete, and the potential risk to others. The effective return to sports practice will depend on the type of sport and should be the result of clear communication between the physician, the athlete, and potentially other stakeholders (family, coach, trainers, team).

With respect to the **underlying pathology**, based on the available evidence, the main general recommendations are as follows (Heidbuchel et al., 2021; Zipes et al., 2015):

- If the sport **contributes to the progression of the underlying disease** (e.g., arrhythmogenic cardiomyopathy or mutations in lamin A/C), it is contraindicated. It is important to emphasize that in no case can the ICD be an excuse to practice this type of sport without restrictions, nor should an ICD be implanted to allow the sports practice.

- If the sport **contributes to the development of ventricular arrhythmias** (e.g., catecholaminergic polymorphic ventricular tachycardia), competitive or high-intensity sports are contraindicated. ICD shocks (even if appropriate), are painful and can have a psychological impact on patients. In the International Sport Safety Registry for ICD patients, 30% 40% of athletes who experienced shocks stopped playing sport, at least temporarily, due to fear of further shocks (Heidbuchel et al., 2021; Pelliccia et al., 2021). Additionally, the proportion of athletes with appropriate and inappropriate shocks during exercise was higher in competitive sports than in recreational sports, highlighting the well known trigger effect of high intensity exercise (Heidbuchel et al., 2019).
- The most frequent cause of inappropriate shocks in ICDs is the appearance of sinus tachycardia and supraventricular arrhythmias. In several heart diseases (e.g., arrhythmogenic cardiomyopathy, Brugada syndrome, long QT syndrome, and short QT syndrome), atrial arrhythmias are more frequent than in the general population. Furthermore, long-term participation in endurance sports carries a higher risk of developing atrial fibrillation.

With respect to the **implantable device**, based on the available evidence, the main general recommendations are as follows (Heidbuchel et al., 2021; Zipes et al., 2015):

- An **impact on the generator** may directly damage the device or may promote bruises, wounds or erosions in the pocket where the generator is located (Heidbuchel et al., 2021; Zipes et al., 2015). Therefore, participation in sports with strong and mandatory body contact is contraindicated, as they may cause physical damage to the device (e.g. rugby, American soccer, shooting and martial arts). For other sports with a lower risk of collision (e.g., soccer, basketball, field hockey, etc.), padding at the ICD implantation site has been recommended, although the effectiveness of these protective systems has never been demonstrated.
- Sports and sports environments that use electromagnetic equipment, which may create interference with pacemaker/ICD functions, should also be avoided. **Electromagnetic interference** can cause oversensing, which may lead to inhibition of pacing in pacemakers, while in ICDs it may result in inappropriate shocks.

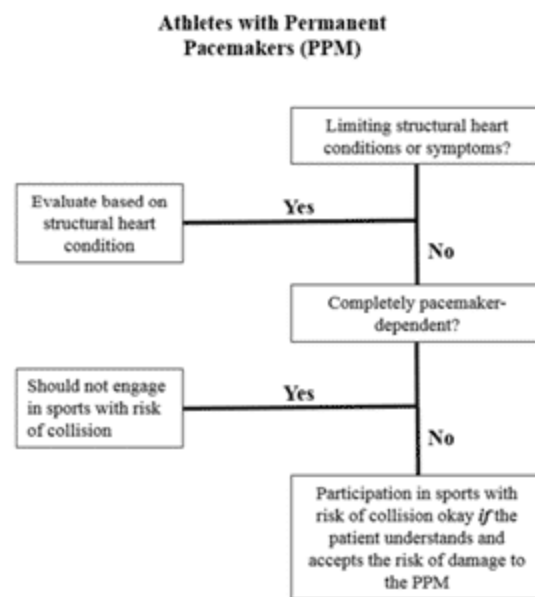
- Another risk for athletes with ICDs is electrode dysfunction, either due to displacement or fracture. **Displacement or dislocation** occurs mainly during the first six weeks post-implantation. Therefore, during this time, sports practice should be avoided, particularly those requiring extreme arm movements on the ipsilateral side of the pacemaker implantation (Pelliccia et al., 2021). **Total or partial electrode fracture** generally occurs later and are caused by extreme and repeated movements of the arm on the ipsilateral side of the implant, particularly in cases of subclavian vein access for lead implantation (subclavian crush).
- **Prolonged ECG monitoring** and device interrogation during and after resuming sports should be considered to allow appropriate programming of rate response pacing parameters, exclusion of myopotential or electromagnetic interference inhibition, and detection of appropriate AV conduction.

