**Worse Hospital Outcomes for Children and Adults with COVID-19 and Congenital Heart Disease**

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**Abstract**

The aim of the current study is to investigate hospitalization outcomes of COVID-19 positive children and adults with moderate or severe congenital heart disease to children and adults without congenital heart disease. Retrospective review using the Vizient Clinical Data Base for admissions of patients with an ICD-10 code for COVID-19 from April 2020 to March 2021. Admissions with COVID-19 and with and without moderate or severe congenital heart disease (CHD) were stratified into pediatric (< 18 years) and adult (≥ 18 years) and hospital outcomes were compared. There were 9478 pediatric COVID-19 admissions, 160 (1.7%) with CHD, and 658,230 adult COVID-19 admissions, 389 (0.06%) with CHD. Pediatric admissions with COVID-19 and CHD were younger (1 vs 11 years), had longer length of stay (22 vs 6 days), higher complication rates (6.9 vs 1.1%), higher mortality rates (3.8, 0.8%), and higher costs ($54,619 vs 10,731; p < 0.001 for all). Adult admissions with COVID-19 and CHD were younger (53 vs 64 years, p < 0.001), had longer length of stay (12 vs 9 days, p < 0.001), higher complication rates (8 vs 4.8%, p = 0.003), and higher costs ($23,551 vs 13,311, p < 0.001). This appears to be the first study to report the increased hospital morbidities and costs for patients with CHD affected by COVID-19. Our hope is that these findings will help counsel patients moving forward during the pandemic.

**Keywords** COVID-19 · Hospital outcomes · Congenital heart disease · Fontan · Tetralogy of Fallot · Transposition of the great arteries

**Introduction**

As of July 2021, there were 183,696,230 cases of coronavirus disease 2019 (COVID-19) globally, with 3,975,227 deaths [1]. Patients who have underlying cardiovascular conditions such as hypertension and coronary heart disease have additional morbidity and mortality for COVID-19 [2, 3]. Patients with moderate and severe congenital heart disease (CHD) have empirically been considered higher risk from COVID-19 [3, 4] though, due to their relatively small population, there are sparse data regarding the outcomes of hospitalized patients with moderate and severe CHD along with COVID-19. The purpose of this study was to use a national discharge database to analyze and report hospital outcomes for COVID-19 in the setting of moderate and severe CHD compared to those without CHD.

**Methods**

The Vizient Clinical Data Base is an analytic platform for performance improvement populated by hundreds of health systems and community hospitals in the USA, including nearly all academic medical centers. The database includes demographics, mortality, length of stay (LOS), complications, readmission rates, resource utilization, and other information. After approval from the University of Arizona Institutional Review Board, which waived the need for informed consent for this retrospective review of deidentified data, we queried the database...
for hospital discharge data from April 2020 to March 2021 for all admissions with an ICD-10 code for moderate or severe CHD, as defined by the 2018 Adult CHD guidelines (Table 1) [5], and the diagnostic code for COVID-19 (U07.1), which went into effect April 1, 2020. The Adult CHD guidelines determined CHD severity by native anatomy, surgical repair, and current physiology [5]. Diagnoses of an isolated atrial septal defect, congenital heart block, isolated levocardia, tortuous aortic arch, anomalous subclavian artery, and any “NOS” cardiac diagnoses were excluded. The comparison group (No CHD) consisted of admissions with no ICD-10 codes for CHD and with the diagnostic code for COVID-19. The groups were further divided into pediatric (<18 years) and adult (≥18 years). Comparison of outcomes between acyanotic and cyanotic lesions was also performed. Demographics, LOS, rate of the presence of complications listed in the Vizient Clinical Data Base [6], in-hospital mortality, and total hospital costs were collected. To determine if there was a difference in admission severity of illness or mortality risk between the groups, queries were performed from Vizient-defined “Acuity Scale Mortality” (severity of illness at admission) and “Relative Expected Mortality” (mortality risk at admission). These were converted to dichotomous values of Low/normal (comparable or less risk) and High (above normal risk) for comparison. Continuous, normally distributed data are presented as mean ± standard deviation, non-normally distributed as median (interquartile range), and categorical data as number (%). Comparisons were made between groups using the t-test for normally distributed data, the Kruskal–Wallis test for non-normally distributed data, and the χ² test for categorical data. A p-value < 0.05 was considered statistically significant.

