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ORIGINAL RESEARCH

# Low Burden of Arrhythmia in Pediatric Patients and Patients With Congenital Heart Disease Participating in Cardiac Rehabilitation

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**BACKGROUND:** Cardiac rehabilitation (CR) is underused in pediatric and congenital heart disease populations. Concern about arrhythmia risk may be an obstacle to CR referral. We sought to describe the frequency and risk factors for arrhythmia in patients who participated in a standardized CR program.

**METHODS:** We conducted a retrospective chart review of all patients who completed at least 1 CR encounter from 2017 to 2022 at a pediatric cardiology center. We used descriptive statistics to determine the frequency of atrial and ventricular ectopy. Logistic regression was performed to identify predictors of frequent ventricular ectopy, nonsustained ventricular tachycardia, or ventricular tachycardia.

**RESULTS:** There were 177 patients who participated in 4494 rehabilitation encounters over the 6-year study period (median age, 17 years [14–22]). Most patients had congenital heart disease (63%). Moderate or severe systolic dysfunction was noted in 14% of patients. Presence of an implantable cardioverter-defibrillator (9% of patients) and a ventricular assist device (5% of patients) was noted. Nonsustained ventricular tachycardia occurred in 7 patients (3.9%) across 18 sessions (0.4%). There was an episode of sustained ventricular tachycardia resulting in an appropriate implantable cardioverter-defibrillator shock. There were no deaths. Patients ≥18 years old (odds ratio, 2.7 [95% CI, 1.1–6.4]) were more likely to have frequent ventricular ectopy, nonsustained ventricular tachycardia, or ventricular tachycardia.

**CONCLUSIONS:** Supervised CR in pediatric and congenital heart disease populations is associated with a low risk for clinically significant arrhythmias, and should not be an obstacle to referral for individuals who would otherwise benefit from CR.

**Key Words:** arrhythmia ■ cardiac rehabilitation ■ congenital heart disease ■ exercise safety ■ pediatric ■ ventricular ectopy

Cardiac rehabilitation (CR) is an important yet underused component in the care of pediatric patients and patients with congenital heart disease (CHD). CR leads to improvement across multiple exercise-related domains including maximal work capacity, cardiopulmonary endurance, and functional strength following repair of CHD.[1–3] CR programs may reduce depressive symptoms and improve the perception of physical fitness.[4] These benefits have also been shown to be sustained after completion of the program.[5,6] The benefits are not dependent on the type of CHD lesion.[4,7,8]

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## CLINICAL PERSPECTIVE

### What Is New?

- The frequency of arrhythmias in pediatric patients and patients with congenital heart disease participating in cardiac rehabilitation is low.

### What Are the Clinical Implications?

- Given the significant benefits and low risk of participating in cardiac rehabilitation, future investigations are needed to evaluate mechanisms to increase participation of eligible patients in cardiac rehabilitation at pediatric and adult congenital cardiac centers.
- Current limits to cardiac rehabilitation research in the congenital heart disease population include heterogenous lesions and small numbers of an individual defect within study populations; this may be overcome by increased collaboration across programs and multicenter studies.

### Nonstandard Abbreviations and Acronyms

| | |
|---|---|
| **CR** | cardiac rehabilitation |
| **NSVT** | nonsustained ventricular tachycardia |
| **SVT** | supraventricular tachycardia |

Despite these benefits and CR programmatic guidelines from the American College of Cardiology and the American Heart Association, there remains significant CR underuse.[9–11] Reasons for low CR participation include lack of insurance coverage, the time-intensive nature of CR programs, and limited accessibility of CR programs.[12–15] Safety concerns, including fear of developing an arrhythmia during physical activity may also limit referral and participation in CR.[16]

In the adult population, the low risk of adverse events related to CR has long been established.[17,18] Although there is some evidence suggesting that cardiopulmonary exercise testing in pediatric patients and patients with CHD is safe, there are limited data in these populations on the burden of arrhythmias during CR.[19–21]

The aims of this study were: (1) to describe the frequency of arrhythmias in pediatric patients and patients with CHD participating in structured CR; (2) to describe negative patient outcomes including unplanned admission and death from our experience as a CR program; and (3) to describe predictors of frequent ventricular ectopy, nonsustained ventricular tachycardia (NSVT), and ventricular tachycardia (VT).

