Module 2. Supraventricular tachycardias

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Introduction

Supraventricular tachyarrhythmias are those arrhythmias in which the atria (or, more specifically, the His bundle or an upper tissue) are a central and necessary part of their maintenance (Brugada et al., 2020). Although supraventricular tachyarrhythmias can be classified according to various parameters, in this module, we will divide them based on their impact and specific characteristics in athletes. On the one hand, high intensity endurance sport has been shown to be a risk factor for the development of **atrial fibrillation** (AF) and atrial flutter. Among the paroxysmal supraventricular arrhythmias, some patients with **ventricular pre excitation** have an increased risk of sudden death, which does not occur in **other paroxysmal supraventricular tachycardias.**

Paroxysmal supraventricular tachycardias

In general, paroxysmal supraventricular tachycardias can manifest as palpitations, dizziness, reduced physical performance or even hemodynamic instability. Treatment by ablation procedures is curative in all of these manifestations. Although in the vast majority

of cases they have a benign course, ventricular preexcitation with or without palpitations—known as Wolff-Parkinson-White syndrome—deserves separate consideration among paroxysmal supraventricular tachycardias due to its importance in preparticipation screening. For this reason, they will be dealt with in a specific section.

Ventricular pre-excitation and accessory pathways

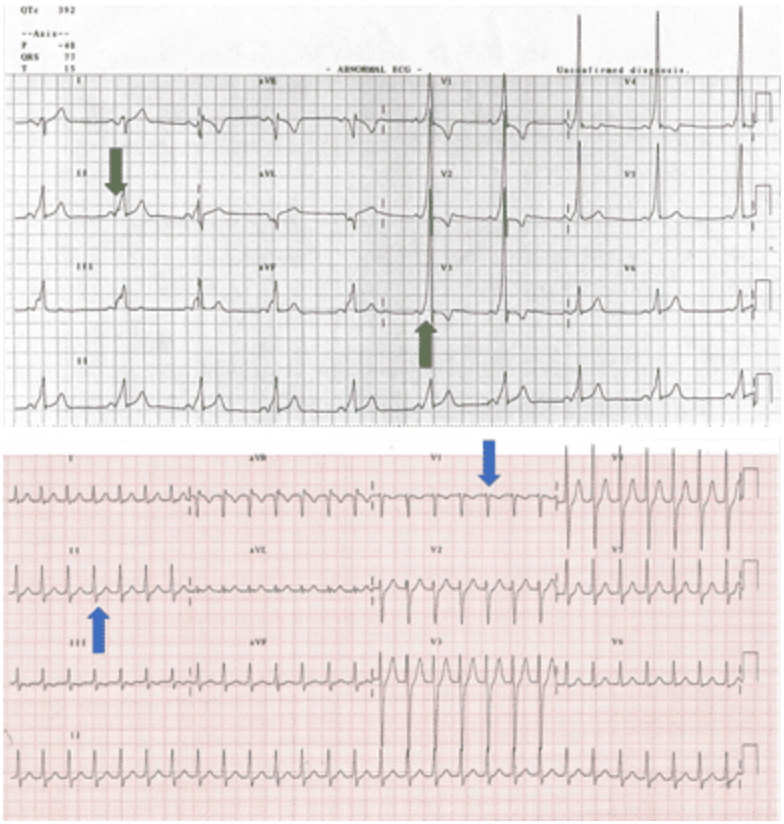
Ventricular pre-excitation syndromes owe their importance to their association, possibly causal but infrequent, with sudden death, both in the general population and especially in athletes. Ventricular pre-excitation consists of an abnormal connection (called accessory pathway) between the atria and the ventricles. This abnormal electrical connection is composed of ventricular myocardium, so its electrophysiological characteristics are those of the ventricle and differ from those of the atrioventricular node. The most significant difference is that accessory pathways do not exhibit decremental conduction, meaning their conduction speed does not slow down at higher heart rates, which limits their ability to filter atrial impulses conducted to the ventricle.

Symptoms and diagnosis

The diagnosis of ventricular preexcitation is established by the presence of the characteristic delta wave on the ECG, along with a short PR interval during sinus rhythm (upper panel in Figure 1). This

electrocardiographic pattern represents early conduction from the atrium to the ventricle through the accessory pathway and its subsequent collision with physiological activation via the atrioventricular node (right panel in Figure 2). Occasionally, the delta wave is difficult to visualize on the electrocardiogram (ECG); in such cases, vagal maneuvers (such as carotid sinus massage) or the administration of adenosine can be helpful. Both maneuvers slow or block physiological conduction in the atrioventricular node, but not in the accessory pathway, thereby magnifying and making the abnormal conduction morphology (delta wave) more evident.

Figure 1. Upper panel: ECG of a patient with ventricular pre excitation; the delta wave is indicated by the green arrow. Lower panel: ECG during tachycardia in a patient with atrioventricular nodal reentrant tachycardia; the blue arrows indicate the retrograde P wave (negative in lead II, positive in lead V1) located just behind the QRS complex