### Table 1 ICD-10 codes for moderate and severe congenital heart disease, as defined by the 2018 Adult Congenital Heart Disease guidelines

| Moderate congenital heart disease | ICD-10 codes |
|----------------------------------|--------------|
| Partial or total anomalous pulmonary venous return | Q26.2, Q26.3, Q26.4 |
| Anomalous left coronary artery from the pulmonary artery | Q24.5 |
| Atrioventricular septal defect | Q21.2 |
| Aortic stenosis (congenital) | Q23.0 |
| Mitral stenosis (congenital) | Q23.2 |
| Coarctation of the aorta | Q25.1, Q25.42 |
| Cor triatriatum | Q24.2 |
| Ebstein anomaly | Q22.5 |
| Subpulmonary stenosis | Q24.3 |
| Patent ductus arteriosus | Q21.4, Q25.0 |
| Pulmonary regurgitation | Q22.2 |
| Pulmonary stenosis | Q22.1 |
| Peripheral pulmonary stenosis | Q25.6, Q25.7, Q25.71 |
| Sinus of Valsalva fistula | Q25.4 |
| Subaortic stenosis | Q24.4 |
| Supravalvar aortic stenosis | Q25.3 |
| Tetralogy of Fallot | Q21.3 |
| Double aortic arch | Q25.45 |
| Complex congenital heart disease | ICD-10 codes |
| Double outlet right ventricle | Q20.1 |
| Interrupted aortic arch | Q25.21 |
| Single ventricle (DILV, TA, HLHS, etc.) | Q20.4, Q22.4, Q22.6, Q23.4, Q25.2, Q25.29, Q25.41 |
| Pulmonary atresia | Q22.0, Q25.5 |
| Transposition of the great arteries (d-, l- or congenitally corrected) | Q20.3, Q20.5 |
| Truncus arteriosus | Q20.0 |
| Criss cross heart, heterotaxy | Q20.6 |
| Eisenmenger | I27.83 |
| Double outlet left ventricle | Q20.2 |

*DILV* double inlet left ventricle; *HLHS* hypoplastic left heart syndrome; *TA* tricuspid atresia
Statistical analyses were performed using SPSS 27 (IBM Corporation, Armonk, New York, USA).

Results

There were 9478 total pediatric COVID-19 admissions, 160 (1.7%) with CHD, and 658,230 total adult COVID-19 admissions, 389 (0.06%) with CHD. Demographics and hospital outcomes are shown in Table 2. Pediatric admissions with COVID-19 and CHD were younger, had longer LOS, higher presence of complications listed in the Vizient Clinical Data Base, higher mortality rates, and higher costs (Table 2). There were no sex-based or race/ethnicity-based differences. Adult admissions with COVID-19 and CHD were younger, had longer LOS, higher presence of complications listed in the Vizient Clinical Data Base, and higher costs (Table 2). There were no differences in in-hospital mortality rates or sex-based or race/ethnicity-based differences. The specific CHD diagnoses for the Pediatric and Adult groups are listed in Table 3. There were no differences in acute hospital outcomes (LOS, presence of complications listed in the Vizient Data Base or mortality) between cyanotic and acyanotic diagnoses (Table 4). Pediatric admissions with CHD had higher severity of illness and mortality risk at admission, but adults with CHD had lower severity of illness at admission with no difference in mortality risk (Table 5).

Discussion

COVID-19 is a rapidly evolving global pandemic. While non-congenital cardiovascular comorbidities have been identified as risk factors for poor outcomes [2], to the best of our knowledge, ours is the first national study to demonstrate worse hospital outcomes for children and adults

| Table 2 | Demographics and hospital outcomes for pediatric (<18 years old) and adult (≥ 18 years) admissions for COVID-19 infection with and without moderate or severe congenital heart disease (CHD) |
|----------------|----------------|----------------|
| **Pediatric (<18 years)** | CHD (n = 160) | No CHD (n = 9,318) | p  |
| Age (year) | 1 (0.2, 5) | 11 (2, 15) | <0.001 |
| Female (n, %) | 77 (48) | 4,770 (51) | 0.442 |
| Race/ethnicity (n, %) | | | |
| White | 72 (45) | 4,146 (45) | 0.899 |
| Black | 40 (25) | 2,054 (22) | |
| Hispanic | 53 (33) | 2,983 (32) | |
| Asian | 3 (2) | 223 (2) | |
| LOS (d) | 22.2 ± 42.7 | 6.3 ± 20.6 | <0.001 |
| Complications (n, %) | 11 (6.9) | 101 (1.1) | <0.001 |
| Death (n, %) | 6 (3.8) | 79 (0.8) | <0.001 |
| Direct costs ($) | 54,619 ± 124,413 | 10,731 ± 39,952 | <0.001 |
| **Adult (≥ 18 years)** | CHD (n = 389) | No CHD (n = 657,841) | p  |
| Age (y) | 53 (35, 65) | 64 (50, 76) | <0.001 |
| Female (n, %) | 192 (49) | 312,510 (48) | 0.465 |
| Race/ethnicity (n, %) | | | |
| White | 236 (61) | 364,706 (55) | 0.121 |
| Black | 70 (18) | 143,500 (22) | |
| Hispanic | 69 (18) | 127,274 (19) | |
| Asian | 17 (4) | 23,057 (4) | |
| LOS (d) | 11.6 ± 14.5 | 8.7 ± 11.0 | <0.001 |
| Complications (n, %) | 31 (8) | 31,385 (4.8) | 0.003 |
| Death (n, %) | 41 (10.5) | 79,594 (12.1) | 0.346 |
| Direct costs ($) | 23,551 ± 44,503 | 13,311 ± 25,891 | <0.001 |