# METHODS

## Study Design and Population

We performed a retrospective chart review using data from the Cincinnati Children's Hospital Medical Center Heart Institute. The local institutional review board reviewed and approved this study before data collection. Informed consent was waived by the institutional review board. Patients were eligible for inclusion if they completed at least 1 CR session between January 1, 2017 and December 31, 2022. Encounters without telemetry data were excluded. Referrals to cardiac rehabilitation were placed by the primary cardiologist or inpatient team. The authors declare that all supporting data are available within the article and its online supplementary files.

## Setting

Cincinnati Children's Hospital Medical Center's cardiac rehabilitation program was formed in 2010 and received program certification from the American Association of Cardiovascular and Pulmonary Rehabilitation in 2019. The CR laboratory is operated by exercise physiologists with master's degrees and overseen by pediatric and adult congenital cardiologists. CR sessions consist of a 5- to 10-minute warm-up, 20 minutes of aerobic exercise (treadmill or bicycle), 20 minutes of weight training, and a 10-minute cool-down (Figure 1). The mix of cardiovascular endurance and weight-based training is common in other rehabilitation programs and in keeping with current recommendations from the American Association of Cardiovascular and Pulmonary Rehabilitation.[22] Telemetry is recorded throughout the session (VersaCare; ScottCare, Cleveland, OH). Exercise physiologists develop an individualized program within this framework based on the patient's ability and needs.

## Key Outcome and Predictor Variables

The primary outcome variables were the presence of ventricular tachycardia and any other form of ectopy. The secondary outcome was death or admission due to a CR session. Isolated ectopy was defined as a single ectopic beat. Rare ectopy was defined as <10 ectopic beats per hour. Occasional ectopy was defined as 10 to 30 beats per hour. Frequent ectopy was defined as >30 beats per hour, which has been used previously in the literature.[23] NSVT was defined as >120 bpm, ≥3 beats, and <30 seconds. VT was determined to be sustained if it lasted ≥30 seconds. We define clinically significant arrhythmia as any occurrence of NSVT, VT, or arrhythmias requiring medical intervention, clinic or emergency room visit, or implantable cardioverter-defibrillator (ICD) therapy, which is modeled off a previously reported definition.[24]