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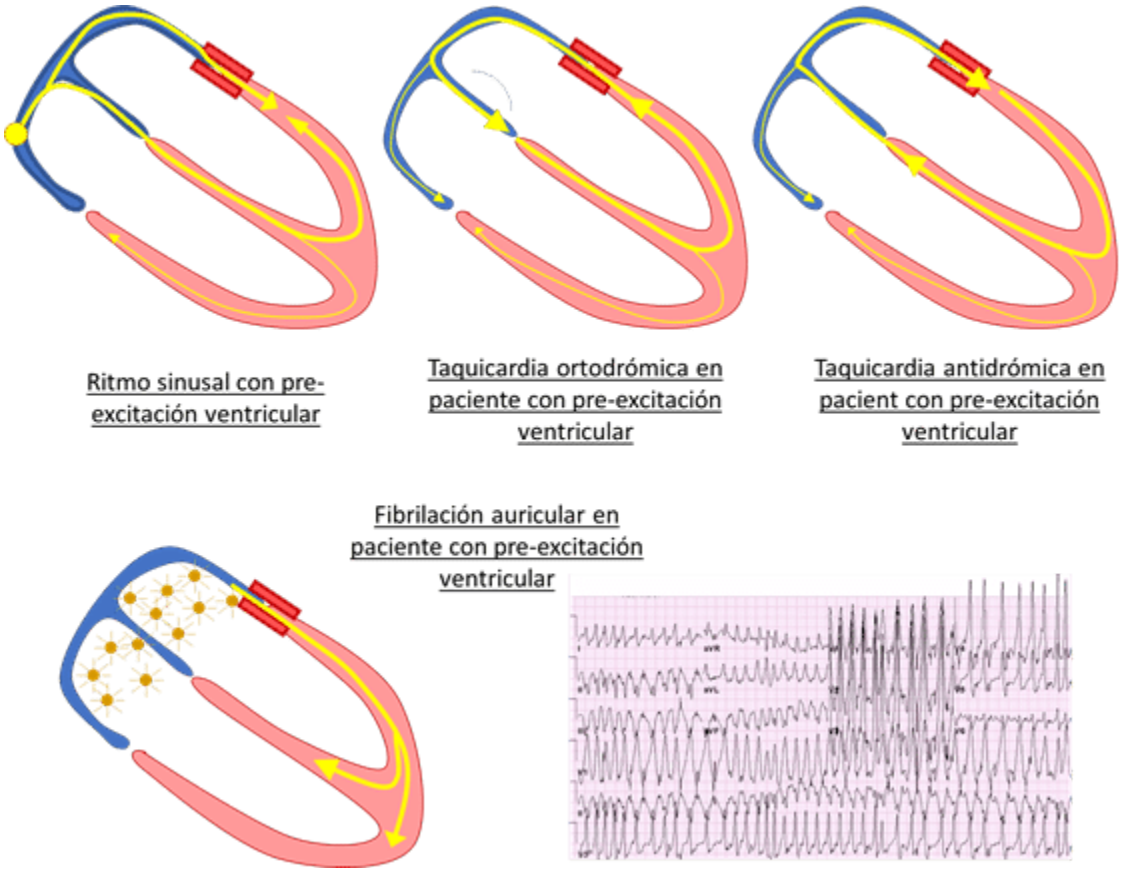
Many patients remain asymptomatic and are diagnosed incidentally during an ECG screening or an ECG performed for other reasons. Other patients present with symptoms due to supraventricular tachycardias caused by the formation of orthodromic or, rarely, antidromic atrioventricular reentry circuits (details in Figure 2, upper, middle and right panels). These tachycardias usually have a sudden onset and termination, with variable duration. The presence of an accessory pathway is also associated with an increased risk of developing AF (Della Bella et al., 1991). Precisely, the multiple simultaneous atrial activations that occur during AF can be conducted to the ventricles through the accessory pathway,

generating very high ventricular rates that can potentially degenerate into ventricular fibrillation and sudden death (lower panel in Figure 2). Although rare, this situation is more frequent during periods of heightened adrenergic tone (e.g., during physical exercise).

Figure 2. Schematic representation of atrial (in blue) and ventricular (in red) activation in a patient with ventricular pre excitation due to a left accessory pathway in sinus rhythm



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Ritmo sinusal con pre-excitación ventricular	Sinus rhythm with ventricular pre-excitation
Taquicardia ortodrómica en paciente con pre-excitación ventricular	Orthodromic tachycardia in patients with ventricular pre-excitation
Taquicardia antidrómica en paciente con pre-excitación ventricular	Antidromic tachycardia in patients with ventricular pre-excitation
Fibrilación auricular en paciente con pre-excitación ventricular	Atrial fibrillation in patients with ventricular pre-excitation

In Figure 2, the left panel shows the collision of activation fronts in the lateral wall of the left ventricle; orthodromic supraventricular tachycardia (middle panel, ventricular activation through the atrioventricular node, retrograde conduction via the accessory pathway), and antidromic supraventricular tachycardia (right panel, ventricular activation through the accessory pathway, retrograde conduction to the atria via the atrioventricular node). In the lower panel, a schematic and ECG of a patient with an accessory pathway and AF are shown; during AF, conduction to the ventricles preferentially occurs through the accessory pathway, potentially leading to very high heart rates in patients with pathways with a short refractory period.

Prognostic stratification and treatment

In general, accessory pathway ablation is the treatment of choice in athletes with symptomatic ventricular preexcitation, i.e., palpitations or documented tachycardia (Brugada et al., 2019; Pelliccia et al., 2021). Although ablation is a valid option for all athletes with ventricular pre-excitation, even if they remain asymptomatic, clinical practice guidelines suggest stratifying the risk of sudden death (Brugada et al., 2019). Non invasive stratification has demonstrated low accuracy in identifying high-risk patients (Escudero et al., 2020). In athletes, it is recommended that this stratification be performed through an electrophysiological study to assess the electrophysiological characteristics of the accessory pathway, with ablation indicated in patients with high risk features; for example, the coexistence of AF, inducibility of supraventricular arrhythmias, a refractory period of the pathway <250 ms, etc., which would allow conduction to the ventricle at very high rates (Pappone et al., 2014). In expert hands, ablation of accessory pathways is a safe procedure with high efficacy.

Eligibility for sporting activity

Based on the various recommendations from European societies, regular sporting activity is allowed in athletes with ventricular pre excitation after a successful ablation procedure or in those considered low risk even without ablation (Table 1) (1, 3).

Other supraventricular tachycardias

This section includes supraventricular tachycardias such as atrial tachycardia, nodal reentrant tachycardias, and atrioventricular reentrant tachycardia through a concealed accessory pathway (with only retrograde conduction, without anterograde conduction). The common factor among all of these is that, unlike ventricular pre excitation, they have not been shown to be associated with sudden death.

Briefly, atrial tachycardia and atrial extrasystoles originate focally from a region in the left or right atrium. In atrioventricular nodal reentrant tachycardia, a reentrant circuit is established between two branches of the atrioventricular node with different electrophysiological characteristics. Finally, concealed accessory pathways establish an abnormal connection between the atria and ventricles, but these do not conduct anterogradely, only retrogradely (from the ventricle to the atrium). As a result, they are not evident on a surface ECG and do not pose a risk of rapid conduction from the atrium to the ventricle; however, they can cause orthodromic atrioventricular reentrant tachycardias (middle panel in Figure 2).

