Cardiology in the Young

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COVID-19 and congenital heart disease: an insight of pathophysiology and associated risks

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Abstract

Objective: We aimed to examine the literature to determine if both paediatric and adult patients diagnosed with congenital heart disease (CHD) are at a higher risk of poor outcomes if they have the coronavirus disease 2019 (COVID-19), compared to those without CHD. *Methods:* A systematic review was executed using the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines. To identify articles related to COVID-19 and CHD, an extensive literature search was performed on EMBASE, Medline, Scopus, and Global Health databases using keywords and MeSH terms. *Results:* A total of 12 articles met the inclusion criteria and were included for analysis in this systematic review. Two themes were identified for data extraction: evidence supporting higher risks in CHD patients and evidence against higher risks in CHD patients. After combining the data, there were 99 patients with CHDs out of which 12 required admissions to ICU. *Conclusion:* This systematic review suggests that CHD may increase the risk of poor outcomes for those with COVID-19, but also highlights the necessity for more research with larger sample sizes in order to make a more justified conclusion, as the majority of papers that were analysed were case series and case reports. Future research should aim to quantify the risks if possible whilst accounting for various confounding factors such as age and treatment history.

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which led to the coronavirus disease 2019 (COVID-19) pandemic, was initially reported in Wuhan, China in December, 2019. The rapid rise in the number of cases worldwide led to hospitals struggling to cope with the sudden influx of patients. This has had a ripple effect on other parts of health care as manpower and supplies needed to be reallocated. Within cardiology, this has led to outpatient appointments and elective surgeries being reduced and/or postponed.[1]

COVID-19 can present asymptomatically but can also include symptoms such as a dry cough, fever, and dyspnoea.[2,3] It can also progress to severe respiratory illness and cause pneumonia.[3,4] It can cause complications within the respiratory system such as respiratory failure, which includes acute respiratory distress syndrome (ARDS), whilst also interacting with other organs such as the central nervous system (CNS) and gastrointestinal (GI) tract.[4] COVID-19 can lead to complications that include acute kidney injury, anosmia, dysgeusia, and diarrhoea.[4,5] Whilst individuals of any age can be infected by the virus and become symptomatic, the higher severity seems to be associated with older age groups, more so males than females, and particularly those who have co-morbidities – these include diabetes, hypertension, and respiratory diseases.[6–9]

COVID-19 appears to have a complicated relationship with the cardiovascular system, as studies have suggested cardiovascular diseases increase disease severity and mortality rates in those who are infected. However, the virus has also been shown to cause cardiovascular complications such as acute myocardial injury, heart failure, and arrhythmia.[4,7,10] CHD is a term for a range of birth defects that have varying levels of severity depending on the type. Studies have suggested that patients with CHD may be at an increased risk of complications, and thus poorer outcomes, if they acquire COVID-19. Although some data have shown no such correlation.[1,6]

In this paper, we aim to determine the risk that COVID-19 may pose to both paediatric and adult patients with CHD in the form of a systematic review, and to subsequently recommend the necessary steps to manage these patients during the pandemic. Moreover, we have

Table 1. Search terms divided into the two categories: COVID-19 and CHD

Category	Search terms
COVID-19	"Coronavirus" OR "nCoV*" OR "2019-nCoV" OR "COVID*" OR "SARS-CoV*"
CHD	"CHD" OR "ACHD" OR "Congenital heart disease*" OR "Congenital heart defect*" OR "Congenital heart anomal*" OR "Congenital heart malformation*" OR "Congenital cardiac disease*" OR "Congenital cardiac defect*" OR "Congenital cardiac anomal*" OR "Congenital cardiac malformation*"

undertaken a review of the latest knowledge of the pathophysiology of COVID-19 in children and its effect on the cardiovascular system.