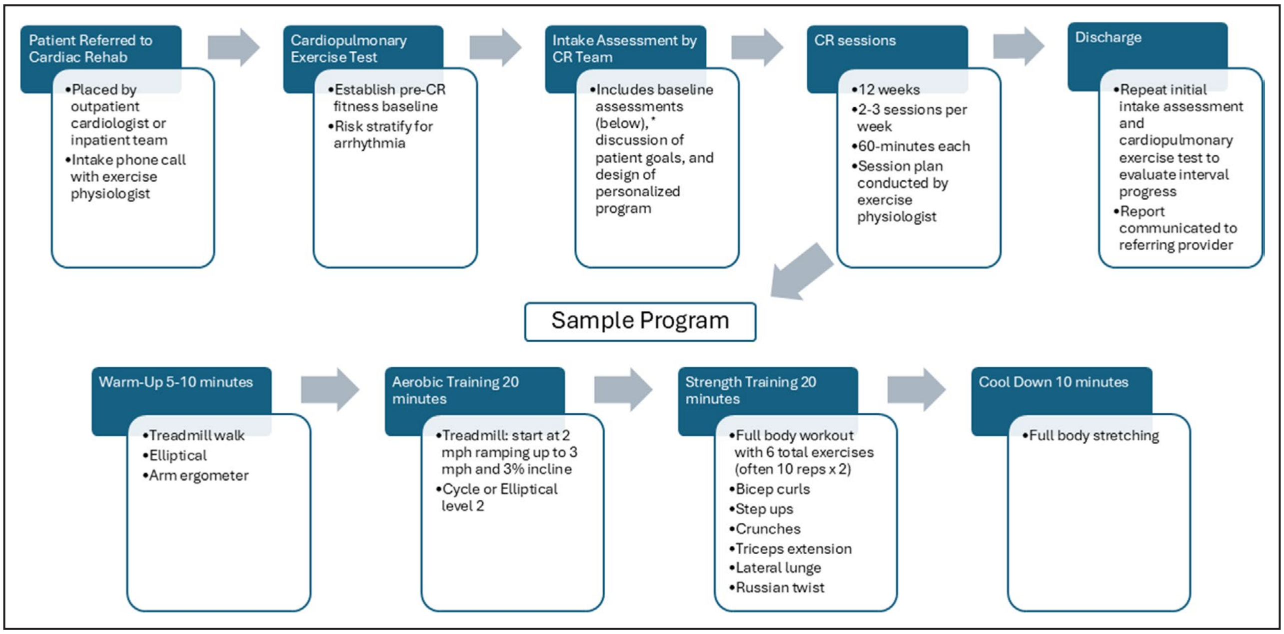


**Figure 1. Cardiac rehabilitation referral process at CCHMC and sample 60-minute CR session activities.**
*Baseline assessment includes handgrip, 6-minute walk, body composition analysis, body circumference measurements, arm curls, sit to stand, sit and reach, self-reported questionnaires. CCHMC indicates Cincinnati Children's Hospital Medical Center; and CR, cardiac rehabilitation.

Patient demographic data including age and sex were recorded. Cardiac disease was classified by CHD, cardiomyopathy, and other (including structurally normal hearts, rheumatic heart disease, pulmonary hypertension, and any other cardiac pathology not meeting criteria for CHD or cardiomyopathy) at the time of the first CR session. The CHD category was further delineated by specific pathology. We detailed whether the encounters involved a patient with an ICD, pacemaker, or ventricular assist device during that specific CR encounter, systolic function on echocardiogram, and presence of resting hypoxemia (peripheral capillary oxygen saturation <90%). Systemic ventricle systolic function on echocardiogram was determined based on their most recent echocardiogram report in the 12 months before participating in their first CR session, or in the 12 months after their first CR visit if there was no preceding echocardiogram. Systolic function was defined as normal for ejection fraction (EF) ≥55%, mildly diminished for EF 41% to 54%, moderately diminished for EF 31% to 40%, and severely diminished for EF ≤30%. If no EF was available, then the qualitative assessment of function listed in the report was used. Patients who experienced NSVT during CR were assessed for the presence of NSVT or sustained VT before the first CR session in which NSVT occurred. These data were all accessible from within the electronic health record. CR session information obtained included baseline ECG data, telemetry recordings, and rehabilitation session reports. The CR ECG interpretation was confirmed by either a pediatric electrophysiologist or congenital cardiologist involved in the CR program.

## Statistical Analysis

Data were summarized as median with interquartile range (IQR) for continuous variables and frequency with percentage for categorical variables stratified by whether or not they had ever had frequent ventricular ectopy. Mixed-effect logistic regression with maximum likelihood estimation was performed to identify factors associated with having frequent ventricular ectopy to account for repeat patient visits. Age, single ventricle versus 2 ventricles, baseline ECG, systolic function, resting hypoxemia (peripheral capillary oxygen saturation <90%), median sternotomy, presence of structural heart disease (CHD and cardiomyopathy), and presence of ICD, pacemaker, or ventricular assist device were evaluated. Step-down Sidak method was used to adjust for the number of variables evaluated in univariate analysis. Finally, a multivariable mixed-effect logistic model was performed to include all variables listed above; interaction with time since baseline visit was included only if significant to prevent the model being too complex and avoid an unstable effect estimate. Because some patients had a change in their classification over the course of their participation in CR, such as getting an ICD or a single-ventricle patient undergoing heart transplantation (and now no longer meeting classification for single ventricle), we

