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ORIGINAL RESEARCH

Tachyarrhythmias During Hospitalization for COVID-19 or Multisystem Inflammatory Syndrome in Children and Adolescents

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BACKGROUND: Cardiac complications related to COVID-19 in children and adolescents include ventricular dysfunction, myocarditis, coronary artery aneurysm, and bradyarrhythmias, but tachyarrhythmias are less understood. The goal of this study was to evaluate the frequency, characteristics, and outcomes of children and adolescents experiencing tachyarrhythmias while hospitalized for acute severe COVID-19 or multisystem inflammatory syndrome in children.

METHODS AND RESULTS: This study involved a case series of 63 patients with tachyarrhythmias reported in a public health surveillance registry of patients aged <21 years hospitalized from March 15, 2020, to December 31, 2021, at 63 US hospitals. Patients with tachyarrhythmias were compared with patients with severe COVID-19–related complications without tachyarrhythmias. Tachyarrhythmias were reported in 22 of 1257 patients (1.8%) with acute COVID-19 and 41 of 2343 (1.7%) patients with multisystem inflammatory syndrome in children. They included supraventricular tachycardia in 28 (44%), accelerated junctional rhythm in 9 (14%), and ventricular tachycardia in 38 (60%); >1 type was reported in 12 (19%). Registry patients with versus without tachyarrhythmia were older (median age, 15.4 [range, 10.4–17.4] versus 10.0 [range, 5.4–14.8] years) and had higher illness severity on hospital admission. Intervention for treatment of tachyarrhythmia was required in 37 (59%) patients and included antiarrhythmic medication (n=31, 49%), electrical cardioversion (n=11, 17%), cardiopulmonary resuscitation (n=8, 13%), and extracorporeal membrane oxygenation (n=9, 14%). Patients with tachyarrhythmias had longer hospital length of stay than those who did not, and 9 (14%) versus 77 (2%) died.

CONCLUSIONS: Tachyarrhythmias were a rare complication of acute severe COVID-19 and multisystem inflammatory syndrome in children and adolescents and were associated with worse clinical outcomes, highlighting the importance of close monitoring, aggressive treatment, and postdischarge care.

Key Words: COVID-19 ■ multisystem inflammatory syndrome in children (MIS-C) ■ tachyarrhythmia

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CLINICAL PERSPECTIVE

What Is New?

- Tachyarrhythmias were rare (1.8%) in a cohort of 3600 children and adolescents with severe acute COVID-19 and multisystem inflammatory syndrome in children from the OC-19 (Overcoming COVID-19) public health registry.
- Tachyarrhythmias occurred most frequently in older and sicker patients with cardiac and multisystem involvement and were associated with prolonged hospital length of stay and higher in-hospital mortality.

What Are the Clinical Implications?

- Longer-term surveillance after hospital discharge will be important to better understand the arrhythmic and other cardiac risks after acute COVID-19 or multisystem inflammatory syndrome in children complicated by tachyarrhythmia.

Nonstandard Abbreviations and Acronyms

MIS-C	multisystem inflammatory syndrome in children
OC-19	Overcoming COVID-19
SVT	supraventricular tachycardia

Children with COVID-19 are more likely to have asymptomatic or mild disease as compared with adults[1–3] but are still at risk of critical illness.[4] Manifestations of cardiovascular involvement include elevated BNP (B-type natriuretic peptide), elevated troponin level, ventricular dysfunction, coronary artery aneurysms, pericardial effusion, and arrhythmias.[5–9] Only limited data are available on arrhythmias in children following COVID-19 infection.[5,8] Using sentinel surveillance data from the OC-19 (Overcoming COVID-19) network, we sought to characterize tachyarrhythmias, including interventions and outcomes in inpatients aged <21 years with acute severe COVID-19 or multisystem inflammatory syndrome in children (MIS-C).

METHODS

Design and Participants

Eligibility criteria and methods for the OC-19 public health surveillance registry have previously been published.[5–6] Patients aged <21 years old hospitalized with SARS-CoV-2–related illness admitted to the hospital from March 15, 2020, to December 31, 2021, were screened. Eligible patients had acute severe COVID-19 (admitted to the intensive care unit or stepdown unit) or MIS-C (Data S1).[5–6] The OC-19 registry was approved by the central institutional review board at Boston Children's Hospital and granted a waiver of consent. It was reviewed by the Centers for Disease Control and Prevention and was conducted consistent with applicable federal law and Centers for Disease Control and Prevention policy (45 C.F.R. part 46.102(l)(2); 21 C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq). The authors declare that all data are available in the article and online supplementary material.

Tachyarrhythmia Case Ascertainment and Definitions

Cases were identified on the basis of a report of a tachyarrhythmia during hospital admission documented in the medical record. Tachyarrhythmia was defined as a report of an atrial, junctional, or ventricular arrhythmia meeting prespecified definitions. Supraventricular tachycardia (SVT) was defined as narrow or usual complex tachycardia >3 beats with ≥1:1 atrial-ventricular association, and further classified as atrial fibrillation, atrial flutter, ectopic atrial tachycardia, or reentrant SVT. Accelerated junctional rhythm was defined as narrow or usual complex tachycardia with ≥1:1 ventricular-atrial association and rates >100 bpm. Ventricular tachycardia was defined as wide complex tachycardia, and further classified as nonsustained (≥3 consecutive ventricular beats, rate>120 bpm and <30 seconds duration), sustained (>30 seconds or requiring intervention for termination), and ventricular fibrillation.

For cases with a reported arrhythmia, an additional case report form (Data S1) was sent to each center's principal investigator to confirm the diagnosis and collect additional information on the course of arrhythmia and treatments required. Deidentified ECGs were reviewed and classified by consensus of 3 pediatric cardiologists (A.D., K.F., J.N.) when available for review. There was consensus from all 3 reviewers for all cases, and 2 patients were reclassified after central review of ECG tracings.

Cardiac involvement was defined as serum BNP or NT-proBNP (N-terminal pro-B-type natriuretic peptide) ≥1000 pg/mL, elevated troponin based on the upper limit of normal for the site laboratory, left ventricular ejection fraction <55%, or coronary artery aneurysm.[5] If no test was performed, it was considered normal. Left ventricular ejection fraction (EF) was categorized as normal if EF was ≥55%, mild–moderate ventricular dysfunction if EF was 35 to <55%, and severe ventricular dysfunction if EF was <35%; in cases where EF was unavailable, qualitative assessment of ventricular

function was used. Coronary artery aneurysm was defined as proximal right coronary artery or left anterior descending coronary *z* score ≥2.5.[10] When >1 echocardiogram was available, patients were classified on the basis of their worst-ever EF and highest coronary artery *z* score during the illness.[11] The Pediatric Sequential Organ Failure Assessment score is a continuous score between 0 and 24, including respiratory, coagulation, hepatic, cardiovascular, neurologic, and renal organ assessment.

Statistical Analysis

Descriptive statistics were obtained for clinical characteristics, tachyarrhythmias, and outcomes. Quantitative variables were summarized as median (Quartile 1 [Q1], Quartile 3 [Q3]), and categorical variables as frequencies and percentages. Patients with and without tachyarrhythmias were compared using the chi-squared test, Fisher exact test, or Mann–Whitney test where appropriate. A 2-tailed *P* value <0.05 was deemed statistically significant. All analyses were performed with R software version 4.0.2 (R Project for Statistical Computing, Vienna, Austria).

RESULTS

Demographics and Clinical Characteristics Among All Patients

Table 1 shows the characteristics of the 3600 surveillance registry patients meeting inclusion criteria: 2097 (58%) male; median age, [10.1 Q1, Q3: 5.4, 14.8] years, including 1257 (35%) with severe acute COVID-19 infection and 2343 (65%) with MIS-C.