Methods and materials

Search strategy

We conducted a comprehensive literature search on EMBASE, Medline, Scopus, and Global Health databases to identify articles related to COVID-19 and CHD. The "Preferred Reporting Items for Systematic Reviews and Meta-analysis" (PRISMA) guidelines were adhered to. The search strategy was split into two categories: "COVID-19" and "Congenital heart disease". Keywords and MeSH terms were also included in the search to optimise results (Table 1). Articles not adhering to the inclusion criteria were also screened for papers. All relevant articles were screened by two authors and any conflicts were resolved through consensus.

Inclusion and exclusion criteria

The main inclusion criteria were articles reporting primary data on patients with CHD and a confirmed COVID-19 diagnosis published after January, 2019 in the English language. All narrative reviews, commentaries, editorials, and guideline/recommendation-based articles were excluded; however, they were screened for any other relevant papers.

Quality assessment

A quality assessment was done for all included articles using the National Institutes of Health (NIH) quality assessment tool. No articles were excluded based on their quality score.

Data extraction

Data were extracted by two authors, tabulated, and outlined in a narrative review based on key themes identified.

Results

A total of 135 articles were identified through database searching and snowballing. After the exclusion of duplicates, 12 articles were selected for inclusion into the analysis (Fig 1).[11–22] These comprised a total of 143 patients, of which 99 had CHDs. The key information from each article is summarised in Table 2.

The main themes identified for data extraction were evidence supporting higher risks in CHD patients and evidence against higher risks in CHD patients.

Discussion

CHD affects approximately 1% of live births globally.[23] Different types of CHDs include coarctation of the aorta (CoA), atrial septal defects (ASDs), and ventricular septal defects (VSDs).[24] Due to advances in medical treatment over the years, more children born with CHDs are able to survive to adulthood. This has resulted in more adult patients with CHD (ACHD) than paediatric patients and subsequently has led to more hospitalisations.[25]

There is scarce scientific evidence detailing how COVID-19 affects CHD patients, as most data have been from case reports, case series, or larger studies that had a small sample size of patients with CHD. With past epidemics, namely, SARS-CoV and H1N1 influenza, patients with CHD who were infected with these viruses had worse outcomes and a higher mortality rate compared to those without CHD.[26,27]

Evidence supporting worse outcomes in CHD-COVID-19 patients

One study reported two patients with unspecified repaired CHD, aged 8 months and 1 year, respectively. These two cases showed the most severe disease progression, as they developed impaired renal function, with high levels of lactate dehydrogenase and impaired coagulative function. One of the reported patients also had a suspected hereditary metabolic disease and malnutrition. They both developed ARDS and were admitted to ICU, requiring mechanical ventilation. One of the patients was discharged, whilst the other was still recovering at the time of publication.[22]

In regard to ACHD, Sabatino et al conducted a nationwide survey in Italy that included patients with CHD who either were suspected of having COVID-19 or confirmed. Interestingly, all patients with poor outcomes were confirmed COVID-19 positive, as opposed to the mild disease progression that was experienced by those only suspected of being COVID-19 positive. Of the nine patients confirmed to be COVID-19 positive, six were adults with a mean age of 40. They suffered from a range of different CHDs including TGA and VSDs. One of them required continuous positive airway pressure (CPAP) therapy, whilst another was put on extracorporeal membrane oxygenation (ECMO) therapy and ended up in ICU. No deaths were reported. The majority of these patients experienced complications including heart failure (55%), stroke, and arrhythmias.[19] Arrhythmias are frequently seen in CHD-COVID-19-positive patients with palpitations accounting for 22% of the presenting complaints and this often requires intensive care treatment.[19,28]

Out of the 12 studies we analysed, 5 included patients who were admitted to ICU.[12,15,19,20,22] Besides those previously mentioned,[19,22] Simpson et al reported 71% (n = 4) of patients being admitted to ICU. One of the patients recovered and was discharged and another recovered after surgical repair. Two patients died, one from unknown causes and the other from a recurrence of ventricular tachycardia.[20] A case report from Bezerra et al reported that the patient was admitted to ICU after undergoing a Fontan procedure for hypoplastic left heart syndrome. Despite a complete AV block 5 days post-op and experiencing other complications, the patient fully recovered and was discharged on 24 days post-op.[12] Krishnan et al reported 67% (n = 2) of patients were admitted to ICU with 1 patient recovering on baseline medications and CPAP and 1 who recovered after receiving a tracheostomy collar.[15]

