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Exercise and Sports Participation in Patients with Cardiac Implantable Electronic Devices

Kardiyak Elektronik Cihaz İmplante Edilen Hastalarda Egzersiz ve Spor

REVIEW
DERLEME

ABSTRACT

The term *cardiac implantable electronic devices* (*CIEDs*) encompasses pacemakers (PMs), implantable cardioverter-defibrillators (ICDs), and cardiac resynchronization therapy (CRT) devices, which are well-established treatments for cardiac arrhythmias and heart failure with reduced ejection fraction. Advances in CIED therapy have led to an increasing number of patients with cardiovascular disease (CVD) receiving such devices. In general, low levels of physical activity are associated with a higher risk of cardiac and all-cause mortality in patients with CIED. These patients are considered eligible for exercise programs not only to improve prognosis related to their underlying heart disease but also to facilitate psychological adaptation to living with the device, to enhance evaluation of device performance and, particularly in ICD recipients, to reduce the risk of inappropriate shocks. Studies have shown that exercise training improves physical performance in CIED patients without increasing the risk of adverse events. A comprehensive clinical evaluation, a personalized exercise plan, appropriate device programming, and regular follow-up are essential to ensure that patients can safely engage in effective physical activity tailored to their specific needs. Participation in sports is another consideration for many CIED patients. Recent guidelines recommend encouraging individuals with CIEDs to engage in sports activities, unless contraindicated by their underlying heart conditions. It is generally accepted that low- to moderate-intensity leisure-time sports activities are safe and clinically beneficial for most individuals with a CIED. However, individualized recommendations may vary significantly depending on the patient's cardiovascular health, the impact of physical activity on their underlying disease, and the type of implanted device.

Keywords: Cardiac resynchronization treatment, exercise, implantable cardioverter defibrillator, pacemaker, sports cardiology

ÖZET

Kardiyak implante edilebilen elektronik cihaz terimi, aritmilerin ve düşük ejeksiyon fraksiyonlu kalp yetmezliklerinin tedavisinde önemli bir yer tutan, kalp pili, implante edilebilen kardiyoverter defibrilatör ve kardiyak resenkronizasyon tedavisini kapsamaktadır. Cihaz tedavisindeki gelişmeler, bu yöntemle tedavi edilen hastaların sayısını arttırmıştır. Genel olarak, yetersiz fizik aktivite, bu hasta grubunda gerek total gerekse kardiyak mortalite riskini arttırmaktadır. Kardiyak implante edilebilen elektronik cihaz taşıyanlar, herhangi bir kontrendikasyon olmadığı sürece, altta yatan kardiyovasküler hastalığa bağlı prognozu düzeltmek, cihazla yaşamaya psikolojik olarak adapte olmayı kolaylaştırmak, cihaz fonksiyonlarını daha iyi değerlendirmek ve implante edilebilen kardiyoverter defibrilatör bulunan hasta grubunda şok sayısını azaltmak için, egzersiz programlarına yönlendirilmelidirler. Çalışmalar egzersiz uygulamalarının bu hastalarda ciddi yan etki riski oluşturmadan fonksiyonel kapasiteyi arttırdığını göstermiştir. Ayrıntılı klinik değerlendirme, kişiye özgü egzersiz planı, uygun cihaz programı ve düzenli takip yapılması, kardiyak implante edilen elektronik cihaz taşıyan kişilere, ihtiyaçlarını karşılayabilecek güvenli ve etkili bir egzersiz yapılabilmesinin temel unsurlarıdır. Spor aktivitelerine katılabilmek cihaz implantasyonu yapılanların çoğunu ilgilendiren bir diğer önemli konudur. Son kılavuzlar, altta yatan kalp hastalığına bağlı bir kontrendikasyon olmadığı sürece, cihaz taşıyan kişilerin spor aktivitelerine katılmalarının desteklenmesini önermektedir. Genel olarak serbest zamanı değerlendirmek için yapılan hafif ve orta şiddetli sporların, kardiyak implante edilebilen cihaz taşıyan birçok hasta tarafından güvenli bir şekilde yapılabileceği belirtilmektedir. Ancak, hastanın kardiyak fonksiyonları, yapılacak sporların altta yatan hastalığa etkisi, takılan cihazın tipi dikkate alınarak önerilerin bireyselleştirilmesi en uygun yaklaşım olacaktır.