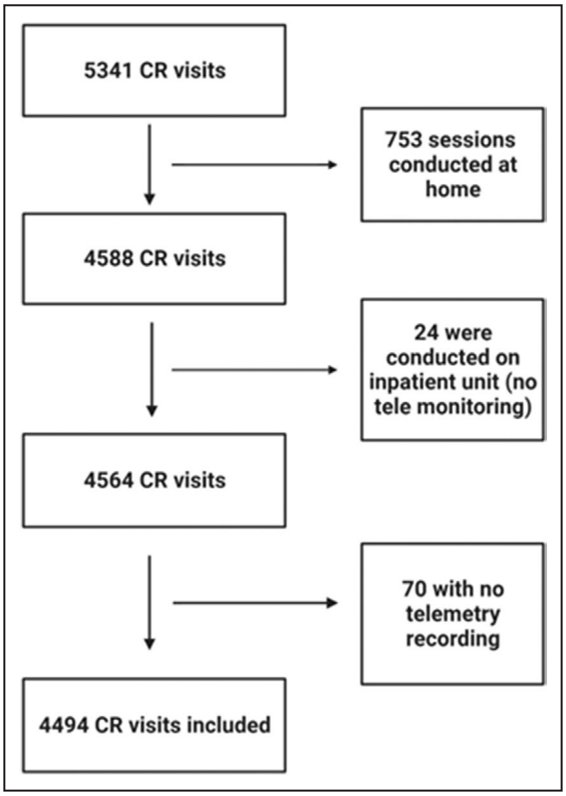


**Figure 2. Study flow diagram.**
Study flow diagram of CR visits. All CR visits at Cincinnati Children's Hospital Medical Center from 2017 to 2022 are listed. Visits without telemetry were excluded. Most exclusions were due to at-home CR sessions conducted during the COVID-19 pandemic. CR indicates cardiac rehabilitation.

performed separate models based on the classification of each patient at the initial and final CR session. All analyses were performed in SAS 9.4. For all statistical tests, a *P* value <0.05 was considered significant.

# RESULTS

There were 5341 CR sessions completed during the 5-year study period (Figure 2). After excluding sessions with no recorded telemetry data, 4494 CR visits by 177 patients were remaining. Virtual CR during the COVID-19 pandemic was responsible for most of the excluded encounters, because remote ECG monitoring is not currently supported by the Cincinnati Children's Hospital Medical Center CR program.

The median age of those participating in CR was 17 years (IQR, 14–22) (Table 1). Most patients were <18 years old (57%). CHD was present in most patients (63%), followed by cardiomyopathy (21%) and other cardiac diagnosis (16%). The baseline ECG was sinus rhythm for nearly all patients (99%), whereas the remaining baseline ECG was atrial fibrillation or paced activity (1%). Patients with support devices included those with an ICD (9%), pacemaker (12%), or ventricular assist device (5%). Most patients had normal systolic ventricular function (69%), whereas a minority had moderately (6%) or severely depressed (8%) function. Resting hypoxemia <90% was uncommon (9%).

The most common CHD lesion involved patients with single-ventricle physiology (29%) followed by tetralogy of Fallot (7%) and mixed lesions (7%) (Table 2). There were minimal encounters for patients with an isolated atrial septal defect, ventricular septal defect, mitral valve disease, or aortic coarctation (1% of patients).

Ectopy was present in one-third of encounters (36%) (Table 3). Supraventricular ectopy (11%) was less common than ventricular ectopy (29%). Supraventricular tachycardia (SVT) was uncommon during CR sessions (1%). Most encounters with SVT involved a single