Tachyarrhythmias

Tachyarrhythmias were reported in 22 (1.8%) registry patients with severe acute COVID-19 and 41 (1.7%) patients with MIS-C (Table 1, Table S1). Among patients with tachyarrhythmias, SVT was diagnosed in 28 (44%) patients (reentrant SVT in 2 patients, ectopic atrial tachycardia in 10, atrial flutter in 8, atrial fibrillation in 9, and unclassified in 1), accelerated junctional rhythm in 9 (14%), and ventricular tachycardia (VT) in 38 (60%) (nonsustained in 28, sustained in 11, ventricular fibrillation in 5; Figure 1, Figure 2). Clinical characteristics of patients grouped by type of tachyarrhythmia are shown in Figure 3, Table S2. More than 1 type of tachyarrhythmia was observed in 12 (19%) patients. Two patients (3%) had high-grade atrioventricular block during hospital admission, in addition to tachyarrhythmias. The diagnosis of tachyarrhythmia was confirmed on 12-lead ECG in 23 (36%) patients and the remainder by review of hospital record documentation by cardiologists (n=37, 59%) or other medical providers (n=3, 5%; Table S3). Tachyarrhythmias were identified a median of 6 (Q1, Q3: 4, 9.5) days after onset of symptoms and 2 (Q1, Q3: 0, 5) days after hospital admission (Table 2). Tachyarrhythmias resolved at a median of 1 (Q1, Q3: 0, 3; range, 0–37) day after onset.

Baseline 12-lead ECGs were available to review in 22 patients (34%) with tachyarrhythmias, including 10 patients with SVT, 2 patients with accelerated junctional rhythm, and 15 patients with ventricular arrhythmia (Table S4). ST-segment changes were the most frequent abnormality (n=15, 68%), including T-wave inversion in 5 patients, ST-segment elevation in 2 patients, ST-segment depression in 1 patient, and nonspecific changes in 8 patients. Prolonged corrected QT interval was observed in 8 (24%) patients. Other changes included axis deviation, right bundle branch block, ventricular hypertrophy, first-degree atrioventricular block, atrial pacing, premature atrial contraction, and atrial enlargement (Table S4). There were no significant differences in baseline ECG among types of arrhythmias, although comparisons are limited by small numbers.

Thirty-seven patients with tachyarrhythmias (59%) required intervention for arrhythmia, and 26 patients (41%) had no interventions recorded (Table 2). Antiarrhythmic medications were used in 31 (49%) patients and included adenosine in 2 patients, beta-blockers in 15, calcium channel blockers in 4, lidocaine in 5, procainamide in 4, and amiodarone in 11. Electrical cardioversion was used in 11 (17%) patients, including 8 patients with SVT (atrial fibrillation in 5, atrial flutter in 3) and 4 patients with VT. Cardiopulmonary resuscitation was required in 8 (13%) patients, and 9 (14%) received extracorporeal membrane oxygenation support because of refractory arrhythmias (SVT in 4 patients, accelerated junctional rhythm in 4, VT in 8). Antiarrhythmic treatment was most often transient, and 14 (22%) patients were discharged home on antiarrhythmic medication. Antiarrhythmic medication at time of discharge was most often a beta-blocker (12 patients, 86%); 1 patient was discharged on digoxin and propafenone (class IC) and 1 on amiodarone. There was no significant difference in cardiac involvement or outcomes between patients treated and not treated for tachyarrhythmia (Table S5).

Comparison of Patients With and Without Tachyarrhythmias

Patients with versus without tachyarrhythmias were older (Table 1). The percentage of patients who had at least 1 underlying medical condition did not differ significantly in those with and without tachyarrhythmias; however, more were obese. In patients with tachyarrhythmias, 8 (13%) had preexisting cardiac conditions,

Table 1. Characteristics of Patients Aged <21 Years With and Without Tachyarrhythmias Hospitalized With COVID-19 or MIS-C in 63 US Hospitals Participating in the "Overcoming COVID-19" Public Health Registry, March 15, 2020, to December 31, 2021

	Tachyarrhythmia (n=63)	No tachyarrhythmia (n=3537)	*P* value
Age, y, median (Q1, Q3)	15.4 (10.4, 17.4)	10.0 (5.3, 14.7)	<0.001
Male sex	39 (62)	2058 (58)	0.64
Met criteria for MIS-C	41 (65)	2302 (65)	1.00
Race and ethnicity			
White, non-Hispanic	16 (25)	1120 (32)	0.07
Black, non-Hispanic	29 (46)	1037 (29)	
Hispanic or Latino	14 (22)	935 (26)	
Other, non-Hispanic	3 (5)	215 (6)	
Unknown	1 (2)	230 (7)	
Underlying conditions			
At least 1 underlying condition	36 (57)	1658 (47)	0.14
Cardiovascular	6 (10)	137 (4)	0.05
Obesity	35/60 (58)	1124/3132 (36)	<0.001
Presentation conditions			
Organ systems involved, median (Q1, Q3)	5 (4, 6)	4 (3, 5)	<0.001
Duration of symptoms prehospitalization, median (Q1,Q3)	4 (3, 5.75)	4 (3, 6)	0.88
Initial laboratory values (within 48 h)			
Neutrophil-to-lymphocyte ratio, median (Q1,Q3)*	9.00 (4.87, 16.74)	5.96 (3.00, 101.17)	0.003
ALT (U/L), median (Q1, Q3)†	48.0 (22.0, 91.0)	32.0 (19.0, 58.0)	0.02
CRP (mg/dL), median (Q1, Q3)‡	14.9 (6.2, 28.0)	12.9 (5.9, 21.0)	0.17
Troponin (ng/mL), median (Q1, Q3)§	0.50 (0.11, 6.75)	0.08 (0.02, 0.59)	<0.001
Cardiac complications			
Cardiac involvement‖	51 (81)	1663 (47)	<0.001
BNP or NT-proBNP>1000 pg/mL	33/40 (83)	1146/1762 (65)	0.03
Elevated troponin	42/51 (82)	700/1939 (36)	<0.001
Echocardiogram performed	62 (98)	2669 (75)	<0.001
Normal ventricular systolic function	20 (32)	1682 (63)	<0.001
Mild–moderate ventricular dysfunction	22 (35)	819 (31)	
Severe ventricular dysfunction	19 (31)	147 (6)	
Unknown ventricular function	1 (2)	22 (1)	
CAA (RCA or LAD *z* score ≥2.5)	15 (24)	256 (10)	<0.001
Pericarditis or pericardial effusion	25 (40)	561 (21)	<0.001
Critical care interventions			
Any respiratory support	51 (81)	2089 (59)	<0.001
Invasive mechanical ventilation	33 (53)	585 (17)	<0.001
Noninvasive mechanical ventilation only	8 (13)	421 (12)	1.00
Vasopressor requirement	52 (84)	1190 (34)	<0.001
ECMO¶	15 (24)	88 (2)	<0.001
Severity scores first 24 h			
pSOFA, median (Q1, Q3)	4 (2, 6)	2 (1, 4)	<0.001
Outcomes			
ICU admission	61 (97)	2630 (74)	<0.001
ICU length of stay, d, median (Q1, Q3)	9 (5, 16)	3 (2, 6)	<0.001
Hospital length of stay, d, median (Q1, Q3)	11.5 (7.25, 18.75)	6 (4, 9)	<0.001
Death	9 (14)	77 (2)	<0.001

n (%) or median (Q1, Q3); chi-squared test, Fisher exact test, or Mann–Whitney test where appropriate. ALT indicates alanine transaminase; CRP, C-reactive protein; BNP, B-type natriuretic peptide; CAA, coronary artery aneurysm; RCA, right coronary artery; LAD, left anterior descending coronary artery; ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; MIS-C, multisystem inflammatory syndrome in children; NT-proBNP, N-terminal pro-B-type natriuretic peptide; and pSOFA, Pediatric Sequential Organ Failure Assessment.