Anahtar Kelimeler: Kardiyak resenkronizasyon tedavisi, egzersiz, implante edilebilir kardiyoverter defibrilatör, kalp pili, spor kardiyolojisi

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The term cardiac implantable electronic devices (CIEDs) includes pacemakers (PMs), implantable cardioverter-defibrillators (ICDs), and cardiac resynchronization therapy (CRT) devices, which are well-established treatments for cardiac arrhythmias and heart failure with reduced ejection fraction.[1,2] Advances in CIED therapy have led to a growing number of patients with cardiovascular disease (CVD) receiving these devices.[3] One of the most important lifestyle considerations for individuals living with a CIED is physical activity and participation in sports.[4,5] In general, low levels of physical activity are associated with an increased risk of cardiac and all-cause mortality in patients with CIEDs.[6-8] Conversely, the beneficial effects of physical activity and structured exercise on cardiovascular health in secondary prevention are well established.[9-11] Therefore, exercise is generally recommended for patients with CIEDs to improve prognosis related to their underlying CVD. In addition, individuals in this group may benefit from exercise for specific reasons, such as facilitating psychological adaptation to living with the device, optimizing evaluation of device performance, and, in the case of ICD patients, reducing the risk of device-related shocks.[12-14] However, these patients may also face various barriers, related to either the patient or the device, that limit their participation in regular physical activity. A thorough clinical evaluation, a personalized exercise plan, appropriate device programming, and regular follow-up are essential to ensure that CIED recipients can safely and effectively engage in physical activity tailored to their individual needs.[14,15]

Participating in sports activities is another important consideration for most patients with CIEDs. Determining the eligibility of these patients for sports participation requires careful assessment of the underlying CVD and arrhythmic risk, as sports activities may increase the risk of sudden cardiac death in susceptible patients.[16-18] Additionally, sports may lead to complications related to the implanted device, such as lead dislocation, lead fracture, or device malfunction. Therefore, it is essential to balance the benefits of sports with the risks that may arise during such activities. Guideline recommendations play a crucial role in ensuring safe participation in sports for patients with CIEDs.[15,19-20] In this review, clinical data and current recommendations regarding exercise and sports participation in individuals with CIEDs are evaluated.

ABBREVIATIONS

AV	Atrioventricular
CIEDs	Cardiac implantable electronic devices
CPET	Cardiopulmonary exercise test
CRT	Cardiac resynchronization therapy
CRT-Ds	Cardiac resynchronization therapy defibrillators
CVD	Cardiovascular disease
ExT	Exercise training
HF	Heart failure
ICDs	Implantable cardioverter-defibrillators
PMs	Pacemakers
PMT	Pacemaker-mediated tachycardia
VF	Ventricular fibrillation
VT	Ventricular tachycardia

Exercise and Sports Activity in Specific Cardiac Implantable Electronic Device Recipients

Pacemaker

Reduced exercise capacity in patients who require a pacemaker can result from a combination of factors, including the underlying cardiac condition, comorbidities, and the effects of the PM itself.[21-23] Two studies investigating whether physical activity levels, measured via sensors in PMs, could predict all-cause mortality found a significant association between lower activity levels and an increased risk of death in patients with these devices.[7,8] Tyagi et al.[7] retrospectively reviewed the physical activity profiles of 96 patients, based on PM records, who underwent de novo implantation. Subjects were categorized into four activity groups: < 1 hour/day, 1 to < 2 hours/day, 2 to < 3 hours/day, and > 3 hours/day. Over a follow-up period of 4.1 ± 2.2 years, they found that all-cause mortality significantly increased as active minutes decreased (7%, 9%, 29%, and 42% all-cause mortality, respectively, from the highest to the lowest activity group; $p = 0.004$). Similar findings were reported by Gotto et al.,[8] who retrospectively examined the impact of daily physical activity duration, as recorded by pacemakers, in 107 consecutive older patients (aged ≥ 75 years) with newly implanted PMs. During a mean follow-up of 3.0 years, low activity levels (< 50 minutes/day) were found to be a strong predictor of all-cause mortality in older pacemaker recipients.