<u>Symptoms and diagnosis</u>

In most cases, the diagnosis is established by obtaining an ECG during tachycardia while symptoms are present. Generally, a regular

tachycardia with a narrow QRS (<120 ms) will be observed, but in the presence of a baseline bundle branch block or after the administration of antiarrhythmic drugs, it may manifest as a wide QRS tachycardia. In this latter case, it is important to perform a differential diagnosis with monomorphic ventricular tachycardia (Moccetti et al., 2022; Brugada et al., 1991). In the case of supraventricular tachycardia, careful observation of the P wave position and morphology (lower panel in Figure 1) and performing vagal maneuvers can guide the diagnosis (Buttá et al., 2013; Borloz et al., 2010). For those athletes in whom the etiological diagnosis cannot be confirmed, or who present suggestive symptoms but an ECG cannot be obtained during the symptoms, an electrophysiological study can induce, diagnose and, in most cases, treat the condition.

Treatment

Ablation is recommended for symptomatic athletes with paroxysmal supraventricular tachycardias, especially if they are recurrent (Brugada et al., 2019). The goal of the procedure will vary depending on the type of tachycardia (elimination of the focus in atrial extrasystole/atrial tachycardia, ablation of the slow conduction pathway of the atrioventricular node in nodal reentrant tachycardias, ablation of the concealed accessory pathway in tachycardias mediated by retrograde accessory pathways). In expert hands, the risk of complications is very low, and the efficacy is high.

Chronic pharmacological treatment is an option for athletes who do not wish to undergo ablation (or after an unsuccessful procedure) and includes the use of beta blockers, non dihydropyridine calcium channel blockers, or class Ic (flecainide, propafenone) or III (amiodarone) antiarrhythmics, depending on the type of tachycardia (Brugada et al., 2019). However, these drugs have drawbacks and contraindications, especially for athletes (as will be described in the section on AF), so their role is very limited.

Eligibility for sporting activity

The most recent clinical practice guidelines allow sporting activity for athletes who have undergone successful ablation, or if ablation is not performed or is ineffective, provided the arrhythmia is infrequent, well tolerated, and unrelated to sports (Brugada et al., 2019; Pelliccia et al., 2020). In this regard, refer to Table 1.

Table 1. Main supraventricular arrhythmias diagnosed in athletes (atrial fibrillation is discussed in a specific section), their management and eligibility for sports participation. EPS: electrophysiological study

Supraventricular arrhythmias	Recommended management	Eligibility for sports practice

Supraventricular extrasystole/atrial tachycardia	Ablation Alternatively: drugs, observation	If ablation is effective or symptoms are infrequent and are not related to exercise
Symptomatic ventricular pre-excitation	Ablation	After effective ablation
Asymptomatic ventricular pre-excitation	Risk stratification (EPS)	High risk: after effective ablation
		Low risk: always
Paroxysmal supraventricular tachycardia	Ablation	After effective ablation
	Observation/ drugs	If symptoms are infrequent and are not related to exercise

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Atrial fibrillation

AF and flutter are discussed in this module due to their characteristic pathophysiology, more complex management, and especially the role

that endurance sports play in increasing the risk of developing these conditions.

Although AF and flutter overlap in some aspects, a brief description of the differential characteristics of flutter is provided after the section dedicated to AF.

Atrial fibrillation and endurance sports

AF is the most common sustained arrhythmia in the general population, but its relevance is particularly significant among athletes, as current evidence points to very high intensity exercise as a major contributor to AF in young patients.

The causal relationship between sports and the risk of AF has been extensively studied over the past two decades, particularly in high level athletes. The risk of AF is eight times higher in marathon runners (Mont et al., 2002) and five times higher in orienteers (Karjalainen et al., 1998) than in the general population, while the prevalence of AF in veteran high level athletes (such as cyclists or cross country skiers) is high, exceeding 10% (Baldesberger et al., 2008; Van Buuren et al., 2012). The proarrhythmogenic effect of very high-intensity sports is not limited to elite athletes but also affects the most active individuals in the general population (Drca et al., 2014; Andersen et al., 2015). For example, in people under 50 years of age, the risk of AF progressively increases with the number of days per week they run

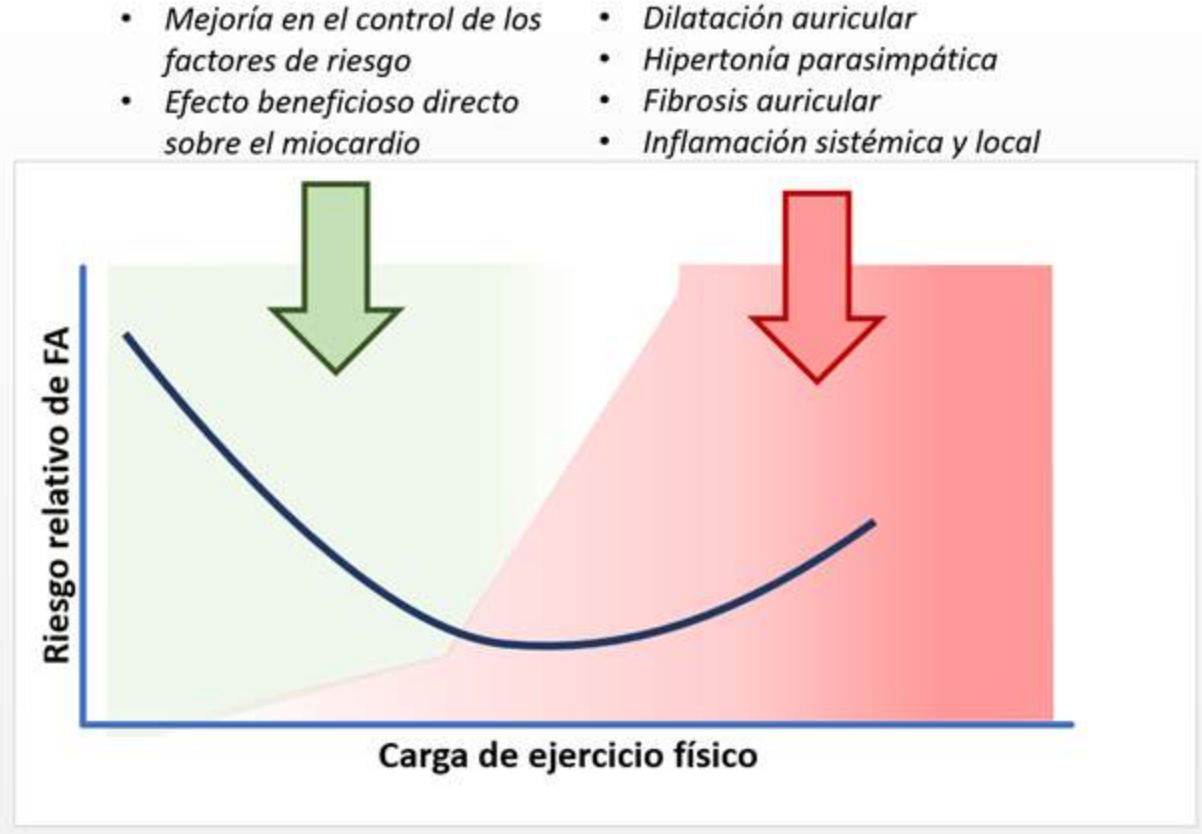
(Aizer et al., 2009), and the risk of AF in long-term follow-up of Swedish military recruits was positively correlated with physical fitness (Andersen et al., 2015).