**Table 1. Demographic and Baseline Clinical Information for Patients Participating in Cardiac Rehabilitation**

| Study Variable | Overall (N=177) (%) | Ever had frequent ventricular ectopy: No (N=119) (%) | Ever had frequent ventricular ectopy: Yes (N=58) (%) |
|---|---|---|---|
| Women | 87 (49) | 59 (49) | 28 (48) |
| Age, y | 16.7 [13.8–21.5] | 15.3 [13.2–18.9] | 20 [15.3–28.1] |
| Age <18 y | 100 (57) | 78 (66) | 22 (38) |
| Structural heart disease | | | |
| None | 28 (16) | 21 (18) | 7 (12) |
| Congenital heart disease | 112 (63) | 74 (62) | 38 (66) |
| Cardiomyopathy | 37 (21) | 24 (20) | 13 (22) |
| Baseline ECG | | | |
| Sinus | 175 (99) | 118 (99) | 57 (98) |
| Other | 2 (1.1) | 1 (0.8) | 1 (1.7) |
| ICD | 16 (9.0) | 7 (5.9) | 9 (16) |
| Pacemaker | 21 (12) | 14 (12) | 7 (12) |
| VAD | 9 (5.1) | 4 (3.4) | 5 (8.6) |
| Systolic function | | | |
| Normal | 122 (69) | 88 (74) | 34 (59) |
| Low-normal | 4 (2.3) | 2 (1.7) | 2 (3.4) |
| Mildly diminished | 19 (11) | 11 (9.2) | 8 (14) |
| Moderately diminished | 11 (6.2) | 5 (4.2) | 6 (10) |
| Severely diminished | 14 (7.9) | 7 (5.9) | 7 (12) |
| Not assessed | 7 (4.0) | 6 (5.0) | 1 (1.7) |
| Resting hypoxemia ($SpO_2$ <90%) | 15 (8.5) | 7 (5.9) | 8 (14) |
| Single ventricle | 52 (29) | 34 (29) | 18 (31) |
| Median sternotomy | 130 (73) | 84 (71) | 46 (79) |

Data are presented as number (percentage) or median [interquartile range]. ICD indicates implanted cardioverter-defibrillator; $SpO_2$, peripheral capillary oxygen saturation measured by pulse oximetry; and VAD, ventricular assist device.

**Table 2. Specific Cardiac Lesion Among Study Population With CHD**

| Study Variable | Overall (N=177) (%) | Ever had frequent ventricular ectopy | |
|---|---|---|---|
| | | No (N=119) (%) | Yes (N=58) (%) |
| CHD lesion | | | |
| None | 65 (37) | 45 (38) | 20 (35) |
| Single ventricle | 52 (29) | 34 (29) | 18 (31) |
| TOF | 13 (7.3) | 11 (9.2) | 2 (3.4) |
| AVSD | 5 (2.8) | 2 (1.7) | 3 (5.2) |
| Aortic valve | 7 (4.0) | 6 (5.0) | 1 (1.7) |
| dTGA | 6 (3.4) | 3 (2.5) | 3 (5.2) |
| Coronary anomaly | 3 (1.7) | 3 (2.5) | 0 (0) |
| Truncus arteriosus | 2 (1.1) | 1 (0.8) | 1 (1.7) |
| ccTGA | 2 (1.1) | 2 (1.7) | 0 (0) |
| Pulmonary valve | 5 (2.8) | 3 (2.5) | 2 (3.4) |
| Ebstein | 2 (1.1) | 1 (<1) | 1 (1.7) |
| VSD | 1 (<1) | 1 (<1) | 0 (0) |
| Mitral valve | 1 (<1) | 1 (<1) | 0 (0) |
| Mixed lesion | 13 (7.3) | 6 (5.0) | 7 (12) |

Data are presented as number (percentage). AVSD indicates atrioventricular septal defect; ccTGA, congenitally corrected transposition of the great arteries; CHD, congenital heart disease; dTGA, dextro-transposition of the great arteries; TOF, tetralogy of Fallot; and VSD, ventricular septal defect.

patient with heterotaxy syndrome and unrepaired complete atrioventricular canal, double outlet right ventricle (Taussig Bing anomaly), and Eisenmenger syndrome with normal ventricular function whose baseline rhythm was atrial fibrillation (63% of all encounters with SVT). The other patients with SVT included a heterogenous mix of cardiac lesions with variable function (Table S1). The longest run of supraventricular tachycardia was 46 beats. None of the encounters with SVT led to the termination of the CR session or required intervention.