*Measured in 60 patients with tachyarrhythmias and 3160 without.

†Measured in 56 patients with tachyarrhythmias and 2778 without.

‡Measured in 41 patients with tachyarrhythmias and 2475 without.

§Measured in 37 patients with tachyarrhythmias and 1397 without.

‖Defined as BNP or NT-proBNP ≥1000 pg/mL, elevated troponin, systolic ventricular dysfunction or coronary artery aneurysm.

¶Includes ECMO (veno-venous and veno-arterial) at any point during hospitalization, irrespective of indication.

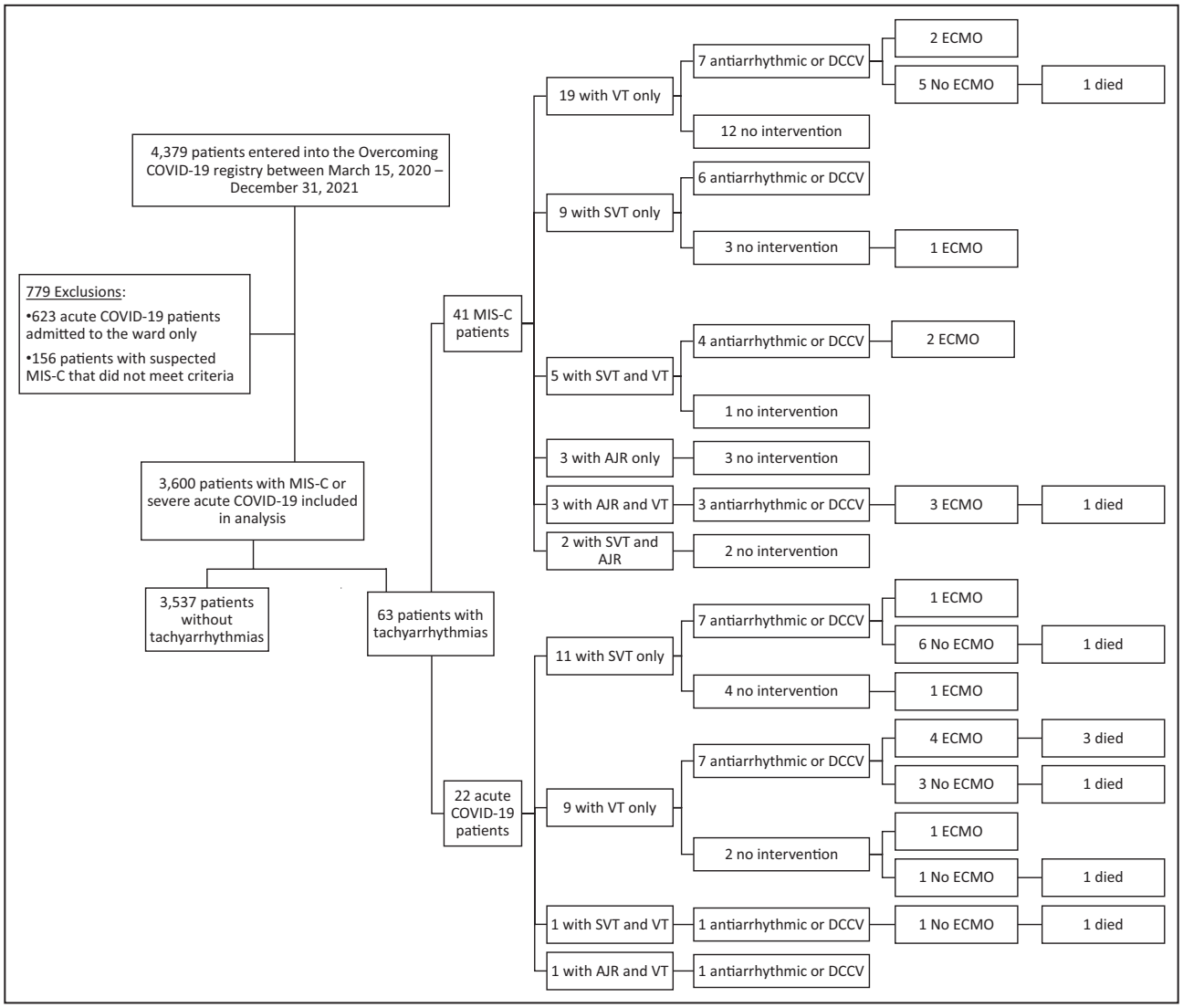

Figure 1. CONSORT-like diagram of tachyarrhythmias and outcomes in patients with acute severe COVID-19 and MIS-C. AJR indicates accelerated junctional rhythm; DCCV, direct current cardioversion; ECMO, extracorporeal membrane oxygenation; MIS-C, multisystem inflammatory syndrome in children; SVT, supraventricular tachycardia; and VT, ventricular tachycardia.

including congenital heart disease in 4 (6%), cardiomyopathy in 2 (3%), and arrhythmias in 2 (4%).

Patients with tachyarrhythmias were sicker at the time of hospital admission, with higher Pediatric Sequential Organ Failure Assessment severity scores, more organ systems involved, and a greater frequency of other cardiac complications (Table 1).

Compared with patients without tachyarrhythmias, children with tachyarrhythmias more frequently required intensive care unit admission, mechanical ventilation, vasopressors, and extracorporeal membrane oxygenation support. Children with tachyarrhythmias had longer hospital length of stay (11.5 [range, 7.25–18.75] versus 6 [range, 4–9] days; $P<0.001$) and higher in-hospital mortality (14% versus 2%; $P<0.001$). In patients with tachyarrhythmias, causes of death were multiorgan failure in 4 (50%) patients, primary cardiac in 2 (25%), and primary respiratory in 2 (25%) (Table S6). All deaths except one occurred in patients with VT (Figure 1). Death in patients with tachyarrhythmias was most common in acute severe COVID-19 than MIS-C ($P=0.006$; Table 2). In patients without tachyarrhythmias, causes of death were primary respiratory in 29 (38%) patients, multiorgan failure in 18 (23%), primary cardiac in 12 (16%), brain death or severe brain injury in 10 (13%), and other in 8 (10%).

Cardiac Involvement and Tachyarrhythmias

Patients with tachyarrhythmias more often had other manifestations of cardiac involvement than those without (81% versus 40%, $P<0.001$; Table 1); however, 700 (20%) patients without recorded tachyarrhythmias did