Finally, both due to the underlying heart disease (e.g., occurrence of sustained arrhythmias) or in relation to specific device-related aspects (such as ICD shocks, pacemaker inhibition due to noise or interference, etc.), it is important to avoid **situations where loss of concentration or loss of consciousness could cause harm to a third party or the**

**athlete** (e.g., motor sports, diving, mountaineering, even cycling) (Heidbuchel et al., 2021; Pelliccia et al., 2021). In cases where participation in these sports is chosen, as many precautions as possible should be taken (e.g., wearing a life jacket when swimming in open waters).

Figures 5 and 6 summarize the recommendations for sports practice for patients with pacemakers and ICDs, respectively.

### Figure 5. Decision making flowchart for athletes with permanent pacemakers



. 13.2 Decision-tree for athletes with permanent pacemakers

Source: Hammond & Saarel, 2021.

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## Figure 6. Decision making flowchart for athletes with implantable cardioverter defibrillator

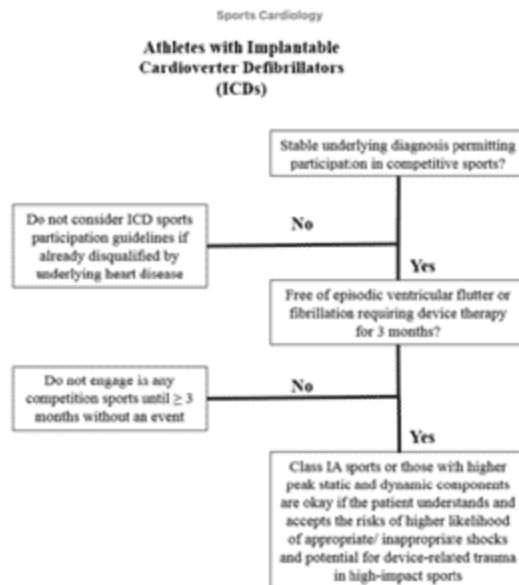


Fig. 13.3 Decision-tree for athletes with ICDs

Source: Hammond & Saarel, 2021.

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## 5. Specific considerations in athletes with pacemakers

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Unlike patients with ICDs, patients with pacemakers have generally not been restricted from participating in competitive sports, although there is very limited published data on the safety of sports participation in this population. In 2004, 9 long distance runners with pacemakers were analyzed as part of a 9 month training program with cardiac monitoring and intermittent device interrogation. Runners with complete AV block required an upper rate limit adjustment to >170-180 bpm to ensure atrioventricular synchrony at high atrial rates. No pacemaker dysfunction was observed during the training program or according to a survey 2 years later (Bennekens et al., 2004). In 1992, Schuger et al. described significant deterioration in two transvenous electrodes implanted on the right side in a softball player with a pacemaker. He was right-handed and trained intensively every day. He presented with an episode of syncope due to bradycardia, which led him to seek medical attention. Complete sectioning of the ventricular electrode and damage to the atrial lead were documented, likely caused by frequent and repetitive arm movements that resulted in crushing between the clavicle and first

rib (Schuger et al., 1992). While implantation techniques and lead designs have improved over the years, there remains a potential risk of damaging pacemaker or ICD leads with repetitive and vigorous arm movements, especially for electrodes located between the clavicle and the first rib.