The causes of the increased risk of AF in athletes are varied and largely still unknown (Guasch et al., 2017). Vagal hypertonia, bradycardia, and atrial dilatation are common features of the athlete's heart, and their contribution to the pathophysiology of AF is well described (Guasch et al., 2017). Excessive collagen deposition, or fibrosis, is a central pathological process in the development of AF in various pathologies, such as heart failure or arterial hypertension (Burstein & Nattel, 2008). Collagen distorts the myocardial structure, disrupts the electrical connections between myocardial cells, and impairs the normal activation of the myocardium, promoting the electrophysiological substrate capable of generating and sustaining AF. Studies in animal models (Guasch & Mont, 2013; Aschar Sobbi, 2015) and clinical studies (Peritz et al., 2020) suggest that atrial fibrosis contributes to the pathophysiology of AF in athletes, although the mechanisms that generate it are not well understood. It is possible that each episode of very high intensity physical exercise inflicts structural and functional damage on the atria (Sanz-de la Garza et al., 2016; Oh et al., 2020). Recent data suggest the involvement of inflammation in the development of atrial fibrosis. Up to a certain point, the systemic pro inflammatory cascade that occurs after each episode of high intensity physical exercise (Bernecker et al., 2013), even with local myocardial involvement (Oláh et al., 2015),

could contribute to its development. Additionally, hemodynamic overload and increased atrial wall tension promote a local pro inflammatory effect, mediated by the activation of tumor necrosis factor-alpha (TNFα) (Aschar-Sobbi et al., 2015; Lakin et al., 2019). The accumulation of subtle atrial microdamage after each exercise episode could ultimately lead to macroscopic atrial fibrosis (Oh et al., 2020).

It is important to remember that, in addition to this direct pathological effect on the atria, physical exercise has a beneficial effect on the incidence and severity of cardiovascular risk factors, which indirectly reduces the risk of AF. This dual effect creates a non-linear relationship between exercise load and AF risk: it is currently accepted that this relationship takes a U-shaped form (Guasch & Mont, 2017; Calvo et al., 2016), as shown in Figure 3, modulated by factors such as age and the presence of cardiovascular risk factors (Guasch & Nattel, 2021).

Figure 3. The relationship between AF risk and exercise load follows a U-shaped curve. At low exercise loads, the beneficial effects of physical exercise (in green) predominate, while at high or very high loads, the direct proarrhythmogenic effect (in red) becomes dominant



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Mejoría en el control de los factores de riesgo	Improvement in the control of risk factors
Efecto beneficioso directo sobre el miocardio	Direct beneficial effect on the myocardium
Dilatación auricular	Atrial dilatation
Hipertonía parasimpática	Parasympathetic hypertonia
Fibrosis auricular	Atrial fibrosis

Inflamación sistémica y local	Systemic and local inflammation
Riesgo relativo de FA	Relative risk of AF
Carga de ejercicio físico	Physical exercise load

Epidemiology and symptoms

AF in athletes is usually diagnosed in the fourth or fifth decade of life, and it is especially frequent in men who have practiced very high intensity sports for prolonged periods (generally, greater than 10 years) (Mont et al., 2002; Aizer et al., 2009; Calvo et al., 2016; Heidbüchel et al., 2006; Molina et al., 2008). In most cases, the sport practiced has a big dynamic component, and they are usually endurance sports, for example, running (Aizer et al., 2009; Molina et al., 2008), cycling (Baldesberger et al., 2008) or cross country skiing (33). The reason for a higher risk in men than in women is unknown (Guasch & Mont, 2015).

In general terms, the natural history of AF consists of short episodes (lasting hours to days), whether self-limiting or not, which progressively become longer until AF becomes sustained. Based on this presumed evolution, the most commonly used classification in clinical practice was described: **paroxysmal**, if AF episodes last less than 7 days; **persistent**, if episodes last more than 7 days; **long-**

standing persistent, when the duration exceeds 12 months; or **permanent**, in cases where AF is accepted as the usual rhythm, and efforts to revert to sinus rhythm are abandoned. This classification has received numerous criticisms. One of them is that it is not uncommon for some patients to experience only paroxysmal AF throughout their evolution, or for others to clinically debut with persistent AF.

The symptomatology of AF is highly variable, ranging from asymptomatic episodes to completely disabling ones that prevent the practice of sports. In general, the frequency of AF derived symptoms is higher among athletes than in the general non athlete population (Proietti et al., 2016; Hoogsteen et al., 2004). AF is a relatively frequent cause of palpitations in athletes, especially when the episodes are of long duration. Among athletes, a reduction in exercise capacity is particularly frequent (Myrstad et al., 2016).