Data are presented as n (%), mean ± standard deviation or median (interquartile range).
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CHD: congenital heart disease; LOS: length of stay; No CHD: no congenital heart disease.
with moderate and severe CHD who are hospitalized for COVID-19.

While young age is thought to be protective from COVID-19 for the general population, our findings do not support this for children or adults with CHD. In addition, the longer LOS and higher costs for patients with CHD is consistent with their expected fragility due to their underlying cardiac diagnoses, which is also highlighted by the higher severity of illness and mortality risk in the Pediatric group. It is also interesting that the adults with CHD had lower severity of illness at admission, but a similar mortality risk. The higher costs may also be due to more aggressive treatment provided to this population. There may be reductions in severe COVID-19 and hospitalizations with the introduction of vaccines against the SARS-CoV-2 virus, but this will not likely be available for young children for some time.

There are limitations to administrative database studies due to a lack of detail for some of the heart conditions and current functional status as well as potential errors in data entry. The code for COVID-19 (U07.1) is utilized for both symptomatic and asymptomatic individuals who have tested positive for the virus. However, it is unlikely that the current findings of worse outcomes in the CHD group were simply due to the group without CHD only having asymptomatic COVID-19 and the group with CHD only having symptomatic COVID-19. Despite these limitations, given the novelty of the COVID-19 pandemic and the relative rarity of moderate and severe CHD, using a large administrative database allows us to have a better sense of the current

| Table 3 Congenital heart defect diagnoses for the pediatric and adult groups |
|-----------------------------------------------|----------------|----------------|
| Moderate congenital heart disease             | Pediatric CHD n | Adult CHD n     |
| Partial or total anomalous pulmonary venous return | 6             | 15             |
| Anomalous left coronary artery from the pulmonary artery | 9             | 89             |
| Atioventricular septal defect                  | 11            | 14             |
| Aortic stenosis (congenital)                  | 1             | 14             |
| Mitral stenosis (congenital)                  | 1             | 6              |
| Coarctation of the aorta                     | 16            | 26             |
| Cor triatriatum                               | 0             | 5              |
| Ebstein anomaly                               | 6             | 16             |
| Subpulmonary stenosis                         | 1             | 2              |
| Patent ductus arteriosus                     | 61            | 34             |
| Pulmonary regurgitation                       | 1             | 5              |
| Pulmonary stenosis                            | 4             | 14             |
| Peripheral pulmonary stenosis                 | 27            | 34             |
| Sinus of Valsalva fistula                     | 0             | 0              |
| Subaortic stenosis                            | 2             | 13             |
| Supravalvar aortic stenosis                   | 0             | 2              |
| Tetralogy of Fallot                           | 22            | 31             |
| Double aortic arch                            | 1             | 4              |
| Complex congenital heart disease              |                |                |
| Double outlet right ventricle                 | 12            | 8              |
| Interrupted aortic arch                       | 2             | 0              |
| Single ventricle (DILV, TA, HLHS, etc.)       | 36            | 34             |
| Pulmonary atresia                             | 13            | 11             |
| Transposition of the great arteries (d-, l- or congenitally corrected) | 8             | 25             |
| Truncus arteriosus                            | 2             | 3              |
| Criss cross heart, heterotaxy                 | 3             | 2              |
| Eisenmenger                                   | 0             | 0              |
| Double outlet left ventricle                  | 0             | 0              |

Note, some admissions may have more than one cardiac diagnosis, so the total number of diagnoses exceeds the total for each group.

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DILV: double inlet left ventricle; HLHS: hypoplastic left heart syndrome; TA: tricuspid atresia.
status of the COVID-19 pandemic than any single center study could provide.

The current study suggests worse hospital outcomes when patients with CHD are hospitalized for COVID-19 infection, including higher mortality for children. These data stress the importance of primary prevention with vaccination, social distancing and masking measures to reduce severe COVID-19 and hospitalizations and also to increase herd immunity to protect the children who are too young to receive the vaccines at this time. These findings can help to further guide treatment strategies and prioritize patients for vaccination.

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**Data Availability** Data not available.

**Code Availability** N/A.
Declarations

Conflict of interest All authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent The need for informed consent was waived for this study of deidentified data.

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