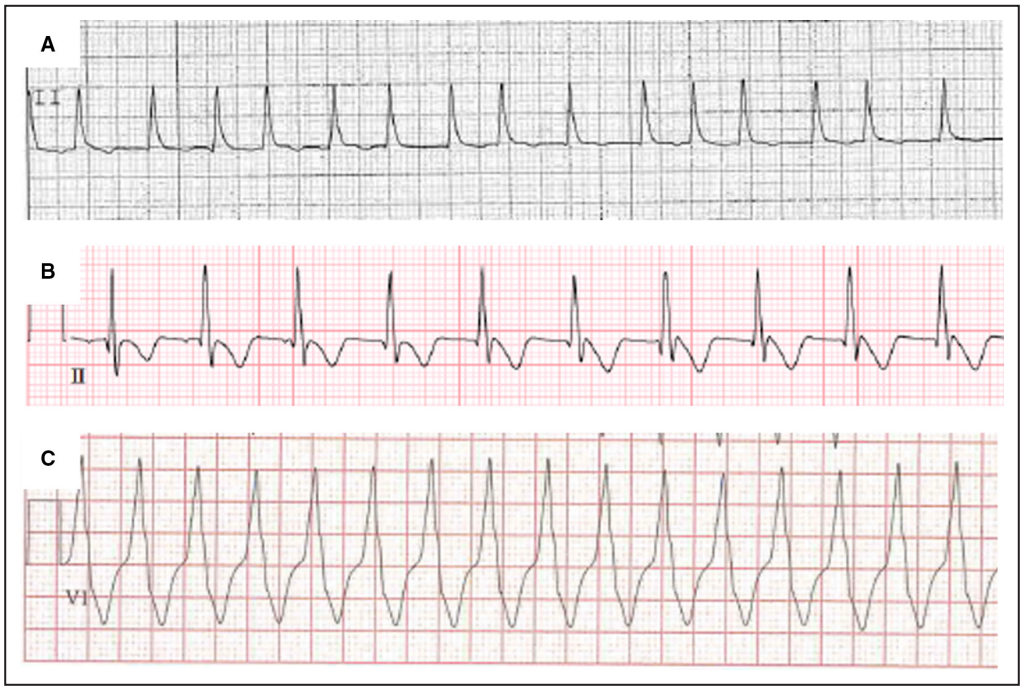

Figure 2. Rhythm strip showing (A) atrial fibrillation, (B) accelerated junctional rhythm, and (C) ventricular tachycardia in patients with COVID-19 and MIS-C.
MIS-C indicates multisystem inflammatory syndrome in children.

not have echocardiograms, BNP, or troponin measured (categorized as no cardiac involvement). Patients with tachyarrhythmias more often had ventricular dysfunction (ejection fraction <55%), with 30% having severe ventricular dysfunction (ejection fraction <35%), coronary artery aneurysms (24%), pericarditis, and pericardial effusion (40%). Coronary artery aneurysms were observed in 37% of patients with MIS-C and tachyarrhythmia, while no patient with severe acute COVID-19 had coronary artery aneurysm (Table S1). Although cardiovascular involvement was more frequent in patients with tachyarrhythmias, hemodynamically significant tachyarrhythmias, including sustained VT, were also observed in patients with normal ventricular systolic function on echocardiogram (Table S2).

Tachyarrhythmias in Acute COVID-19 and MIS-C

The majority (82%) of patients with acute COVID-19 who developed tachyarrhythmias had underlying medical conditions compared with a minority (42%) of patients with MIS-C. Nearly one-quarter of patients with acute COVID-19 and tachyarrhythmias had underlying cardiovascular conditions (n=5, 23%), including congenital heart disease in 3 (14%) patients, cardiomyopathy in 2 (9%), and arrhythmia in 2 (9%). Intensive care unit length of stay was significantly longer in patients with acute COVID-19 versus MIS-C (18 [Q1,Q3: 6, 28] versus 8 [Q1,Q3: 5, 12] days; *P*=0.043); however, there was no difference in need for mechanical ventilation (50% versus 54%, *P*=0.99) or extracorporeal membrane oxygenation (36% versus 17%; *P*=0.16). In-hospital mortality was more frequent in patients with acute COVID-19 and tachyarrhythmias than MIS-C (32% versus 5%; *P*=0.006).

DISCUSSION

In this national multicenter registry of children and adolescents hospitalized with severe complications related to COVID-19, tachyarrhythmias were infrequent, occurring in 1.8% of patients hospitalized in the intensive care unit for acute severe COVID-19 and in 1.7% of those hospitalized for MIS-C. Tachyarrhythmias occurred most frequently in older patients and sicker patients with cardiac or multisystem involvement. Patients with tachyarrhythmias had prolonged hospital length of stay and higher in-hospital mortality.

There are many possible causes for tachyarrhythmias in children with SARS-CoV-2–related illnesses, including hypoxia, myocarditis, myocardial ischemia, electrolyte abnormalities, and medication side effects.[12] Myocardial injury, likely resulting from systemic inflammation, direct viral infection of the heart, hypoxia, stress cardiomyopathy, ischemia, or combination of these factors,[13–14] is associated with tachyarrhythmias in children with SARS-CoV-2–related illness.

Tachyarrhythmias are frequently reported in non–COVID-related myocarditis; a large, multicenter series using the Pediatric Health Information System database

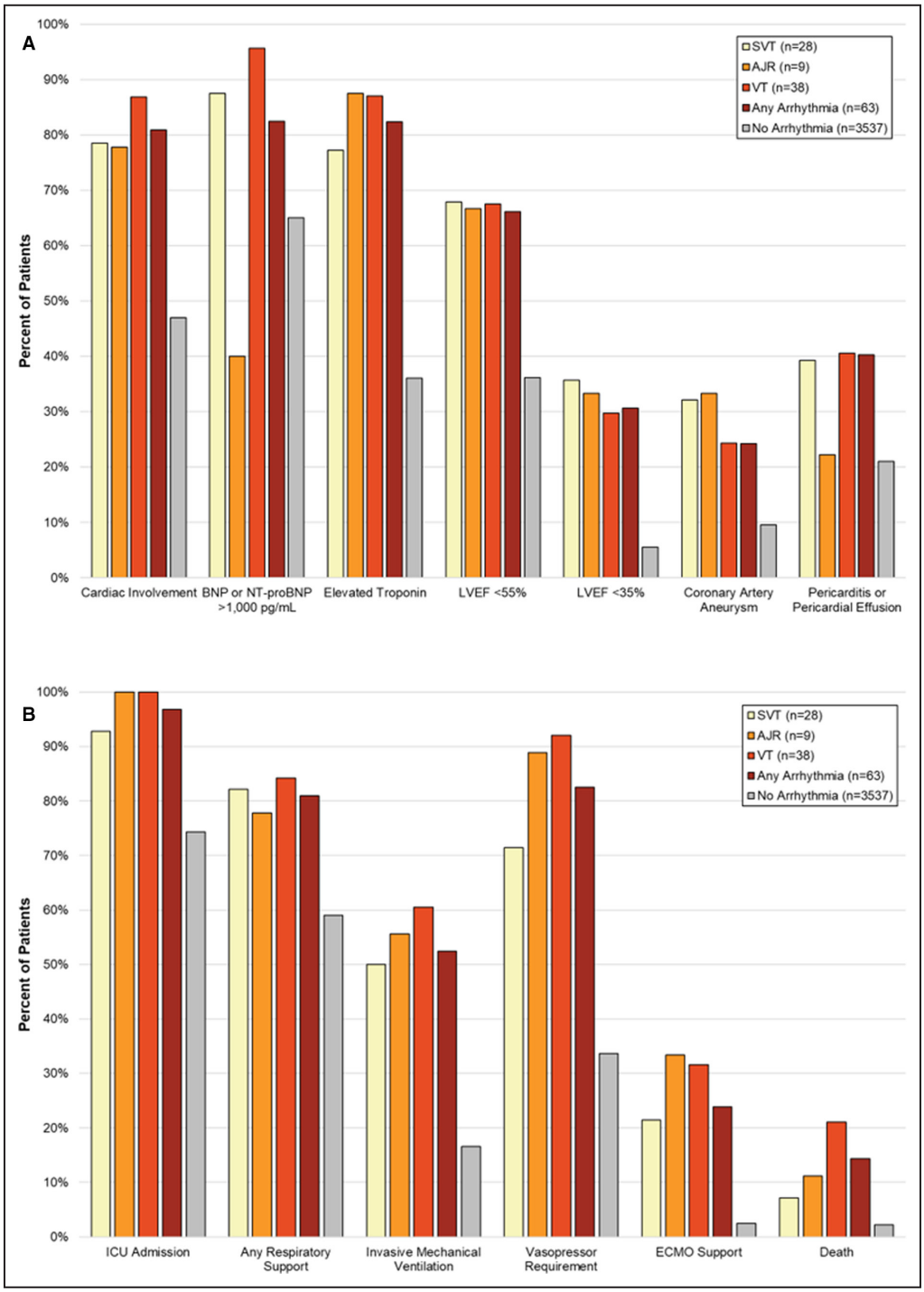

Figure 3. Cardiac involvement (A) and outcomes (B) by type of tachyarrhythmia.
AJR indicates accelerated junctional rhythm; BNP, B-type natriuretic peptide; ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; LVEF, left ventricular ejection fraction; NT-proBNP, N-terminal pro-B-type natriuretic peptide; SVT, supraventricular tachycardia; and VT, ventricular tachycardia.