It is common practice for implanting physicians to recommend limiting certain physical activities after PM implantation. Vigorous exercises, particularly those involving the upper body and excessive ipsilateral arm movements, should be avoided until the leads are fully secured, typically for 4 to 6 weeks.[4,21] During this period, walking and lower-body exercises are considered safe and encouraged. Several studies have demonstrated the efficacy and safety of exercise-based rehabilitation programs, including aerobic training or a combination of aerobic, strength, and flexibility training, in patients with PM, provided that patients are appropriately supervised and pacemaker settings are properly adjusted.[22-24]

Recent guideline recommendations for participation in sports activities are more liberal for patients with PMs than for those with ICDs. There is a general consensus that PM patients without structural heart disease or other cardiac conditions may participate in most forms of recreational or even competitive sports. This approach is based on the lower risk of complications from underlying heart disease, arrhythmias, and lead-related issues during exercise in PM patients compared to those with ICDs.[15,19,25] Pacemaker recipients with underlying CVD should only participate in sports that are compatible with the limitations imposed by their specific condition. Regardless of cardiac status, all PM patients should avoid sports with a high risk of chest trauma, such as boxing, wrestling, rugby, ice hockey, and martial arts, due to the potential risk of damage to the lead or the device. The most recommended sports for PM patients include walking, jogging, running, swimming, ballet, dancing, fishing, and cycling.[25,26] Sports such as football, basketball, handball, volleyball, and baseball are generally less recommended due to the increased risks of falls or chest impact. These sports may be permitted with the use of appropriate protective padding. Athletic activities involving vigorous arm movements, such as volleyball, tennis, golf, hammer throwing, rowing, and climbing,

Table 1. Characteristics of Included Exercise Training Studies in Patients with Implantable Cardioverter-Defibrillators (ICDs)

Study	Sample Size	Exercise Training Protocol	Measurement Period of Exercise Capacity	Outcome	Adverse Events and/ or ICD Intervention
Piccini et al.[30]	546 (ICD with ExT) vs. 507 (ICD without ExT)	Supervised aerobic ExT (walking, treadmill, or cycle ergometer); 36 sessions at 60-70% target heart rate, 3 times per week, followed by home-based exercise 5 times per week	Baseline and 3 months follow-up	Improvement in peak VO_2 in the ExT group	Exercise training was not associated with the occurrence of ICD shocks
Isaksen et al.[31]	24 (ICD with ExT) vs. 11 (ICD without ExT)	Supervised ExT 60 min., 3 times per week for 12 weeks at 85% of maximum heart rate; AIT plus strength training	Baseline and 3 months follow-up	AIT led to a significant increase in peak VO_2 compared to control group	No sustained arrhythmias, ATP, or ICD discharges related to exercise sessions
Piotrowicz et al.[32]	75 with ExT (56 with ICD) vs. 32 without ExT (16 with ICD)	Home-based telemonitored ExT (Nordic walking), 5 times per week for 8 weeks at 40-70% of heart rate reserve	Baseline and 2 months follow-up	Significant improvement in peak oxygen uptake in the ExT group	No deaths, hospitalizations, or ICD interventions during exercise
Dougherty et al.[33]	84 (ICD with ExT) vs. 76 (ICD without ExT)	Home-based ExT: 1 hour/day of aerobic training 5 days/week at 60-85% of heart rate reserve for 8 weeks, followed by 16 weeks of home-based walking for 150 minutes/ week at 80% of heart rate reserve, or approximately half the duration of aerobic training, in any configuration of the patient's choice	Baseline, 2 months, and 6 months follow-up	ExT significantly increased peak VO_2 at 8 weeks, and this improvement was sustained at 24 weeks	There were no deaths or incidents of SCA associated with ExT, and no ICD shocks occurred during exercise; however, one episode of ATP therapy was associated with exercise
Berg et al.[34]	99 (ICD with ExT) vs. 97 (ICD without ExT)	Supervised or home-based ExT (based on patient preferences); 2 times per week, aerobic plus resistance training for 12 weeks at 50-80% of maximum heart rate	Baseline, 3 months, and 6 months follow-up	Significant increase in VO_2 uptake over time in the ExT group	No serious cardiac events or ICD shocks during exercise intervention or testing
Smolis-Bak et al.[35]	31 (ICD with ExT) vs. 32 (ICD without ExT)	Supervised ExT: 5-20 minutes, 5 times per week in hospital; 3 times per week post-discharge; aerobic plus resistance training for 24 weeks	Baseline, 6 months, and 18 months follow-up	Significant improvement in peak VO_2 in the ExT group	No ICD shocks occurred during training sessions or exercise

AIT, Aerobic Interval Training; ExT, Exercise Training; ICD, Implantable Cardioverter Defibrillator; SCA, Sudden Cardiac Arrest; VO_2, Oxygen Uptake.