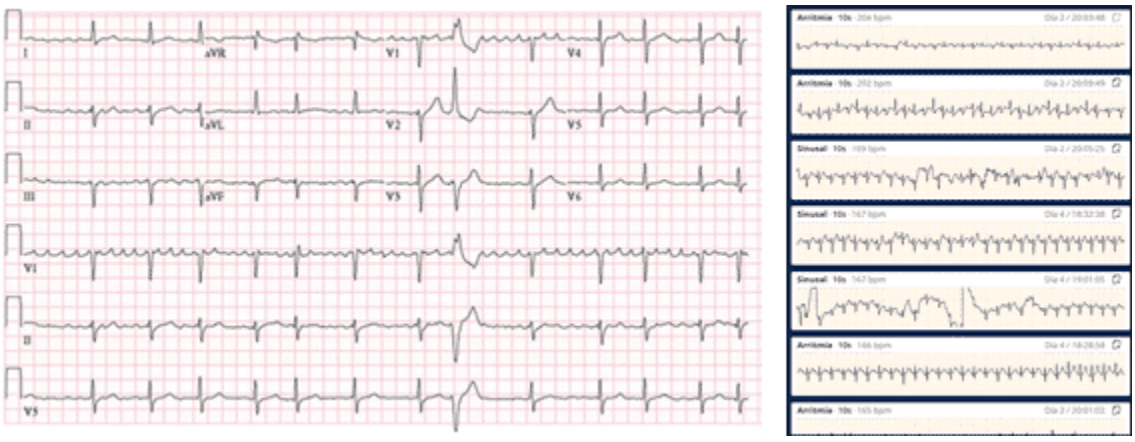
Diagnosis of atrial fibrillation

The only method to establish the diagnosis of AF is through the demonstration of a characteristic electrocardiographic tracing showing the absence of P waves and, instead, the presence of an irregular baseline (f waves), generally associated with the irregularity of QRS complexes. This tracing can be obtained through a standard 12 lead resting ECG, a Holter ECG recording 1 or 2 leads, or a portable

(wearable) device capable of recording single lead electrocardiographic tracings (Figure 4).

Among the latter, some portable devices have been approved by the relevant authorities (marked with Conformité Européenne [CE] or approval by Food and Drug Administration [FDA] from the United States) for performing on demand ECGs, and include smartwatches (such as Apple Watch, Samsung Galaxy Watch, Fitbit Sense, Withings ScanWatch, Google Pixel Watch, or Huawei Watch) and phone-adaptable accessories (such as AliveCor's Kardia). Many of these devices have algorithms capable of identifying episodes of atrial fibrillation with acceptable reliability in a controlled environment (in a laboratory, for example), but their sensitivity and specificity, and therefore their diagnostic performance, may be low in real life and have a high percentage of inconclusive tracings (Mannhart et al., 2023). This is why the conclusion reached by these algorithms should not be considered sufficiently reliable to obtain a definitive diagnosis, and the tracing should always be reviewed and confirmed by a healthcare professional trained to make the diagnosis of AF.

Figure 4. Diagnostic electrocardiographic tracings of atrial fibrillation obtained through a 12 lead ECG (left panel) and a 2 lead patch ECG (right panel, upper strips)



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Some devices used for heart rate monitoring do not rely on obtaining an electrocardiographic tracing and, therefore, cannot be used for the diagnosis of AF. These devices, such as fitness bands, watches, sports chest straps, or the use of smartphone cameras, are mostly based on photoplethysmography and only record the pulse wave. Some of these devices incorporate diagnostic algorithms trained with artificial intelligence, allowing them to identify pulse irregularities and suggest the presence of AF, but they are not considered sufficient to establish a diagnosis. The identification of these pulse irregularities suggestive of AF should lead to a presumptive diagnosis, prompting consideration of an ECG based screening strategy, especially in symptomatic athletes or those at high risk of complications.

Many athletes, especially high level athletes, monitor their heart rate by using the devices described above. In parallel, and often unintentionally, a screening process is established that allows for the

diagnosis of AF in young, low risk patients with a high rate of asymptomatic cases. These patients have not been included in the majority of clinical studies. Diagnostic and therapeutic management in these patients is uncertain and must be individualized.

Management of atrial fibrillation

Several ongoing studies aim to improve the management of AF in athletes and tailor it to their specific needs. Until the results of these studies are available, we must follow the recommendations based on studies conducted in the non athlete general population, while taking into account some findings from observational studies in athletes (Hindricks et al., 2020).

After the diagnosis of AF, and even with a clear history of high-intensity sports practice over long periods of time, other treatable causes of AF, such as thyroid disorders, alcohol consumption, or obstructive sleep apnea, should be ruled out in all cases. Especially in high performance athletes, the use of stimulants or anabolic substances should be ruled out. The 12-lead ECG allows the diagnosis of some primary arrhythmic pathologies associated with AF, such as Brugada syndrome. Echocardiography allows screening for structural heart disease and provides prognostic information, such as the size of the left atrium. In athletes who experience arrhythmias only during exercise, electrolyte abnormalities secondary to stress should be ruled out.

Anticoagulation

The risk of stroke increases significantly (by up to 5 times) in patients diagnosed with AF, so the need for anticoagulation should be assessed in all patients with AF, including athletes. Sports practice does not reduce the increased embolic risk attributable to AF (13, 40-42). In general, athletes have a lower risk of stroke than untrained individuals. However, in case control and cohort studies, athletes with AF have a 2 to 3 times higher stroke risk than athletes without AF (Svedberg et al., 2019; Myrstad et al., 2020; Hållmarker et al., 2015), especially in those over 65 years of age (Myrstad et al., 2020). Therefore, and in the absence of specific studies, the embolic risk in athletes should be assessed in the same way as for non athletes, following current guidelines based on the CHA2DS2-VASc score (Hindricks et al., 2020). Scores of 2 or higher in men or 3 or higher in women indicate the need for chronic anticoagulation; scores of 1 in men or 2 in women suggest, but do not mandate, initiating anticoagulation.

Given the criteria for initiating chronic anticoagulation, athletes will usually be considered to be at low risk. However, in addition to chronic anticoagulant therapy, it will be necessary to administer anticoagulant treatment for short periods of time, typically 1 to 3 months, in those low-embolic-risk athletes who undergo cardioversion or ablation procedures (Hindricks et al., 2020).