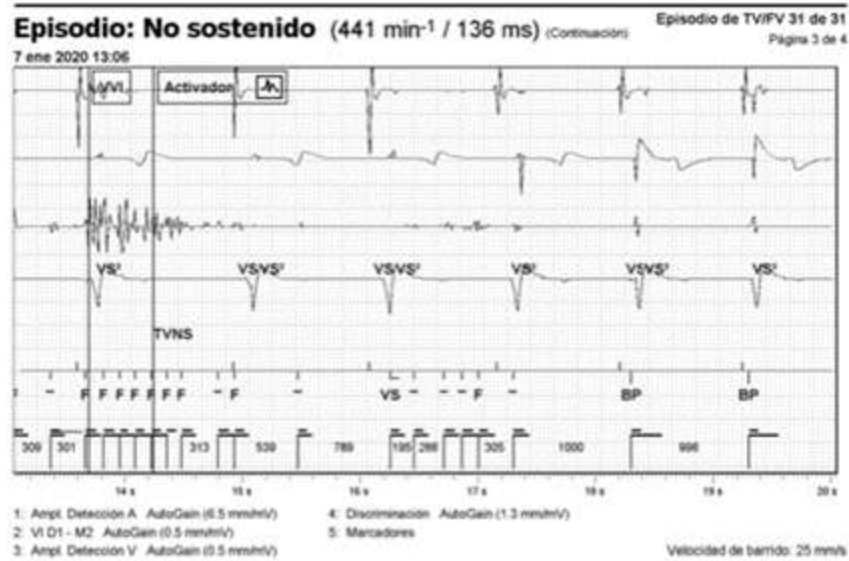
The risks for athletes with pacemakers, most of whom have structurally normal hearts without cardiomyopathy or a primary hereditary arrhythmic syndrome, are primarily centered around the possibility of damaging the device, including the pulse generator and leads. However, in cases where a pacemaker is implanted in the presence of heart disease (e.g., congenital heart disease, ventricular dysfunction without an indication for an ICD, etc.), it is important to note that physical exercise recommendations will also depend on the underlying pathology. In other words, in these cases, the heart disease dictates both the intensity and type of sport that can be performed; the pacemaker is not the primary limiting factor for sports practice.

Similarly, when estimating the risk associated with sports participation, it is important to know the patient's dependence on the pacemaker (i.e., the degree of ventricular pacing required). It is not the same for someone 100% dependent on pacemaker stimulation (with very low intrinsic cardiac rhythm or no intrinsic cardiac rhythm) as for those individuals with blockages or with paroxysmal (intermittent) pauses that cause the pacemaker to intervene on a few occasions. In

patients without an own rhythm or with a high percentage of pacemaker driven cardiac stimulation, it is essential to avoid sports that could endanger the patient's or teammates' lives in the event of pacemaker dysfunction (e.g., diving or climbing, as electrode fracture or electromagnetic interference could cause “noise” in the ventricular channel, inhibiting the pacemaker and resulting in loss of consciousness).

Electrode fracture in pacemaker patients may cause the pacemaker to mistakenly detect extracardiac signals (resulting in oversensing of interference or myopotentials), leading to inhibition of cardiac pacing or tachycardia (in the case of myopotential sensing in the atrial lead in dual- or triple chamber pacemakers) (Figure 7).

**Figure 7: Intracavitary electrograms showing ICD dysfunction due to myopotential sensing (extracardiac signals); F: myopotentials are falsely interpreted by the device as fast ventricular rate in the ventricular fibrillation zone; VS: right ventricular sensing outside the tachycardia zone; BP: bi ventricular pacing**



Source: own source.

## 5.1 Specific considerations in athletes with implantable cardioverter defibrillators

The practice of sporting activity in patients with ICD has traditionally been very restricted, partly due to the fear that sports practice increases the frequency of ventricular arrhythmias, the number of therapies (shocks for arrhythmic events or device dysfunction), the likelihood of generator or electrode damage, or harm to the athlete due to loss of consciousness (Pelliccia et al., 2021).