or exercises that involve heavy weightlifting with intense use of the arm muscles may increase the risk of subclavian crush syndrome.[2,25] There are case reports of lead damage associated with activities like softball and weightlifting.[27,28] To increase the durability and longevity of the device system, it is recommended that pacemakers be implanted on the side opposite the dominant arm, with submuscular placement or, alternatively, through the use of leadless pacing systems.[15,19,29] Regular follow-up and careful monitoring of device function are essential to ensure safety during sports participation. During pacemaker checks, the potential for electromagnetic interference in certain athletic environments, such as those with electronic equipment (e.g., electronic sensors used in fencing), should be carefully assessed.

Implantable Cardioverter-Defibrillator

An implantable cardioverter-defibrillator is used to treat individuals at high risk of sudden cardiac death.[1] An ICD continuously monitors the heart's rhythm and delivers electric shocks or pacing to restore normal rhythm if it detects life-threatening ventricular tachyarrhythmias. ICD shocks can be both physically and emotionally distressing for patients, and many ICD recipients experience anxiety about the possibility of receiving future shocks. This fear can impact quality of life, often leading to behavioral changes such as avoidance of physical activity and self-imposed limitations on daily activities.[14] A study by Zhao et al.,[6] retrospectively analyzed the relationship between physical activity levels, measured by ICDs or cardiac resynchronization therapy defibrillators (CRT-Ds), and long-term mortality in 845 patients. The primary endpoint was cardiac death, and the secondary endpoint was all-cause mortality. Physical activity data were collected during the first 30-60 days following ICD/CRT-D implantation and were expressed as a percentage of total daily activity per 24 hours. The study found that patients whose baseline physical activity was ≤ 7.84% (equivalent to approximately 113 minutes) had a higher risk of both cardiac death and all-cause mortality compared to those whose activity levels were > 7.84%.

Physical activity restrictions for ICD recipients are, in many respects, similar to those for PM patients. After implantation, patients may resume sports or an exercise program following a six-week period of relative rest, ideally after undergoing an exercise test. Evidence from exercise training (ExT) studies focusing on safety and potential improvements in physical capacity for individuals with ICD supports the benefits of exercise in this specific patient group (Table 1).[30-35] In the studies reviewed, including five randomized trials and one non-randomized study,[31] aerobic exercise, resistance/strength training, or a combination of both modalities were implemented under careful monitoring. Structured exercise programs varied in frequency (3-5 sessions per week), intensity (ranging from 40-85% of peak oxygen uptake or maximum heart rate), and duration (12-24 weeks). These studies showed no significant increase in arrhythmic events or adverse outcomes related to ExT.

Traditionally, participation in sports for patients with an ICD was restricted due to concerns about potential risks, including both appropriate and inappropriate shocks, possible device malfunction, and the risk of trauma-related injury to the patient or damage to the device.[5,20] However, in the past decade, new scientific data have demonstrated that ICDs effectively prevent sudden cardiac death (SCD) during sports activities. The Multinational Prospective ICD Sport Safety Registry evaluated 372 athletes who participated in both organized and high-risk sports.[36] The study found that more individuals received both appropriate and inappropriate shocks during physical activity compared to rest. However, shock frequency did not significantly differ between those participating in competitive sports and those engaged in other forms of physical activity. Although many ICD shocks occurred during or after sports participation, there were no deaths, resuscitated cardiac arrests, or shock-related injuries. Additionally, lead malfunction rates at 5 and 10 years post-ICD implantation were not significantly different from those in non-athletic ICD patients,[17] and no device malfunctions were reported.

The long-term results of the same registry further reinforced the initial findings by providing extended follow-up data for athletes with ICD.[37] Over the long-term follow-up period, there were no deaths attributed to arrhythmic events or injuries resulting from arrhythmia-related syncope or ICD shocks during sports participation. As in the earlier report, a greater number of participants experienced both total and appropriate shocks while engaged in competition/practice activities or physical activity compared to rest. No generator malfunctions were reported. The estimated lead survival free from definite or possible malfunction was 94% at 5 years and 85% at 10 years.

Overall, the results of the registry suggest that many athletes with ICDs can safely engage in vigorous and competitive sports without injury or failure to terminate arrhythmias, despite the occurrence of both appropriate and inappropriate shocks.