Clinically significant ventricular ectopy was rare (Table 3). NSVT occurred in 7 patients across 18 encounters (<1%; 7 patients). Sustained VT occurred in a single encounter (<1%). Seven of the 8 patients with NSVT or sustained VT had a prior history of NSVT or sustained VT before beginning CR (Table 4). Of the encounters with NSVT, 17 out of 18 (94%) also had frequent ventricular ectopy. None of the encounters with NSVT led to session termination or required intervention. A patient with D-transposition of the great arteries status post Mustard in infancy and current ventricular assist device placement as an adult accounted for 12 encounters with NSVT. The 6 remaining encounters with NSVT occurred in 6 individual patients with variable systolic ventricular function and underlying cardiac pathology.

A single episode of sustained VT occurred in a 16-year-old patient with myocarditis and VT that was inducible during electrophysiology study (ablation attempted and failed). He underwent placement of an ICD. There was concern for an underlying cardiomyopathy, although genetic testing was inconclusive. Seven months after the initial myocarditis diagnosis he was referred to CR. He had mildly diminished function and normal inflammatory markers. During his fifth CR encounter, he developed VT and received an appropriate

**Table 3. Frequency of Ectopy During Cardiac Rehabilitation**

| Study Variable | Overall (N=4494) (%) |
|---|---|
| Overall ectopy | |
| No ectopy | 2861 (64) |
| Supraventricular or ventricular ectopy | 1633 (36) |
| Supraventricular ectopy | |
| None | 4007 (89) |
| Isolated | 136 (3) |
| Rare | 191 (4) |
| Occasional | 84 (2) |
| Frequent | 39 (1) |
| SVT | 62 (1) |
| Ventricular ectopy | |
| None | 3188 (71) |
| Isolated | 260 (6) |
| Rare | 430 (10) |
| Occasional | 284 (6) |
| Frequent | 332 (7) |
| NSVT | 18 (<1) |
| VT | 1 (<1) |

Data are presented as number (percentage). Rare ectopy was defined as <10 ectopic beats per h. Occasional ectopy was defined as 10 to 30 beats per h. Frequent ectopy was defined as >30 beats per h. SVT was defined as ≥3 beats, narrow QRS complex (according to age-related normative values) tachycardia. NSVT was defined as wide complex rhythm, >120 bpm, ≥3 beats, and <30 seconds. VT was defined by the same features but lasting ≥30 seconds. NSVT indicates nonsustained ventricular tachycardia; SVT, supraventricular tachycardia; and VT, ventricular tachycardia.

**Table 4. Description of Patient Encounters With NSVT**

| Cardiac diagnosis | Encounters with NSVT | Total encounters | Description | Activity during NSVT | Prior history of NSVT/VT? | Active antiarrhythmia medication | Systolic function | Support device |
|---|---|---|---|---|---|---|---|---|
| dTGA status post Mustard, status post VAD | 12 | 41 | Multiple episodes (longest 29 beats), none after encounter 26 | Rest in between exercise, cool down after exercise, weights, recumbent bike | Yes | No | Moderately diminished | Heartmate 3 |
| DCM | 1 | 64 | 3 beats during encounter 16 | Recumbent bike | Yes | No | Moderately diminished | None |
| DCM | 1 | 50 | 3 beats during encounter 29 | Rest in between exercise | Yes | No | Severely diminished | None |
| Tricuspid atresia with normally related great vessels s/p Fontan | 1 | 33 | 5 beats during encounter 3 | Treadmill | No | No | Normal | None |
| OHT (failed single ventricle palliation) | 1 | 23 | Multiple episodes (longest 8 beats) during encounter 1 | Rest in between exercise | Yes | No | Normal | None |
| Rhabdomyosarcoma | 1 | 29 | Multiple episodes (longest 10 beats) during encounter 25 | Weights | Yes | No | Normal | None |
| OHT (DCM) | 1 | 31 | 9 beats during encounter 11 | Weights | Yes | No | Severely diminished | None |

DCM indicates dilated cardiomyopathy; dTGA, dextro-transposition of the great arteries; ICD, implantable cardioverter-defibrillator; NSVT, nonsustained ventricular tachycardia; OHT, orthotopic heart transplant; and VT, ventricular tachycardia.

ICD shock (Figure S1). He was seen in an outpatient clinic following the event and sent home from the clinic that day. This patient returned to CR after undergoing successful VT ablation and completed 36 additional CR encounters following the same protocol without further arrhythmia or event. There were no other significant interventions required during a CR session and no deaths throughout the study period.