Recently, data from a registry of 440 athletes with ICDs has provided more clarity regarding sports participation in these patients (Lampert et al., 2017). During 44 months of follow-up, competitive or high-

intensity sports were not associated with more arrhythmic events, appropriate or inappropriate therapies, nor with increased dysfunction or electrode fracture. In this registry, ICD shocks were frequent, 10% of patients had an appropriate shock; however, although it was observed that therapies were more frequent during activity than at rest, no differences were observed with appropriate shocks whether the activity was sports or not. On the other hand, ICD therapies did differ according to the intensity of the exercise or sport performed, with a lower rate of appropriate and inappropriate shocks in those patients who practiced recreational sports compared to those who practiced sport at a competitive level. Since high-intensity sport at a competitive level has a trigger effect on these patients, it is important to make decisions in conjunction with the athlete to evaluate the intensity of the exercise to be performed.

Even in light of these reassuring data, patients with ICDs face more challenges when participating in sports compared to those with pacemakers. On the one hand, all ICD patients have structural heart disease, which limits their ability to engage in sporting activities; on the other hand, the ICD is more complex than the pacemaker and has a greater tendency to experience device dysfunction (Deharo et al., 2012).

The possibility of T wave oversensing during exercise has also been described in both endovenous and subcutaneous ICDs (Srivathsan et al., 2008; Ishibashi et al., 2017). Unfortunately, adjusting

programming based on stress test does not necessarily result in fewer inappropriate shocks for this reason, so it is not routinely recommended in this context (Cohen et al., 2011; Larbig et al., 2018). On the other hand, as previously mentioned, endurance sports can increase the risk of developing atrial fibrillation (Andersen et al., 2013), which can also predispose to inappropriate therapies in cases of poor ventricular rate control. In this case, an aggressive approach to rhythm control strategies is recommended, particularly through ablation techniques, given the drawbacks of antiarrhythmic treatment in this population.

Taking into consideration all of the above, in patients with ICDs, the current recommendations of the Cardiac Scientific Societies, both American (Zipes et al., 2015) and European (Heidbuchel et al., 2021; Pelliccia et al., 2021), are as follows:

- 1 Patients should follow the specific recommendations for their underlying disease.
- 2 Direct impact on the device should be prevented by: adapting the implant site of the generator or electrode(s), applying padding, or restricting contact sports.
- 3 Continuous ECG monitoring during sports practice should be considered to allow for appropriate device

programming.

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When considering participation in competitive or high intensity sports, shared decision making with the ICD recipient should be taken into account, considering the underlying condition, the fact that arrhythmias can promote the occurrence of more appropriate and inappropriate shocks, the psychological impact of shocks, and the potential risk to others.

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The ICD is not an alternative to allowing sport in individuals suffering from diseases that contraindicate it.

In individuals with ICDs who, considering the above, participate in sports, a 3-month window free of sustained ventricular arrhythmias is recommended before engaging in sports activity (Heidbuchel et al., 2021; Pelliccia et al., 2021).

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## 6. Considerations regarding the implantation of devices in athletes

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Even though many of the recommendations described below are appropriate for any patient with an indication for pacemaker or ICD implantation, we will place special emphasis on the differential aspects relevant to athletes.

### 6.1 Implant site and technique

The considerations regarding the side of the implant, the implantation technique and the complexity of the device are valid for both pacemakers and ICDs. The general rule is: the simpler, the better (Sweeney, 2012).

Another thing to keep in mind is the **implant side of the device**. The device should be implanted on the side opposite to the arm that the athlete uses for their sports practice (for example, tennis). However, it should be noted that, in the case of ICDs, right-sided implants can

result in higher defibrillation thresholds (Ziegelhoeffer et al., 2016), and for this reason, the left pectoral region is preferred in most cases. Typically, the generator is implanted in the pre-pectoral region due to the simplicity of the procedure. However, in individuals at risk of direct impact, submuscular implantation can be considered. The distance from the ipsilateral shoulder must be sufficient to allow a full range of motion without the device obstructing it.