Some sports have a high physical contact component, which increases the risk of bleeding in anticoagulated patients. In these cases, sporting activity should be restricted while anticoagulant treatment is administered. Intermittent anticoagulant therapy, which involves anticoagulation only during and after episodes of AF, might seem like an attractive option, especially for athletes with paroxysmal AF who remain in sinus rhythm. Although this strategy has been investigated in small randomized studies with patients using pacemakers (Waks et al., 2018) or smartwatches capable of identifying AF episodes (Stavrakis et al., 2017), current evidence is insufficient to recommend it. Moreover, the lack of temporal correlation between thromboembolic events and AF paroxysms (Brambatti et al., 2022), supported by the recent concept of atrial cardiomyopathy (Vassiliki' Coutsoumbas & Pasqueale, 2022), would favor a strategy of continuous anticoagulation. The recently initiated REACT AF study (NCT05836987) will be crucial in determining the efficacy and safety of this strategy. Until its results are available, as a general rule, anticoagulant treatment should not be temporarily or permanently discontinued simply because the patient remains asymptomatic.

Although not specifically studied in athletes, beyond isolated cases (Briosa et al., 2020), and not routinely recommended as an alternative to anticoagulation (Hindricks et al., 2020), percutaneous left atrial appendage closure could be considered a valid option in athletes

involved in contact sports with a diagnosis of AF and high embolic risk.

Decision on antiarrhythmic strategy: Rhythm or rate control

After assessing the need for anticoagulation, the strategy for antiarrhythmic treatment of AF should be decided. Based on current evidence, this decision should not depend on the need for anticoagulation, and vice versa.

Generally speaking, in the treatment of AF, one can choose to try to maintain sinus rhythm (**rhythm control** strategy) or accept the presence of AF and focus on maintaining a heart rate in an appropriate range (**rate control** strategy). The decision will depend on the symptoms or associated pathology, and should be agreed upon in an informed manner with the patient. Classic studies found no differences in prognosis between these two strategies for AF patients (Bloom, 2004), but advances in therapeutic tools seem to be shifting the landscape. A recent randomized trial showed that early rhythm control reduced mortality, stroke, and hospitalization for heart failure in high risk patients (Kirchhof et al., 2020), regardless of the presence of symptoms (Willems et al., 2022). Observational studies suggest a similar benefit in low risk patients (Kim et al., 2022).

In general, the rhythm control strategy will be preferred in athletes who want to maintain a sporting practice, since AF episodes are

usually symptomatic and associated with a reduction in physical performance. This strategy often involves cardioversion, the prescription of antiarrhythmic drugs, and ablation procedures to try to maintain sinus rhythm for as long as possible and prevent recurrences. A rate control strategy will be preferred only in completely asymptomatic patients or based on the patient's preference. The goal will be to maintain a heart rate around 80 beats per minute at rest, with values up to 110 beats per minute being acceptable in the absence of symptoms or heart failure (Hindricks et al., 2020).

Antiarrhythmic drugs

Antiarrhythmic drugs are typically considered as a first-line option for managing AF and preventing recurrences, especially when the risk of recurrence is estimated to be high or when episodes are frequent. However, in some athletes with infrequent recurrences, a pill-in-the-pocket strategy may be recommended. This involves taking a single dose of a class Ic antiarrhythmic drug (200-300 mg of flecainide or 450-600 mg of propafenone) when symptoms arise. When episodes are frequent, a chronic antiarrhythmic treatment should be considered.

Choice and precautions for the use of antiarrhythmic drugs

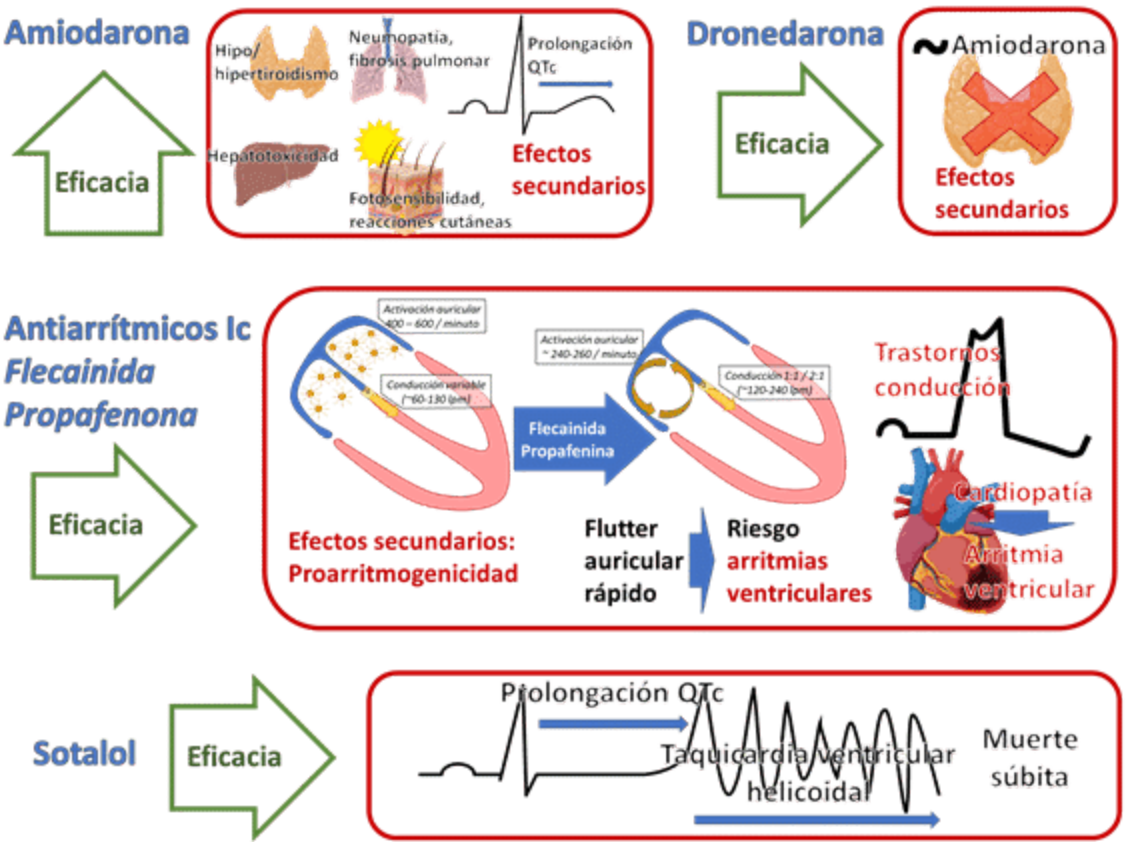
In our setting, the antiarrhythmic drugs used to prevent AF recurrences are almost exclusively amiodarone, dronedarone, and class Ic antiarrhythmics (flecainide, propafenone) (Figure 5). **Sotalol** is possibly the least effective drug and carries a significant proarrhythmic potential, including sudden death, so it is rarely used. Due to the specific demands and demographics of athletes diagnosed with AF, the use of antiarrhythmics requires careful consideration.