Subsequently, the European cohort of the Multinational Prospective ICD Sports Safety Registry investigated the safety of intensive recreational sports participation among individuals with ICDs.[38] Participants in the recreational arm were individuals who engaged in regular, high-level physical activities, though not necessarily in professional or competitive sports. The study found that recreational athletes experienced fewer total, appropriate, and inappropriate shocks during physical activity, and no episodes of ventricular tachycardia (VT) or ventricular fibrillation (VF) storms were observed. Importantly, none of the athletes in either group died, required external resuscitation, or sustained injury due to arrhythmia or shocks. These findings suggest that recreational athletes with ICDs can safely participate in a wide range of sports activities without severe adverse outcomes.

In line with these emerging data, recent guidelines now recommend that individuals with an ICD should be encouraged to participate in appropriate sports activities, provided that exercise is not contraindicated by their underlying heart disease and they have remained free of ventricular tachyarrhythmias requiring device therapy for at least three months.[15,19,20] Leisure-time sports activities of moderate intensity appear to be safer and are associated with a lower risk of device shocks compared to high-intensity competitive sports.[17,19] Competitive sports may be permitted in selected ICD recipients, in accordance with guideline recommendations. These state that: "Shared decision-making should be considered when determining whether individuals with an ICD should continue intensive or competitive sports participation, taking into account the impact of sports on the underlying cardiac substrate, the increased likelihood of appropriate and inappropriate shocks during intensive activity, the psychological impact of shocks on the athlete or patient, and the potential risk to third parties."[15] Sport activities associated with a risk of chest trauma and those in which a loss of focus or consciousness could pose a danger to the athlete or bystanders, such as motorsports, diving, or climbing, should generally be avoided. Weightlifting and sports involving pronounced arm movements, such as volleyball or racquet sports, may increase the risk of late lead damage due to subclavian crush. The use of a subcutaneous ICD system may help reduce lead-related complications in sports that require intense chest, shoulder, or upper arm movements.[39] Ongoing studies are expected to provide further clarity on this issue.[40]

Specific device settings are required to optimize ICD function and minimize inappropriate shocks during sports activities. ICD shocks have a significant psychological impact on athletes, and some individuals who receive a shock may temporarily or permanently withdraw from sports participation.[36] Careful follow-up of both the patient and the device, ideally including remote monitoring, is essential as long as the individual remains active in sports.

Cardiac Resynchronization Therapy

CRT is a treatment used in heart failure (HF) patients with reduced ejection fraction and electrical dyssynchrony. CRT has been shown to improve exercise capacity, increase peak VO_2, enhance quality of life, and reduce the risk of hospitalizations.[2] The positive effects of CRT on exercise capacity are primarily attributed to improvements in central hemodynamics. However, peripheral factors, such as impaired metabolic vasodilatation and reduced skeletal muscle function, also contribute to the limitation in exercise capacity observed in patients with chronic HF.[41,42] Therefore, ExT following CRT implantation may offer additional benefits by addressing these peripheral limitations.[41,43] Studies have demonstrated that a 12-14 week exercise program can further improve exercise capacity in chronic HF patients following CRT implantation, compared to CRT alone, during short-term follow-up (Table 2).[44–47] Notably, in these studies, no patients experienced any adverse events related to exercise.[46] However, it has been emphasized that large-scale studies are needed to better define the benefits of ExT in heart failure patients after CRT implantation, as the current evidence is based primarily on small-scale studies.[14,41]

Table 2. Characteristics of Included Exercise Training Studies in Patients with Cardiac Resynchronization Therapy (CRT)