described tachyarrhythmias in 12% of patients,[15] and a 2-center series described an incidence of 40% in children with ventricular dysfunction.[16] Myocardial involvement was recorded in 67% of patients with MIS-C and was likely a cause for tachyarrhythmias. In contrast, 23% of children with severe acute COVID-19 and tachyarrhythmia had a preexisting cardiac condition, compared with only 2% of patients with MIS-C. A large, worldwide survey of COVID-19–associated arrhythmia in adults (69% with underlying cardiac comorbidities) found an incidence of tachyarrhythmia of 14%, highlighting underlying cardiovascular disease as

Table 2. Tachyarrhythmia, Intervention, and Outcomes in Patients Hospitalized With MIS-C and Acute COVID-19 in 63 US Hospitals Participating in the "Overcoming COVID-19" Public Health Registry, March 15, 2020, to December 31, 2021

	All patients (n=63)	Patients with MIS-C (n=41)	Patients with acute COVID-19 (n=22)	SVT (n=28)	Accelerated junctional rhythm (n=9)	Ventricular tachycardia (n=38)
Days from symptoms to arrhythmia onset	6 (4, 9.5)	7 (5, 9)	5 (2, 14)	6 (4, 9)	5 (5, 7)	7 (4, 12.5)
Days from hospitalization to arrhythmia onset	2 (0, 5)	2 (1, 4)	2 (0, 6.25)	2 (0, 3)	1 (0.25, 1)	2 (1, 8.5)
Duration of arrhythmia, d	1 (0, 3)	1 (0, 3)	1 (0, 3)	1 (0, 4)	1 (0, 3)	1 (0, 4)
Arrhythmia interventions						
None	26 (41)	20 (49)	6 (27)	9 (32)	4 (44)	15 (39)
Antiarrhythmic medication	31 (49)	17 (41)	14 (64)	15 (54)	3 (33)	20 (53)
Electrical cardioversion	11 (17)	5 (12)	6 (27)	8 (29)	0 (0)	4 (11)
CPR	8 (13)	4 (10)	4 (18)	2 (7)	2 (22)	8 (21)
ECMO*	9 (14)	6 (15)	3 (14)	4 (14)	4 (44)	8 (21)
Outcomes						
Discharged home without antiarrhythmic medication	38 (60)	28 (68)	10 (45)	16 (57)	6 (67)	21 (55)
Discharged home with antiarrhythmic medication	14 (22)	10 (24)	4 (18)	8 (29)	1 (11)	9 (24)
Transferred to other facility	2 (3)	1 (2)	1 (5)	2 (7)	1 (11)	0
Died	9 (14)	2 (5)	7 (32)	2 (7)	1 (11)	8 (21)

n (%) or median (Q1, Q3). CPR indicates cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation; MIS-C, multisystem inflammatory syndrome in children; and SVT, supraventricular tachycardia.

*Includes ECMO cannulation specifically used for treatment of tachyarrhythmia.

a risk factor.[17] Thus, while tachyarrhythmias were observed in a similar frequency in patients with severe acute COVID-19 and MIS-C, underlying mechanisms may differ.

Patients with tachyarrhythmias had worse clinical outcomes, which has also been described in children with non-COVID viral myocarditis[15] and adults with COVID-19.[17] Worse outcomes may result from the underlying condition that promoted arrhythmia, such as myocardial injury, or from hemodynamic compromise produced by the arrhythmia itself. Patients with tachyarrhythmias had multiple indicators of higher illness severity on presentation. Regardless of whether adverse outcomes associated with arrhythmias reflect a more severe underlying condition, sequelae of the arrhythmia itself, or an interaction of the 2, the occurrence of arrhythmia in patients with SARS-CoV-2–related illness identifies a high-risk group of patients. The risk of VT or sudden cardiac death following viral myocarditis can be as high as 50% in adults, likely from persistent inflammation or postinflammatory myocardial scar, highlighting the importance of follow-up.[18] Cases of arrhythmias and sudden cardiac death have also been reported in children following myocarditis, including in patients with normal ventricular function. However, there is no good estimate of the risk, likely because of the rarity of events. The 2021 American Heart Association guidelines recommend avoidance of competitive sports for 3 to 6 months after myocarditis to minimize the risk of life-threatening arrhythmia, with Holter monitoring and exercise stress testing performed in athletes before they return to sports.[19] Cardiac magnetic resonance may help better understand the long-term myocardial and arrhythmic risk in patients with significant arrhythmias following SARS-CoV-2–related illness.

Limitations of this investigation include that the OC-19 registry did not capture all eligible patients and may be biased toward the capture of more severely ill patients. Transient and benign episodes could have been underreported, with more serious events requiring intervention being captured. ECG tracings were reviewed and adjudicated when available; however, as hospital telemetry data are not routinely saved, tracings were unavailable for review in most cases because of transient and nonsustained arrhythmias. Missing data may have led to the misclassification of patients. In our adjudication, the 2 cases that were overturned were ectopic atrial tachycardia and atrial fibrillation; both of which can be challenging to distinguish clinically as well. Importantly, none of the patients with ventricular arrhythmias were re-adjudicated. In patients with underlying cardiac disease, tachyarrhythmias may be related to exacerbation of the underlying condition, and not necessarily COVID-19 infection. In addition, other factors related to the acute management of acutely ill patients may contribute to arrhythmias, including the use of corrected QT interval prolonging medications and electrolyte abnormalities. Most patients

with acute COVID-19 did not undergo echocardiography (n=807, 64%) or have values for BNP or troponin (n=924, 74%), potentially overestimating differences in cardiac involvement between groups. Because of the lack of long-term follow-up, the risk of recurrence of tachyarrhythmias following hospital discharge remains unknown.

CONCLUSIONS

Although tachyarrhythmias are an infrequent complication of SARS-CoV-2–related illnesses in hospitalized children and adolescents, they portend poor clinical outcomes. This highlights the importance of close monitoring and aggressive treatment in these patients. Longer-term surveillance after hospital discharge will be important to better understand the arrhythmic and other cardiac risks after acute COVID-19 or MIS-C complicated by tachyarrhythmia.

ARTICLE INFORMATION

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Disclosures

None.

Supplemental Material

Appendix S1
Data S1
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Data S1.

Supplemental Methods

Case-Definition for Severe Acute COVID-19 [a]

- Admitted to the hospital intensive care unit or high-acuity stepdown unit with symptoms suspected to be related to COVID-19
- Evidence of infection with SARS-CoV-2 based on a positive RT-PCR test result during current illness
- Severe organ system involvement including at least 1 of the following:
    - **Respiratory**
        - Receipt of mechanical ventilation or any type of supplemental oxygen (or increased support for patients receiving respiratory support at baseline)
        - Severe bronchospasm requiring continuous bronchodilators
        - Pulmonary infiltrates on chest radiograph
        - Lower respiratory infection
        - Pleural effusion
        - Pneumothorax or other signs of barotrauma
        - Pulmonary hemorrhage
        - Chest tube or drainage required
    - **Cardiovascular**
        - Cardiac dysrhythmia or arrhythmia
        - Ejection fraction <55%
        - Pulmonary edema due to left heart failure
        - Coronary artery aneurysm (LAD or RCA *z* score ≥2.5)
        - B-type natriuretic peptide ≥1000 pg/mL
        - Elevated troponin-based on the upper limit of normal for the site laboratory
        - Receipt of vasopressor or vasoactive support
        - Receipt of cardiopulmonary resuscitation or ECMO support
    - **Kidney**