No patient was admitted secondary to a CR-related event. There was a teenage patient with a Fontan circulation who presented to their CR session in atrial tachycardia and was subsequently admitted, but the arrhythmia occurred before the start of exercise.

Patients with frequent ventricular ectopy had more CR sessions (25 versus 13, $P$=0.008) and a longer follow-up time (23 weeks versus 14 weeks, $P$=0.006) than those without frequent ventricular ectopy (Table S2). There was no clear correlation between CR visit number and timing of ectopy.

In univariate analysis after adjusting for multiple tests, only moderate or greater systolic dysfunction was associated with frequent ventricular ectopy, NSVT, or VT (odds ratio [OR], 5.3 [95% CI, 1.9–14.8]; Table 5). There was no significant association with sex, ventricular morphology, median sternotomy, baseline ECG, resting hypoxemia, presence of structural heart disease, or pacemaker.

In multivariable analysis, patients ≥18 years old (OR, 2.7 [95% CI, 1.4–6.4]) were more likely to have frequent ventricular ectopy, NSVT, or VT. There was a significant interaction between pacemaker and time since the initial visit. The risk of having frequent ventricular ectopy lessened with time in patients with pacemakers (OR, 0.96 [95% CI, 0.92–1.00]; Table S3) compared with patients without pacemakers (OR, 1.00 [95% CI, 01.00–1.01]).

## DISCUSSION

In this large cohort of 177 pediatric patients and patients with CHD participating in 4494 CR encounters, the burden of clinically significant arrhythmias was low. To the best of our knowledge, this is the largest number of pediatric patients and patients with CHD ever evaluated for arrhythmia in the CR setting. There was a single hemodynamically significant arrhythmia that required intervention and termination of the CR session over the 6-year study period. Of note, this patient received an appropriate ICD discharge and was discharged home from cardiology clinic following the

**Table 5. Unadjusted OR for Frequent Ventricular Ectopy, Nonsustained Ventricular Tachycardia, or Ventricular Tachycardia**

| Variable | OR (95% CI) | *P* value* |
|---|---|---|
| Women | 0.59 (0.26–1.34) | 0.81 |
| Age ≥18y | 2.95 (1.32–6.62) | 0.09 |
| Congenital heart disease | 1.29 (0.39–4.26) | 1.00 |
| Cardiomyopathy | 1.47 (0.37–5.91) | 1.00 |
| Baseline sinus rhythm | 1.00 (0.14–7.02) | 1.00 |
| ICD | 3.63 (1.04–12.72) | 0.33 |
| Pacemaker | 0.98 (0.28–3.47) | 1.00 |
| VAD | 6.44 (1.28–32.29) | 0.21 |
| Resting hypoxemia ($SpO_2$ <90%) | 2.98 (0.83–10.67) | 0.54 |
| Single ventricle | 1.45 (0.55–3.84) | 0.97 |
| Median sternotomy | 1.09 (0.42–2.85) | 1.00 |
| ≥Moderate systolic dysfunction | 5.28 (1.89–14.75) | 0.02 |
| Time from the initial visit (wk) | 1.00 (1.00–1.01) | 1.00 |

ICD indicates implantable cardioverter-defibrillator; OR, odds ratio; $SpO_2$, peripheral capillary oxygen saturation measured by pulse oximetry; and VAD, ventricular assist device.

*Step-down Sidak adjusted *P* value.

event. There were no deaths or events that required hospitalization in this cohort.