On the other hand, as described in the previous section, electrode fracture due to repeated arm movements occurs primarily from trauma or chronic friction of the lead between the first rib and the clavicle (subclavian crush). Changing the implantation technique—by **accessing the venous system** through the axillary or cephalic vein instead of puncturing the subclavian vein—can reduce these types of complications (Jiménez-Díaz et al., 2019). Transcatheter pacemakers, which do not have electrodes (Seriwala et al., 2016), or subcutaneous ICDs (in patients without pacemaker indications or the need for antitachycardia pacing) (Knops et al., 2020) are valid alternatives to transvenous implantation with a lower rate of complications. While there is no specific data in athletic subpopulations, both leadless pacemakers and subcutaneous ICDs could be particularly beneficial in sports with extensive arm movements (e.g., swimming and rowing) to avoid friction or subclavian crush.

The number of electrodes will depend primarily on the indication for implantation, always keeping in mind the principle of 'the simpler, the

better. Patients with bradycardia requiring pacing should receive a dual-chamber device (Glikson et al., 2021). A dual-chamber ICD can be considered in other specific pathologies (e.g., long QT syndrome type 2 or 3 with pause dependent arrhythmias or hypertrophic cardiomyopathy with an outflow tract gradient). In all other cases, single-chamber devices are preferred, as greater complexity increases the risk of complications (Lee et al., 2010; Kirkfeldt et al., 2011; Hawkins et al., 2018). For ICDs, the implantation of a dual-chamber device solely to assist in the discrimination of supraventricular tachycardias is discouraged (Heidbuchel et al., 2021), given the lack of evidence that dual chamber algorithms reduce the number of inappropriate shocks or improve mortality (Zeitler et al., 2018), even in the athlete population (Olshansky et al., 2019).

### **6.3 Device programming**

### **6.4 Antibradycardia pacing (available in pacemakers and ICDs)**

In athletes with AV block (and in patients without chronotropic incompetence), dual chamber pacing is recommended to allow for more physiological pacing and chronotropic competence, which includes atrial sensing and ventricular pacing (or sensing/pacing in both chambers). Stress tests, or preferably ECG monitoring during

sports practice, can help determine the appropriate pacemaker programming parameters and are recommended for all athletes with pacemakers before allowing them to return to sports after implantation (Heidbuchel et al., 2021).

In cases of chronotropic incompetence, the predicted maximum heart rate for age should be used as the upper tracking rate limit.

Upper tracking rate limits are important for sports participation to avoid pacemaker upper rate behavior. Upper rate behavior occurs when a detected atrial systole (P wave) falls within the programmed post-ventricular atrial refractory period (PVARP) and is therefore not detected, leading to a Wenckebach pattern with a sudden deceleration of ventricular rate when the athlete is potentially at peak exercise.

In athletes with chronotropic incompetence, care must be taken in selecting the type of activity response sensor based on the predominant sport they perform. Piezoelectric motion sensors perform worse in cyclists who do not generate significant upper body movement during exercise. Equestrian sports would produce the opposite result (here, the horse generates the movement that leads to an increase in heart rate, while the rider does not necessarily perform the same intense exercise) (Lamas & Keefe, 1990). To overcome these limitations, minute ventilation sensors have been developed, which respond to exercise more proportionately but more slowly. Another

option is closed-loop pacing, in which intracardiac impedance is measured beat by beat and compared to a reference curve. There is limited evidence that patients prefer this method of frequency response to an accelerometer. Dual-sensor devices can be considered in selected cases, as they have been shown to improve quality of life, but not exercise capacity in a limited group of patients (Pilat et al., 2008). Prolonged ECG monitoring and stress test can also be useful in optimizing sensor response.

It is uncommon to find athletes with an indication for cardiac resynchronization therapy (either recreational or competitive), as these are typically individuals with severe left ventricular systolic dysfunction. If this is the case, AV and ventricular ventricular optimization should be performed during exercise, as ventricular asynchrony can change during exercise (Bennekers et al., 2004; Lafitte et al., 2006; Valzania et al., 2008).