Although **amiodarone** is the most effective drug, its chronic use is discouraged in young patients due to its many and frequent systemic side effects, including thyroid dysfunction (commonly hypothyroidism, rarely hyperthyroidism), pulmonary fibrosis, photosensitivity, and hepatotoxicity, among others. These side effects can occur in up to 20% of patients after one year of treatment, and can reach up to 50% after prolonged treatment. Corneal deposits occur in all patients receiving amiodarone chronically. Although **dronedarone** avoids some of these side effects, especially thyroid effects, its antiarrhythmic efficacy is lower and its use is contraindicated in patients with heart failure.

Class Ic antiarrhythmic drugs (**flecainide** and **propafenone**) lack significant systemic side effects but should be prescribed with caution, particularly due to their effect on slowing conduction in the cardiac conduction tissue and ventricles. They should not be administered in patients with significant conduction disorders, such as left bundle branch block, or in patients with preexisting heart

disease due to the risk of inducing ventricular arrhythmias. Additionally, the slowing of atrial conduction may convert atrial fibrillation into slow atrial flutter, but with 1:1 conduction to the ventricle, leading to high ventricular rates and potentially serious ventricular arrhythmias (Figure 5).

Figure 5. Most commonly used drugs for the prevention of arrhythmic recurrences in patients with AF, and their main cardiac and systemic side effects



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Amiodarona	Amiodarone
Hipotiroidismo, hipertiroidismo	Hypothyroidism/hyperthyroidism
Hepatotoxicidad	Hepatotoxicity
Neuropatía, fibrosis pulmonar	Lung disease, pulmonary fibrosis
Prolongación QTc	QTc prolongation
Fotosensibilidad, reacciones cutáneas	Photosensitivity, skin reactions
Efectos secundarios	Side effects
Dronedarona	Dronedarone
Eficacia ~Amiodarona	Efficacy ~Amiodarone
Efectos secundarios	Side effects
Antiarrítmicos Ic	Class Ic antiarrhythmic drugs
Flecainida	Flecainide
Propafenona	Propafenone

Activación auricular 400-600/minuto	Atrial activation 400-600/minute
Activación auricular ~240-260/minuto	Atrial activation ~240-260/min
Conducción 1:1/2:1 (~120-240/lpm)	Conduction 1:1/2:1 (~120-240/bpm)
Conducción variable (~60-130/lpm)	Variable conduction (~60-130/bpm)
Eficacia	Efficacy
Efectos secundarios: Proarritmogénicidad	Side effects: Proarrhythmogenicity
Flutter auricular rápido	Rapid atrial flutter
Riesgo arritmias ventriculares	Risk of ventricular arrhythmias
Trastornos conducción	Conduction disorders
Cardiopatía	Heart disease
Arritmia ventricular	Ventricular arrhythmia
Sotalol	Sotalol
Eficacia	Efficacy
Prolongación QTc	QTc prolongation

Taquicardia ventricular helicoidal	Helical ventricular tachycardia
Muerte súbita	Sudden death

To avoid flutter with rapid conduction to the ventricle, the administration of flecainide or propafenone should be accompanied by atrioventricular node blocking drugs, especially in young patients who engage in physical exercise or may experience other states of heightened adrenergic tone. **Beta-blocking** drugs and non-dihydropyridine **calcium channel blockers** (verapamil, diltiazem) are the drugs of choice for this purpose. Although digoxin is useful for reducing resting heart rate, it has low efficacy in reducing atrioventricular conduction during exercise (Matsuda et al., 1991).

When prescribing beta-blockers and calcium channel blockers, it should be taken into account that they reduce heart rate during exercise, but also at rest, both during AF and in sinus rhythm. The sinus bradycardia characteristic of athletes usually limits the ability to achieve therapeutic doses of both pharmacological groups. Additionally, from a practical perspective, and something that should be explained to the athlete, the use of beta-blockers makes it difficult to use heart rate as a marker to guide exercise load during training. This is because it alters the slope of the relationship between heart

rate reserve and VO2 reserve, which will differ significantly from the theoretical value of around 1 (Verdicchio et al., 2023).

The impact of these drugs on physical performance is especially relevant for those patients diagnosed with AF who wish to maintain competitive or high-level sporting activity. Beta-blockers appear to be especially detrimental. Both acute and long-term administration reduce exercise capacity in a peak stress test by around 10% in healthy individuals in sinus rhythm (Mitchell et al., 2019) and in patients with permanent AF (Ulimoen et al., 2014). This reduction is not as pronounced with non dihydropyridine calcium channel blockers (verapamil, diltiazem). Although verapamil reduced heart rate at peak exercise in a study conducted on healthy volunteers, the maximum exercise load achieved was not affected (Petri et al., 1986).

The results of a randomized study in patients with permanent AF support the superiority of non dihydropyridine calcium channel blockers: in 60 patients with permanent AF, a baseline stress test was performed, followed by 4 therapeutic regimens. Compared to the baseline determination, peak VO2 was reduced only when patients took metoprolol and carvedilol, but was maintained when they took diltiazem and verapamil (Ulimoen et al., 2014). Most of these studies included patients of advanced age or with various cardiovascular risk factors, a pattern that does not usually coincide with that of athletes with AF, so the conclusions should be considered as indicative and not definitive.

Beta-blockers and doping

The use of diuretics and beta-blockers, commonly prescribed for the treatment of cardiovascular pathologies, is prohibited in certain sports by the World Anti-Doping Agency (WADA) (2023). Specifically, beta-blockers are banned, both during competition and even outside of it, in precision sports (Table 2), as they reduce tremors and improve stability and accuracy, leading to enhanced performance and scoring (Kruse et al., 1986). However, a recent randomized study has challenged this dogma (Ergen et al., 2021). Nonetheless, their use should be avoided in athletes participating in these disciplines.