These results are in line with previously reported research on arrhythmia development during exercise in patients with CHD. Many patients with CHD who underwent cardiopulmonary exercise testing had a low incidence of clinically significant arrhythmia, occurring in 5 tests out of >5000 encounters.[19] Of note, the type of exercise for cardiopulmonary exercise testing is different than CR. Cardiopulmonary exercise testing tends to be shorter (8–12 minutes) with gradual increases of intensity until exhaustion, whereas CR is longer with variations in intensity throughout. A smaller group of 20 patients on inotropic support awaiting heart transplantation had no adverse cardiac events while engaged in low-intensity aerobic activity during CR.[20] Although deaths have been reported in the adult CR population, to the best of our knowledge there are no reported deaths for pediatric patients and patients with CHD engaging in this controlled exercise environment.[10,14,22]

The low burden of arrhythmias in our study is notable given the relatively high prevalence of complex CHD, depressed left ventricular function, and ICDs. There is emerging evidence that certain populations, such as those with hypertrophic cardiomyopathy, may not be at as high of an increased risk of death or life-threatening arrhythmias during participation in vigorous exercise as previously thought.[25] Given the lack of serious adverse events during CR reported in the literature and present in our study, we may be able to consider increasing exercise intensity during these controlled sessions with certain predetermined populations using shared decision-making.[26] Additionally, structured CR can provide reassurance and supervision for those with kinesiophobia related to their heart disease, such as those with an ICD who have had a previous shock.[27] The infrequent burden of VT even in those with an ICD in our cohort may make CR a reasonable instrument to reassure these patients, further removing barriers to those with heart disease.

Despite the low rate of clinically significant arrhythmia in our cohort, we were able to identify high-risk characteristics for pediatric patients and patients with CHD undergoing CR. Our multivariate analysis showed that age ≥18 years was associated with an increased risk of frequent ventricular ectopy, NSVT, and VT. Although there was only a single episode of sustained VT in our cohort, the case highlights that precautions must be taken in patients with a high risk of life-threatening arrhythmia to ensure safety during exercise training. It should be noted that the data gained from this patient's monitored CR encounter resulted in a clinical intervention (VT ablation) that led to reduced activity restrictions.

Fitness has been shown to be protective in patients with CHD, and CR has been shown to improve fitness in this population.[1,2,6,28,29] Yet, there remain significant time and accessibility issues that reduce participation of patients with CHD in CR. Benefits of CR have been shown to occur in nontraditional settings, including in monitored virtual rehabilitation or smartphone-based rehabilitation.[4,30,31] Given the lack of significant arrhythmias reported in our study, expansion of virtual CR might improve CR participation and expand the receipt of benefits to more patients while at the same time adding negligible risk. We have shown with our data that a transition for certain patients to virtual CR is safe and effective in patients with CHD during the COVID-19 pandemic.[4] Furthermore, our data suggest that some patients without high-risk characteristics may not require any telemetry recording. The necessity of telemetry recording for all patients and the optimal duration of telemetry recording during CR should be evaluated in future research. On the contrary, episodes of clinically significant arrhythmia did not clearly correlate with earlier or later visits, suggesting that all patients with high risk of clinically significant arrhythmia be monitored on telemetry at all visits.

## Limitations

Our study is limited in part by the study design and retrospective nature of data collection. This impairs our ability to assess any correlation between exercise intensity and ectopy burden. Each training session was individualized to the patient's needs, which limits assessment of whether specific training techniques are associated with a higher risk of arrhythmia. It is possible that patients at the highest risk of developing arrhythmia during exercise were not referred to CR, and therefore this selection bias may affect the results. The large burden of complex CHD in the patient population at this single, quaternary cardiology referral center may not be generalizable to other centers. However, it is reasonable to expect the overall ectopy burden in more mild forms of CHD to be even less than the frequency present in our group. Finally, there was a small sample size of certain variables that resulted in wider confidence intervals and may suggest greater uncertainty with these estimates.

Most of the encounters for SVT involved a patient whose baseline rhythm was atrial fibrillation, and therefore the SVT was not related to participation in CR. This likely results in an overestimation of the SVT related to CR. This study does not evaluate the reasons why some patients might not complete their prescribed CR course, which merits evaluation in future research.

## CONCLUSIONS

The burden of arrhythmias in pediatric patients and patients with CHD participating in structured CR is low. Precautions should be taken for patients who are known to have a high risk of developing ventricular arrhythmias, particularly adult patients with CHD and an ICD.

## ARTICLE INFORMATION

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### Disclosures

None.

### Supplemental Material

Tables S1–S3
Figure S1

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