Study	Sample Size	Exercise Training Protocol	Measurement Period of Exercise Capacity	Outcome	Adverse Events and/or ICD Interventions
Conraads et al.[44]	8 (CRT with ExT) vs. 9 (CRT without ExT)	Supervised ExT for 4 months; 60-minute sessions; 3 times per week at 90% of ventilatory threshold (determined by CPET)	Before and at 5 months after CRT	Significant increase in peak VO_2 in the ExT group with CRT	N/A
Patwala et al.[45]	25 (CRT with ExT) vs. 25 (CRT without ExT)	Supervised moderate to high-intensity ExT for 3 months; 30-minute sessions; 3 times per week at 80% of peak heart rate (first 4 weeks), 85% (next 4 weeks), and 90% (final 4 weeks)	Before and at 3 and 6 months after CRT	Significant increase in peak VO_2 in the ExT group with CRT	No adverse events reported
Smolis-Bak et al.[46]	26 (CRT with ExT) vs. 26 (CRT without ExT)	Hospital-based ExT for ~3 weeks, followed by home-based telemonitored ExT 5 times per week for 8 weeks; the program included low-intensity exercises targeting small and progressively larger muscle groups of the lower and upper limbs, respiratory exercises, and range-of-motion exercises for the shoulder joint on the implantation side	Before and at 3-4 and 12 months after CRT	After 3-4 months, the ExT group with CRT showed improved peak VO_2; however, by 12 months, the measurements had returned to baseline levels	No significant differences between the groups in terms of ICD interventions, mortality, or hospitalization rates
Nobre et al.[47]	14 (CRT with ExT) vs. 16 (CRT without ExT)	Supervised moderate-intensity ExT for 4 months; 60-minute sessions, 3 times per week; exercise intensity based on heart rate corresponding to anaerobic threshold up to 10% below the respiratory compensation point determined by CPET	At 1 month (baseline) and at 5 months after CRT	Significant increase in peak VO_2 in the ExT group	N/A

CPET, Cardiopulmonary Exercise Testing; CRT, Cardiac Resynchronization Therapy; ExT, Exercise Training; N/A, Not Available; VO_2, Oxygen Uptake.

Table 3. Recommendations for Sports Participation in Patients with Cardiac Implantable Electronic Devices

Recommended Sports	**Low-intensity:** Walking, jogging, recreational swimming, recreational alpine skiing **Moderate-intensity:** Speed walking, middle/long-distance running, dancing, stationary cycling, recreational gymnastics
Limited Recommendation	Volleyball, football (soccer), basketball, handball, baseball
Not Recommended Sports	**High-intensity sports with risk of chest trauma:** Rugby, boxing, wrestling, hockey, ice hockey, American football, martial arts (e.g., judo, karate, kickboxing) **Sports that pose a life-threatening risk due to the potential for falls or loss of consciousness:** Mountain climbing, diving, motor sports, flying, hang gliding **Sports that carry a risk of electrode damage (e.g., subclavian crush syndrome):** Tennis, table tennis, golf, cricket, bowling, discus/hammer throwing, archery, rowing, weightlifting

Based on current evidence, exercise training is recommended for all stable HF patients with CRT to improve exercise capacity and quality of life. The optimal exercise program should be individualized, taking into account the patient's functional capacity, comorbidities, and the results of an exercise test, preferably a cardiopulmonary exercise test (CPET). A structured aerobic exercise program of light to moderate intensity should be initiated in a hospital setting, with gradual incorporation of home-based sessions. Training programs can vary in frequency (3-5 days per week), session duration (20-60 minutes), intensity (40%-80% of peak oxygen uptake or maximal heart rate), and overall program length (4-12 weeks).[48,49] Careful adjustment of CRT device parameters is necessary to ensure an appropriate chronotropic response, maintain biventricular pacing, and, in CRT-D patients, prevent inappropriate shocks during exercise.[14]

Participation in sports activities should be considered for individuals with chronic HF and CRT who are in stable condition and have no contraindications related to either the patient or the device. Low-to moderate-intensity endurance-based recreational sports may be considered for all asymptomatic individuals.[14,15] High-intensity recreational sports and competitive sports should be reserved for asymptomatic HF patients with preserved or mid-range ejection fraction, and only if they do not experience exercise-induced arrhythmias or exercise-induced hypotension.[15]

Recommendations for sports participation in patients with CIEDs are summarized in Table 3.

Appropriate Programming of Cardiac Implantable Electronic Devices During Exercise

Common problems that may arise during exercise in patients with CIEDs are summarized in Table 4. Chronotropic incompetence, defined as the inability to adequately increase heart rate during physical activity, can limit exercise tolerance.[14] In such cases, rate-adaptive pacing should be programmed to "ON." Special attention must be given to the proper adjustment of rate-

Table 4. Common Problems During Exercise and Proposed Solutions in Patients with Cardiac Implantable Electronic Devices