### **6.5 Antitachycardia programming, antitachycardia pacing and shocks (ICD only)**

It has been described that programming high heart rate cut off points (>200 bpm) with prolonged detection times reduces both appropriate and inappropriate device shocks without worsening survival or increasing syncopal episodes (Olshansky et al., 2019). The athlete with

an ICD should also be informed about the heart rate cut off points programmed for delivering therapies, as well as the type of therapy. It is generally recommended to advise the athlete to stay 10 beats below the lowest programmed cut off rate. This implies a “strategic” device programming, which should ideally be adapted to the heart rate response during exercise (via stress test or, better yet, more realistically, through ECG monitoring during training or competition, aiming to program the lowest cutoff point above the maximum sinus rate reached).

With the current optimal programming for the S ICD, the inappropriate shock rate is 4.3% per year (Theuns et al., 2018), while data from the PainFree SST study in single chamber transvenous ICDs show an inappropriate shock rate of 2.5% per year (Auricchio et al., 2015). However, real-world data from the Altitude registry in transvenous ICDs show an inappropriate shock rate of 6% per year (Saxon et al., 2010).

Additionally, programming prolonged detection times (at least 6 to 12 seconds or for 30 intervals before completing detection) reduces the need for total and inappropriate therapies, with a tendency to reduce appropriate shocks as well (Olshansky et al., 2019).

Regarding the type of programming, there is no specific data for athletes. Based on PainFREE Rx II data, it seems logical to program at

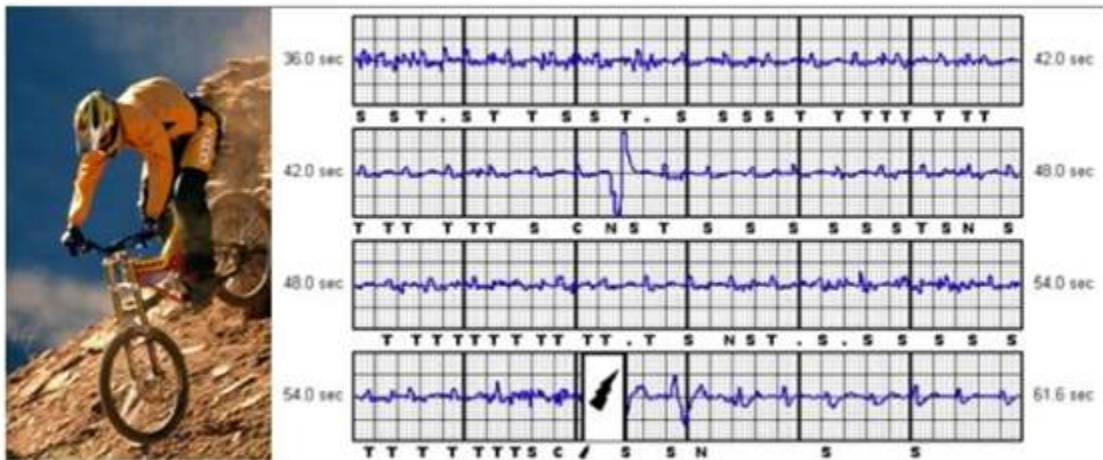
least one antitachycardia pacing (ATP) sequence (Wathen et al., 2004).

In subcutaneous ICDs, programming 2 zones potentially reduces the rate of inappropriate shocks (Gold et al., 2014). The Smart-Pass filter should be programmed “on”, as it appears to halve the incidence of inappropriate shocks (Theuns et al., 2018).

Remote monitoring has also been shown to reduce and detect ICD-associated complications early, and it is recommended that athletes with ICDs have remote follow-up (Heidbuchel et al., 2021; Pelliccia et al., 2021).

Figures 8 and 9 show episodes of appropriate and inappropriate ICD therapies that can be reviewed during device follow-up, either in person or via remote monitoring.

**Figure 8. Inappropriate shock from subcutaneous ICD due to myopotential sensing during extreme BMX downhill riding**



Source: own source.