Table 2. Sports in which beta-blocker drugs are prohibited. The federation responsible is shown in brackets. (*) indicates prohibition also out of competition

Sport discipline
Archery (World Archery, WA)*
Auto Racing (Fédération Internationale de l'Automobile, FIA)
Billiards (all disciplines) (World Confederation of Billiards Sports, WCBS)
Darts (World Darts Federation, WDF)

Golf (International Golf Federation, IGF)
Mini-Golf (World Minigolf Federation, WMF)
Shooting (International Shooting Sport Federation, ISSF; International Paralympic Committee, IPC)*
Skiing/snowboarding (Fédération Internationale de Ski, FIS) in jumps, freestyle skiing/half-pipe, and snowboard half-pipe
Underwater sports (Confédération Mondiale des Activités Subaquatique, CMAS)* in all apnea disciplines, spearfishing, and target shooting

Source: own source based on World Anti-Doping Agency, 2023.

Ablation of atrial fibrillation

Technological advancements and significant improvements in safety have made ablation procedures a cornerstone in the management of AF in numerous situations (Hindricks et al., 2020). Initially reserved for highly symptomatic patients refractory to antiarrhythmic treatment, their high efficacy and low complication rates have progressively broadened their indications. Despite attempts to improve efficacy through strategies that more extensively target the atrial

arrhythmogenic substrate, the foundation of ablation procedures today remains the electrical isolation of the pulmonary veins.

The efficacy of AF ablation in athletes has been demonstrated in several studies. In the first published study involving a small cohort of 20 high performance athletes diagnosed with AF and debilitating symptoms, ablation increased exercise capacity, and all were able to resume competitive sports (Furlanello et al., 2008). However, the role of ablation in improving functional capacity has not been robustly demonstrated (Liu et al., 2022; Toso et al., 2022). Most studies conducted in Europe and North America show similar ablation procedure efficacy in both athletes and non athletes (Mandsager et al., 2020; Koopman et al., 2011; Calvo et al., 2010). Only one small study involving 39 athletes suggested a lower success rate in athletes (Liu et al., 2022), although it should be noted that in this study the prevalence of hypertension was particularly high among athletes. These studies report an efficacy after a single ablation procedure ranging between 40% and 60% at three years (Liu et al., 2022; Yamaguchi et al., 2012), achieving rates close to 80-90% also at 3 years after multiple procedures (Furlanello et al., 2008; Koopman et al., 2011; Calvo et al., 2010; Yamaguchi et al., 2012). Predictors of ablation response in athletes are similar to those in the general population: arrhythmic pattern (Decroocq et al., 2019; Calvo et al., 2010), atrial size (Mandsager et al., 2020; Calvo et al., 2010), and the time from AF diagnosis to ablation (Mandsager et al., 2020). In this regard, a delay of more than 2 years triples the risk of a failed

procedure (Mandsager et al., 2020), emphasizing the need for early consideration of ablation procedures.

Safety has improved significantly in recent years (Benali et al., 2023). Currently, complications from ablation procedures affect less than 4% of cases, and less than 2% are considered severe. Vascular access-related complications constitute the majority of complications (Benali et al., 2023). Additionally, athletes should be aware that ablation may result in changes to cardiac innervation, likely due to its effect on autonomic ganglia, leading to an increase in heart rate after the procedure (Mandsager et al., 2022).

The most recent clinical practice guidelines recommend considering AF ablation after the failure of at least one antiarrhythmic drug or even as a first option, before antiarrhythmic drugs, after informing the patient of the options, risks, and benefits (Pelliccia et al., 2020; Hindricks et al., 2020).

Sport after diagnosis of atrial fibrillation

The decision regarding the continuation of sports practice after an AF diagnosis is complex, with limited scientific evidence. It largely depends on discussions with the patient and their informed decision, weighing the benefits of physical exercise, the risk of AF recurrence and progression, and personal priorities.

On the one hand, the benefits of moderate physical activity on quality of life in patients with AF (Lambert et al., 2018), cardiovascular morbidity and mortality, and recurrence risk are well known. A randomized study demonstrated that 12 weeks of intervallic aerobic physical exercise reduced arrhythmic burden in patients with AF (Malmo et al., 2016). However, this study included mostly elderly patients with multiple cardiovascular risk factors, so these conclusions cannot be directly extrapolated to athletes with AF.

On the other hand, maintaining high-intensity activity could theoretically perpetuate or accelerate the progression of the atrial arrhythmogenic substrate. However, there is no solid scientific evidence to support this hypothesis. Studies in animal models seem to suggest a benefit from stopping physical activity in the progression of the arrhythmogenic substrate or the development of AF (Guasch et al., 2017; Regouski et al., 2011). However, a retrospective observational study found no differences in AF recurrence between athletes who continued physical activity and those who reduced or stopped it after an ablation procedure (Decroocq et al., 2019). It is possible that experimental models reflect early or preclinical stages of AF, in contrast to the more advanced stages seen in athletes with clinical AF, which might justify an early intervention approach. In any case, the results of the randomized NEXAF study (NCT04991337), which is still ongoing, will help confirm or refute these hypotheses.

Fitness for sports practice

The diagnosis of AF does not exclude affected patients from competitive sports. As long as certain conditions are met, depending on the AF pattern and treatment, any type of sport may be permitted in the absence of symptoms.

For patients with infrequent paroxysmal AF who follow a pill in the pocket strategy, high intensity activity should be restricted for 24 to 48 hours after administration of the class Ic antiarrhythmic drugs due to the risk of 1:1 atrial flutter. For athletes with paroxysmal or persistent AF who are on chronic class Ic antiarrhythmic therapy (flecainide, propafenone), an atrioventricular node blocking drug must always be included, as previously described. Finally, in patients with permanent AF, proper heart rate control during exercise should be verified by means of a stress test or monitoring during training.

Atrial flutter

Although less common in athletes than AF, some studies suggest that the incidence of atrial flutter is also increased in athletes compared to the non-athlete population (Baldesberger et al., 2008; Claessen et al., 2019; Myrstad et al., 2014). The available information and anticoagulant treatment are similar to that of AF. However, the first-line treatment for typical atrial flutter is ablation of the cavotricuspid isthmus. It should be noted that the risk of AF after typical flutter ablation is higher in athletes who continue high-intensity sports than in those who stop (Heidbüchel et al., 2006).

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