- Receipt of dialysis (for patients without chronic kidney failure)
- Acute kidney injury[b] (in patients without prior kidney disease)

- **Neurologic**
  - Stroke or acute intracranial hemorrhage
  - Seizures
  - Coma
  - Encephalitis, aseptic meningitis, or demyelinating disorder (eg, acute disseminated encephalomyelitis) diagnosed by a neurologist
  - Decreased hearing or vision
  - Iritis or uveitis
- **Gastrointestinal**
  - Appendicitis
  - Pancreatitis
  - Hepatitis or hepatomegaly
  - Gallbladder hydrops or edema
  - Other complications as determined by site clinicians included ileitis, colitis, or mesenteric adenitis
- **Hematologic**
  - Absolute lymphocyte count $<1 \times 10^3$ cells/μL
  - Absolute neutrophil count $<0.5 \times 10^3$ cells/μL excluding chemotherapy patients[3]
  - Severe anemia[c]
  - Platelet count <50 000/μL
  - Deep vein thrombosis
  - Pulmonary embolism
  - Hemolysis
  - Bleeding
  - Ischemia of an extremity
  - Other complications as determined by site clinicians included hemolytic uremic syndrome, anemia requiring transfusion, and pancytopenia

Abbreviations: COVID-19, coronavirus disease 2019; ECMO, extracorporeal membrane oxygenation; LAD, left anterior descending; MIS-C, multisystem inflammatory syndrome in children; RCA, right coronary artery; RT-PCR, reverse transcriptase–polymerase chain reaction; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

[a] Case definition was created by clinical consensus among the Overcoming COVID-19 steering committee principal investigators.

[b] Acute kidney injury was defined as a creatinine level equal to or above the following values by age: less than 4 weeks: 1.59 mg/dL; 4 weeks to less than 1 year: 0.62 mg/dL; 1 to 10 years: 1.13 mg/dL; and ≥11 years: >1.59 mg/dL.

[c] Severe anemia was defined as hemoglobin level less than 7 g/dL among children younger than 59 months of age, otherwise hemoglobin level less than 8 g/dL.

Centers for Disease Control and Prevention Case-Definition for MIS-C[a]

- Age <21 y
- Fever ≥38.0 °C for ≥24 h or report of subjective fever lasting ≥24 h
- Laboratory evidence of inflammation[b]
- Evidence of clinically severe illness requiring hospitalization with multisystem (≥2) organ involvement (cardiac, kidney, respiratory, hematologic, gastrointestinal, dermatologic, or neurological)
- No alternative plausible diagnoses
- Positive for current or recent SARS-CoV-2 infection by RT-PCR, antibody, or antigen test; or exposure to a suspected or confirmed COVID-19 case within the 4 wk prior to the onset of symptoms[c]

Abbreviations: COVID-19, coronavirus disease 2019; MIS-C, multisystem inflammatory syndrome in children; RT-PCR, reverse transcriptase–polymerase chain reaction; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

[a] Must meet all criteria after adjudication by site and coordinating center principal investigators.

[b] Including, but not limited to, 1 or more of the following: an elevated C-reactive protein, erythrocyte sedimentation rate, fibrinogen, procalcitonin, D-dimer, ferritin, lactate dehydrogenase, interleukin 6, elevated neutrophils, reduced lymphocytes, and low albumin level.

[c] Patients without a positive SARS-CoV-2 test result were excluded after May 31, 2020, when site RT-PCR and antibody testing was more available.

Arrhythmia Case Report Form

Dear Overcoming COVID-19 Investigators,

You have identified _____ as having an arrhythmia during hospitalization for COVID-19 / MIS-C. We are working on the spectrum of tachyarrhythmias in this disease and hoping you can provide us with additional information on the arrhythmia.

1. Please confirm all observed tachyarrhythmia during hospitalization (please select all that apply).
   a. ☐ Supraventricular tachycardia (narrow- or usual-complex tachycardia more than 3 beats with ≥1:1 atrial-ventricular association)
      Please specify type if known
      1. ☐ Atrial fibrillation
      2. ☐ Atrial flutter
      3. ☐ Ectopic atrial tachycardia
      4. ☐ Reentrant supraventricular tachycardia

   b. ☐ Accelerated junctional rhythm / Junctional ectopic tachycardia (narrow- or usual- complex tachycardia with ≥1:1 ventricular-atrial association and rates > 100 bpm)
   c. ☐ Non-sustained ventricular tachycardia (3 consecutive ventricular beats at a rate of 120 bpm and <30 seconds duration)
   d. ☐ Sustained ventricular tachycardia (>30 seconds or requiring intervention for termination)
   e. ☐ Ventricular fibrillation

2. Where did the diagnosis of arrhythmia come from (select all that apply)?
   a. ☐ Non-cardiac ICU progress note
   b. ☐ Cardiac ICU progress note
   c. ☐ Non-cardiology inpatient progress note
   d. ☐ Cardiology inpatient progress note
   e. ☐ Cardiology consultation
   f. ☐ 12-lead ECG

3. What date was an arrhythmia first observed?

   Date:

4. What date was an arrhythmia last observed?

   Date:

5. Were any interventions required for treatment of tachyarrhythmias (please select all that apply)?
   a) ☐ No treatment
   b) ☐ Antiarrhythmic medication
      If yes, please specify:
      Medication:
      Route administration (oral vs IV):
      Dose:

c) ☐ DC cardioversion
d) ☐ CPR
e) ☐ ECMO

6. Was the patient discharged home on antiarrhythmic medication?
   a) ☐ Yes
      If yes, please specify:
      Medication:
      Dose:

   b) ☐ No

Please provide any available de-identified ECG or rhythm strips either embedded within this document or as an additional attachment to the email response.

Thank you

Table S1: Characteristics of patients hospitalized with acute COVID-19 and MIS-C with a reported tachyarrhythmia in 63 U.S. hospitals participating in the 'Overcoming COVID-19' public health registry, March 15—December 31, 2021.

	MIS-C (n=41)	Acute COVID-19 (n=22)	P value
Age (years)	14.5 [10.2, 16.9]	16.6 [11.2, 18.2]	0.18
Male Sex	26 (63)	13 (59)	0.95
At least one underlying condition	18 (44)	18 (82)	0.007
Cardiovascular	1 (2)	5 (23)	0.02
Congenital Heart Disease	1 (2)	3 (14)	0.12
Cardiomyopathy	0 (0)	2 (9)	0.12
Arrhythmia	0 (0)	2 (9)	0.12
Acquired Heart Disease	0 (0)	0 (0)	1.00
Other	0 (0)	0 (0)	1.00
Obesity	23/41 (56)	12/19 (63)	0.82
Presentation Conditions			
Duration of Symptoms Pre-Hospitalization (days)	4 [3, 6]	3 [1, 4.5]	0.048
Organ systems involved	5 [5, 6]	4 [2.25, 5]	0.001
Initial Laboratory Values			
Neutrophil to Lymphocyte Ratio	12.17 [5.74, 17.82]	5.90 [2.77, 12.57]	0.02
ALT (U/L)	60.5 [36.0, 90.5]	28.5 [18.0, 79.0]	0.06
CRP (mg/dL)	18.0 [13.4, 28.7]	1.1 [0.7, 2.7]	<0.001
Troponin (ng/mL), median [Q1,Q3**]**	0.50 [0.11, 6.75]	0.08 [0.02, 0.56]	0.77
Cardiac Complications			
Cardiovascular Involvement*	38 (93)	13 (59)	0.002
BNP or NT-proBNP >1,000 pg/mL	29/31 (94)	4/9 (44)	0.003
Elevated Troponin	33/38 (87)	9/13 (69)	0.21
Echocardiogram performed	41 (100)	21 (95)	0.35
Normal ventricular systolic function	9 (22)	11 (52)	0.03
Mild-moderate ventricular dysfunction	18 (44)	4 (19)	0.09
Severe ventricular dysfunction	13 (32)	6 (29)	1.00
Unknown ventricular function	1 (2)	0	1.00
CAA (RCA or LAD z-score ≥ 2.5)	15 (37)	0	0.001
Pericarditis or Pericardial Effusion	18 (44)	7 (33)	0.560
Critical Care Interventions			