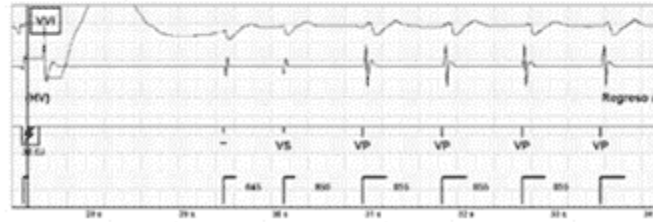
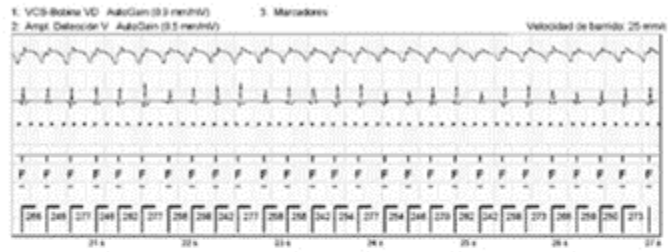
**Figure 9. Intracavitary ECG recordings of appropriate shock for rapid ventricular tachycardia in a patient with a transvenous ICD. VS: ventricular sensing outside of tachycardia zones; VP: ventricular paced rhythm; F rhythm in the ventricular fibrillation zone; \* declaration of VF and start of capacitor charging; HV: electric shock and post-shock rhythm**

Episodio: FV (226 min<sup>-1</sup> / 265 ms) (Continuado)

Episodio de TVIFV 1 de 1

5 de 2014 13:26

Página 3 de 3



Source: own source.

CONTINUE

## 7 Follow-up for athletes with a device

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It is important to inform the athlete about potential sources of electromagnetic interference (exit gates, scoring equipment during fencing, transcutaneous electrical nerve stimulation [TENS] during physiotherapy, etc.). In case of doubt, a Holter monitor or another ECG or heart rate monitor could be used to assess the device's functioning under such circumstances. The following link lists multiple possible causes of electromagnetic interference with implanted cardiac devices:

<https://www.heart.org/en/health-topics/arrhythmia/prevention--treatment-of-arrhythmia/devices-that-may-interfere-with-icds-and-pacemakers>

Additionally, although rare, it is important to note that placing a magnet over the ICD can inhibit therapies (as long as the magnet is in contact).

It is important to explain and inform the athlete's environment (coaches, family members, teammates, etc.) about the presence of the

ICD and how to act in case of shock. Likewise, the athlete must know how to act in the event of shock or syncope (Sears et al., 2005):

- In the event of a single shock at rest, without associated symptoms, the patient should contact their treating physician to assess the course of action.
- In the event of a shock during exercise, in the absence of symptoms, the patient should stop physical activity and contact their treating physician to assess the course of action.
- More than one shock within 24-48 hours, whether at rest or during exercise, requires immediate medical attention.

Additional measures, such as having resuscitation equipment on site, are not recommended. Currently, most sports facilities have automated external defibrillators (AEDs). In very specific situations, it may be helpful to have someone present who knows how to perform basic cardiopulmonary resuscitation (CPR) and use an AED.

Remote monitoring is highly recommended: it allows for early detection of potential issues with the device or leads, and also identifies arrhythmias that may impact sports participation. In the

ICD population, it has been shown to reduce mortality (Akar et al., 2015; Varma et al., 2015). Additionally, most pacemakers and ICDs now have diagnostic algorithms that enable the detection of both atrial and ventricular rapid heart rates. Device interrogation allows these events to be evaluated and provides better patient follow-up.

**CONTINUE**

## 8 Conclusions

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There is evidence suggesting that certain athletes with ICEDs may participate in high-intensity or competitive sports with a low incidence of adverse events. To provide appropriate recommendations, it is necessary to carefully assess the underlying heart disease, the indication for device implantation, and the type and intensity of the planned sporting activity. The most recent guidelines and expert consensus open the door to participation in high-intensity sports, as long as it is clinically reasonable and through shared decision-making, where the athlete understands and assumes the potential risk of adverse events. Additionally, the athlete's environment (coaches, physical trainers, sports organizations, etc.) must understand and anticipate the potential risks for an athlete with an ICED, and all possible means should be used to promote greater safety during sporting activity.

[CONTINUE](#)

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