Problem	Programming Solution
Chronotropic incompetence, inappropriate sensor function	Activate RRP; adjust sensor reactivity
Sinus rate exceeding upper tracking limit	Increase the upper tracking limit
2:1 block during exercise	Shorten sensed AV delay and/or PVARP; consider rate-adaptive AV delay and rate-adaptive PVARP
Undersensing or oversensing during exercise	Adjust sensitivity settings (increase or decrease); avoid electrical or magnetic interference sour-ces
Accelerated junctional rhythm during exercise	Increase lower rate limit in dual-chamber and CRT devices; activate overdrive algorithms
Multiple supraventricular or premature ventricular beats, pacemaker-mediated tachycardia	Activate PMT intervention algorithm in dual chamber and CRT devices; activate PVC response algorithm in dual chamber device; consider increasing lower rate limit
Inappropriate shocks due to sinus tachycardia or supra-ventricular tachycardia	Prolong detection intervals in ICDs; activate VT/SVT discrimination algorithms; increase tachy-cardia detection rate if appropriate
Non-sustained ventricular tachycardia	Prolong detection intervals in ICDs
Loss of resynchronization due to shortened intrinsic AV interval	In CRT: Shorten sensed AV delay or activate rate-adaptive AV delay; consider negative AV hyste-resis if available

AV, Atrioventricular; CRT, Cardiac Resynchronization Therapy; ICD, Implantable Cardioverter-Defibrillator; PM, Pacemaker; PMT, Pacemaker-Mediated Tachycardia; PVARP, Post-Ventricular Atrial Refractory Period; PVC, Premature Ventricular Complex; RRP, Rate-Responsive Pacing; SVT, Supraventricular Tachycardia; VT, Ventricular Tachycardia.

responsive pacemaker sensor parameters to achieve an adequate pacing rate during exercise. In patients with dual-chamber PMs, the device must maintain synchrony between atrial and ventricular contractions to preserve optimal ventricular filling while also allowing for appropriate heart rate acceleration during exercise. To ensure 1:1 conduction, the upper tracking limit should be programmed above the maximum sinus rate. If the sinus rate continues to increase and surpasses the total atrial refractory period, which consists of the programmed sensed atrioventricular delay plus the post-ventricular atrial refractory period, it may lead to a pacemaker-induced 2:1 atrioventricular (AV) block. A sudden drop in heart rate and cardiac output at a given level of exercise causes symptoms such as dyspnea and fatigue. Additionally, a decrease in atrial signal amplitude during exercise may lead to atrial sensing issues. Therefore, P-wave amplitude should be assessed during exercise, and atrial sensitivity settings should be adjusted if necessary. Similarly, oversensing issues that occur during exercise may require sensitivity adjustments (Table 3). Furthermore, ventricular or supraventricular premature beats triggered during exercise can induce pacemaker-mediated tachycardia (PMT) in patients with dual-chamber pacemakers or CRT devices. To prevent or manage PMT, PMT intervention algorithms should be activated.

Supraventricular tachycardias and non-sustained ventricular tachycardia during exercise should not trigger ICD therapies. Setting the VT detection rate above the expected peak heart rate during exercise, prolonging the tachycardia detection time, and activating algorithms to discriminate between ventricular and supraventricular tachycardia can effectively prevent inappropriate and unnecessary ICD interventions, while still ensuring the delivery of life-saving treatment for dangerous ventricular tachyarrhythmias.[50,51]

In CRT systems, optimal device programming is particularly important to maintain effective resynchronization during exercise. Several factors may lead to CRT interruption during physical activity, including sinus rate exceeding the upper tracking limit, atrial fibrillation with rapid conduction, accelerated junctional rhythm, shortening of intrinsic atrioventricular delay due to increased adrenergic tone, and atrial under-sensing. Patients should receive device programming that maximizes resynchronization (Table 4).[14,23,52]

Conclusion

Structured exercise training improves exercise capacity in patients with CIEDs and is not associated with an increased risk of adverse events. Based on current knowledge, exercise interventions should primarily consist of aerobic activity combined with resistance exercise. A comprehensive clinical evaluation, a personalized training program, appropriate device programming, and regular follow-up are essential components to ensure that exercise is both safe and effective in patients with CIEDs.

The growing body of scientific data on sports participation in patients with CIEDs has led to a re-evaluation of previously restrictive recommendations. Recent guidelines suggest that individuals with a CIED should be encouraged to participate in sports activities, unless contraindicated by the underlying cardiac conditions. It is generally accepted that leisure-time sports activities of low to moderate intensity are safe and clinically beneficial for most individuals with CIEDs. Competitive sports may also be considered for selected athletes, in accordance with guideline recommendations. However, individualized recommendations remain essential, depending on the patient's cardiovascular health, the impact of sports on the underlying disease, and the type of implanted device.

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