Any respiratory support	35 (85)	16 (73)	0.38
Invasive Mechanical Ventilation	22 (54)	11 (50)	0.99
Non-Invasive Mechanical Ventilation Only	5 (12)	3 (14)	1.00
Vasopressor Requirement	38 (93)	14 (64)	0.01
ECMO†	7 (17)	8 (36)	0.16
Severity Scores 1st 24 Hours			
pSOFA, median [Q1,Q3**]**	4 (3, 7)	3.5 (1, 4.75)	0.04
Outcomes			
ICU Admission	40 (98)	21 (95)	1.00
ICU Length of Stay, median [Q1,Q3**], days**	8 [5, 12]	18 [6, 28]	0.04
Hospital Length of Stay, median [Q1,Q3**], days**	12 [9 , 18]	8 [5, 37]	0.73
Death	2 (5)	7 (32)	0.006

n (%) or median [Q1,Q3]

* defined as BNP ≥1,000 pg/mL, elevated troponin, systolic ventricular dysfunction or coronary artery aneurysm

†Includes ECMO (veno-venous and veno-arterial) at any point during hospitalization, irrespective of indication

ALT: alanine transaminase, CRP: C-reactive protein, BNP: B-type natriuretic peptide, CAA: coronary artery aneurysm, RCA: right coronary artery, LAD: left anterior descending coronary artery, ECMO: extracorporeal membrane oxygenation, ICU: intensive care unit, MIS-C: multisystem inflammatory syndrome in children. NT-proBNP: N-terminal pro B-type natriuretic peptide, pSOFA: pediatric sequential organ failure assessment

Table S2: Characteristics of patients hospitalized with acute COVID-19 and MIS-C and ventricular tachycardia in 63 U.S. hospitals participating in the 'Overcoming COVID-19' public health registry, March 15—December 31, 2021.

	Sustained VT (n=13)	**Non-sustained VT (n=25)**
Age (years)	14.3 [6.9, 15.7]	15.6 [9.1, 17.4]
Male Sex	6 (46)	15 (60)
MIS-C diagnosis	7 (54)	20 (80)
Underlying Conditions		
At least one underlying condition	8 (62)	9 (16)
Cardiovascular	2 (15)	2 (8)
Obesity	8/12 (67)	14/25 (56)
Presentation Conditions		
Duration of Symptoms Pre-Hospitalization (days)	4 [3, 5]	4 [2, 6]
Number Organ Systems Involved	6 [4, 6]	5 [5, 6]
Initial Laboratory Values		
Neutrophil to Lymphocyte Ratio	6.95 [5.07, 14.5]	12.25 [5.72, 15.93]
ALT (U/L)	49 [28.32, 92.75]	48 [24.5, 71.5]
CRP (mg/dL)	26.4 [7.63, 44.38]	17.33 [8.77, 29.23]
Troponin (ng/mL), median [Q1,Q3**]**	2.66 [0.73, 4.58]	0.78 [0.1, 13]
Cardiac Complications		
Cardiovascular Involvement *	12 (92)	21 (84)
BNP or NT-proBNP >1,000 pg/mL	6/6 (100)	16/17 (94)
Elevated Troponin	9/10 (90)	18 (86)
Echocardiogram performed	13 (100)	24 (96)
Normal ventricular systolic function	3 (23)	9 (38)
Mild-moderate ventricular dysfunction	4 (31)	10 (42)
Severe ventricular dysfunction	6 (46)	5 (21)
CAA (RCA or LAD z-score ≥ 2.5)	3 (23)	6 (25)
Pericarditis or Pericardial Effusion	4 (31)	11 (46)
Critical Care Interventions		
Any respiratory support	12 (92)	20 (80)
Invasive Mechanical Ventilation	11 (85)	12 (48)

Non-Invasive Mechanical Ventilation Only	0 (0)	3 (12)
Vasopressor Requirement	13 (100)	22 (88)
ECMO †	7 (54)	5 (20)
Severity Scores 1st 24 Hours		
pSOFA, median [Q1,Q3**]**	3 [2, 5]	3 [1, 5]
Outcomes		
ICU Admission	13 (100)	25 (100)
ICU Length of Stay, median [Q1,Q3**], days**	16 [7, 28]	9 [6, 12]
Hospital Length of Stay, median [Q1,Q3**], days**	19 [14 , 75]	12 [9, 19]
Death	6 (46)	2 (8)

n (%) or median [Q1,Q3]

* defined as BNP ≥1,000 pg/mL, elevated troponin, systolic ventricular dysfunction or coronary artery aneurysm

† Includes ECMO (veno-venous and veno-arterial) at any point during hospitalization, irrespective of indication

ALT: alanine transaminase, CRP: C-reactive protein, BNP: B-type natriuretic peptide, CAA: coronary artery aneurysm, RCA: right coronary artery, LAD: left anterior descending coronary artery, ECMO: extracorporeal membrane oxygenation, ICU: intensive care unit, MIS-C: multisystem inflammatory syndrome in children. NT-proBNP: N-terminal pro B-type natriuretic peptide, pSOFA: pediatric sequential organ failure assessment

Table S3: Characteristics of patients with adjudicated and not-adjudicated tachyarrhythmia in 63 U.S. hospitals participating in the 'Overcoming COVID-19' public health registry, March 15—December 31, 2021.

	Adjudicated Arrhythmia (n=23)	No available tracing for review (n=40)	P-value
Age (years)	15.68 [10.74, 17.22]	15.1 [9.9, 17.51]	0.92
Male sex	15 (65)	24 (60)	0.89
MIS-C diagnosis	14 (61)	27 (68)	0.80
Arrhythmia			
SVT	12 (52)	16 (40)	0.50
Accelerated junctional rhythm	6 (26)	3 (8)	0.06
Ventricular tachycardia	11 (48)	27 (68)	0.20
Cardiovascular involvement			
Cardiovascular involvement*	18 (23)	33 (83)	0.94
BNP or NT-proBNP >1,000 pg/mL	13/16	20/24	1.00
Elevated troponin	14/18	28/33	0.70
Echocardiogram performed	23 (100)	39 (98)	1.00
Normal ventricular systolic function	7 (30)	13 (33)	
Mild-moderate ventricular dysfunction	8 (35)	14 (36)	0.93
Severe ventricular dysfunction	8 (35)	11 (28)	
Unknown	0	1 (3)	
CAA (RCA or LAD s-score ≥ 2.5)	5 (22)	10 (26)	0.97
Pericarditis or Pericardial Effusion	4 (17)	21 (54)	0.007
Arrhythmia intervention			
None	8 (35)	18 (45)	0.60
Antiarrhythmic medication	15 (65)	16 (40)	0.10
Electrical cardioversion	6 (26)	5 (13)	0.31
CPR	4 (17)	4 (10)	0.45
ECMO for arrhythmia	5 (22)	4 (10)	0.27
Critical Care Interventions			
Any respiratory support	18 (73)	33 (83)	0.94
Invasive mechanical ventilation	13 (57)	20 (50)	0.81
Non-invasive mechanical ventilation only	4 (17)	4 (10)	0.45
Vasopressor Requirement	19 (83)	33 (83)	1.00
ECMO†	6 (26)	9 (23)	0.99
Outcomes			

ICU length of stay, median [Q1,Q3], days	7 [5, 10.75]	9 [5.5, 17.5]	0.30
Hospital Length of Stay, median [Q1,Q3], days	12 [6, 16]	10 [8, 19]	0.56
Death	4 (17)	5 (13)	0.71

n (%) or median [Q1,Q3]

* defined as BNP ≥1,000 pg/mL, elevated troponin, systolic ventricular dysfunction or coronary artery aneurysm

†Includes ECMO (veno-venous and veno-arterial) at any point during hospitalization, irrespective of indication

BNP: B-type natriuretic peptide, CAA: coronary artery aneurysm, RCA: right coronary artery, LAD: left anterior descending coronary artery, ECMO: extracorporeal membrane oxygenation, ICU: intensive care unit, MIS-C: multisystem inflammatory syndrome in children, NT-proBNP: N-terminal pro B-type natriuretic peptide, pSOFA: pediatric sequential organ failure assessment, SVT: supraventricular tachycardia

Table S4: ECG findings in patients with tachyarrhythmias hospitalized with MIS-C and acute COVID-19 in 63 U.S. hospitals participating in the 'Overcoming COVID-19' public health registry, March 15—December 31, 2021.

	All patients (n=22)	SVT (n=10)	Accelerated junctional rhythm (n=2)	Ventricular tachycardia (n=15)	Underlying cardiac disease (n=3)
ST segment changes	15 (68)	10 (100)	1 (50)	8 (53)	2 (67)
ST segment elevation	2 (9)	0 (0)	1 (50)	2 (13)	0 (0)
ST segment depression	1 (5)	1 (10)	0 (0)	1 (7)	1 (33)
T-wave inversion	5 (23)	3 (30)	0 (0)	2 (13)	0 (0)
Non-specific	7 (32)	6 (60)	0 (0)	3 (20)	1 (33)
Prolonged QTc interval	8 (36)	3 (30)	1 (50)	5 (33)	2 (67)
Right bundle branch block	3 (14)	0 (0)	1 (50)	2 (20)	1 (33)
Incomplete right bundle branch block	3 (14)	3 (30)	0 (0)	1 (7)	0 (0)
Axis deviation					
Right axis	2 (9)	1 (10)	0 (0)	1 (7)	0 (0)
Left axis	2 (9)	1 (10)	0 (0)	1 (7)	1 (33)
Ventricular hypertrophy					
Right	2 (9)	1 (10)	1 (50)	1 (7)	1 (33)
Left	1 (5)	0 (0)	0 (0)	1 (7)	1 (33)
Atrial enlargement	1 (5)	0 (0)	0 (0)	1 (7)	1 (33)
1st degree atrioventricular block	1 (5)	0 (0)	0 (0)	1 (7)	0 (0)
Premature atrial beat	1 (5)	1 (10)	0 (0)	0 (0)	0 (0)

n (%)
SVT: supraventricular tachycardia

Table S5: Characteristics of patients treated and not treated for tachyarrhythmia in 63 U.S. hospitals participating in the 'Overcoming COVID-19' public health registry, March 15—December 31, 2021.

	Intervention for tachyarrhythmia (n=37)	No intervention for tachyarrhythmia (n=26)	P value
Age (years)	15.62 [10.62, 17.63]	14.74 [10.6, 16.79]	0.64
Male Sex	21 (57)	18 (69)	0.46
Underlying Conditions			
At least one underlying condition	22 (59)	14 (54)	0.85
Cardiovascular	5 (14)	1 (4)	0.39
Cardiac Complications			
Cardiovascular Involvement *	28 (76)	23 (88)	0.33
BNP or NT-proBNP >1,000 pg/mL	19/20 (95)	14/20 (70)	0.09
Elevated Troponin	23/30 (77)	19/21 (90)	0.28
Echocardiogram performed	37 (100)	25 (96)	0.41
Normal ventricular systolic function	14 (38)	6 (24)	
Mild-moderate ventricular dysfunction	11 (30)	11 (44)	0.49
Severe ventricular dysfunction	11 (30)	8 (32)	
Unknown ventricular function	1 (3)	0 (0)	
CAA (RCA or LAD z-score ≥ 2.5)	10 (27)	5 (20)	0.74
Pericarditis or Pericardial Effusion	11 (30)	14 (56)	0.07
Critical Care Interventions			
Any respiratory support	30 (81)	21 (81)	1.00
Invasive Mechanical Ventilation	23 (62)	10 (38)	0.11
Non-Invasive Mechanical Ventilation Only	2 (5)	6 (23)	0.06
Vasopressor Requirement	30 (81)	22 (85)	1.00
ECMO†	12 (32)	3 (12)	0.07
Severity Scores 1st 24 Hours			
pSOFA, median [Q1,Q3**]**	4 [2, 6]	4 [2.25, 5.75]	0.78
Outcomes			
ICU Admission	37 (100)	24 (92)	0.17

ICU Length of Stay, median [Q1,Q3**], days**	11 [5, 20]	7.5 [5, 10.25]	0.23
Hospital Length of Stay, median [Q1,Q3**], days**	15 [7, 22]	10 [8, 15]	0.42
Death	8 (22)	1 (4)	0.07

n (%) or median [Q1,Q3]
* defined as BNP ≥1,000 pg/mL, elevated troponin, systolic ventricular dysfunction or coronary artery aneurysm
[a]Includes ECMO (veno-venous and veno-arterial) at any point during hospitalization, irrespective of indication
BNP: B-type natriuretic peptide, CAA: coronary artery aneurysm, RCA: right coronary artery, LAD: left anterior descending coronary artery, ECMO: extracorporeal membrane oxygenation, ICU: intensive care unit, MIS-C: multisystem inflammatory syndrome in children, NT-proBNP: N-terminal pro B-type natriuretic peptide, pSOFA: pediatric sequential organ failure assessment

Table S6: Clinical characteristics of patients with tachyarrhythmias who died during hospitalization in 63 U.S. hospitals participating in the 'Overcoming COVID-19' public health registry, March 15—December 31, 2021.

Patient	Age	MIS-C	Organ systems involved	Ventricular dysfunction	Tachyarrhythmia	ECMO	Cause of death
1	18–<21	No	Respiratory Cardiac Neurologic Hematologic	Mild	Supraventricular tachycardia (atrial flutter)	No	Primary respiratory
2	<1	No	Respiratory Cardiac Neurologic Hematologic	Severe	Supraventricular tachycardia (ectopic atrial tachycardia), Sustained ventricular tachycardia, and ventricular fibrillation	Yes	Primary respiratory
3	13–<18	Yes	Respiratory Cardiac Neurologic Gastrointestinal Hematologic Renal	None	Accelerated junctional rhythm, Non-sustain ventricular tachycardia, and Ventricular fibrillation	Yes	Primary cardiac
4	18–<21	No	Respiratory Cardiac Neurologic Gastrointestinal Hematologic Renal	None	Non-sustained ventricular tachycardia	Yes	Multiorgan failure
5	13–<18	No	Respiratory Cardiac Neurologic Hematologic Renal	ECHO Not Performed	Non-sustained ventricular tachycardia	No	Multiorgan failure
6	18–<21	No	Respiratory Cardiac Neurologic Gastrointestinal Hematologic Renal	Severe	Non-sustained ventricular tachycardia, Sustained ventricular tachycardia, and ventricular fibrillation	Yes	Multiorgan failure
7	6–<13	No	Respiratory Cardiac Renal	Severe	Sustained ventricular tachycardia	No	Primary cardiac
8	13–<18	Yes	Respiratory Cardiac Neurologic	None	Sustained ventricular tachycardia and ventricular fibrillation	No	Multiorgan failure

9	13–<18	No	Respiratory Cardiac Neurologic Gastrointestinal Hematologic Renal	Mild	Ventricular fibrillation	Yes	Multiorgan failure

MIS-C: multisystem inflammatory syndrome in children