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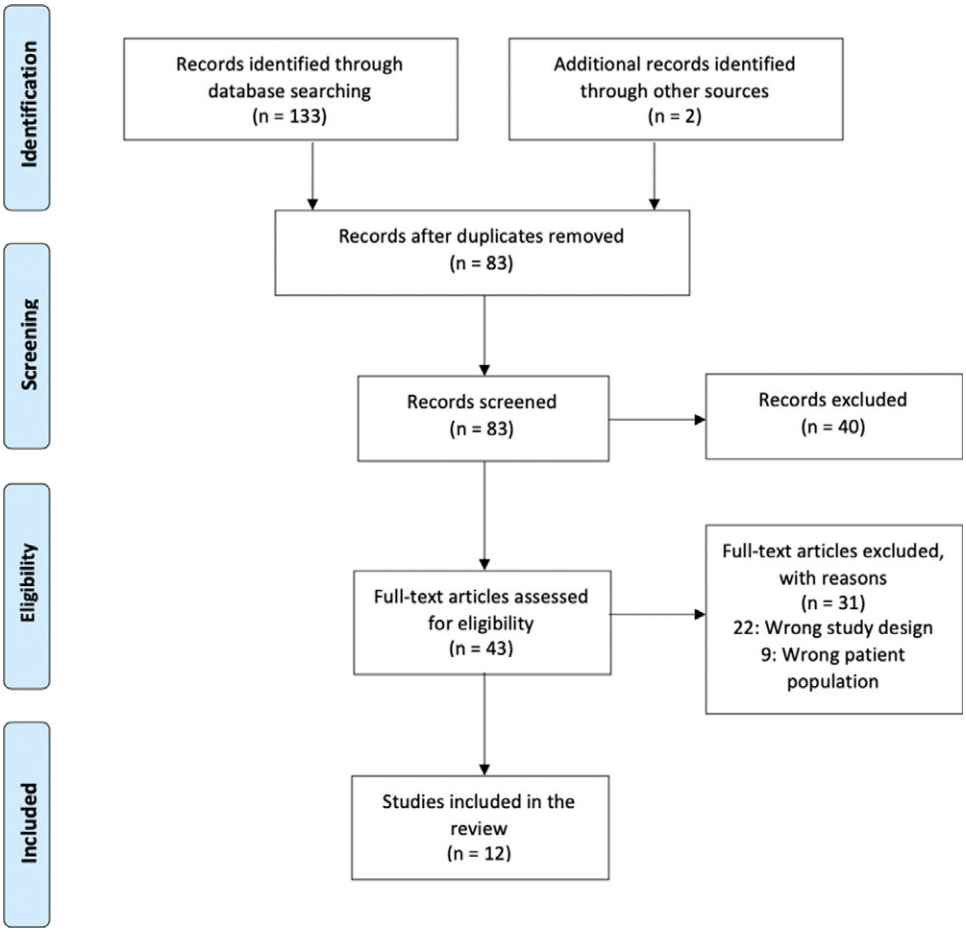

Figure 1. PRISMA chart of the literature research. This figure illustrates the selection process of articles for this review.

Evidence against worse outcomes in CHD-COVID-19 patients

Although several studies report cardiovascular complications associated with COVID-19 in most patients, 87 (88%) patients were not admitted to ICU. Xia et al reported two patients with ASD who had prior repair surgery were not admitted to ICU, and were eventually discharged as they did not experience any cardiovascular complications.[21] A group of case reports which collectively had three patients with CHDs also reported no cardiovascular complications or ICU admissions. At the time of publication, one patient was discharged and the remaining two were still receiving hospital care.[11,13,16]

Based on these numbers and outcomes described, it can be seen that patients with underlying CHD are more likely to develop complications than the overall population; however, 82% of patients recovered and were discharged within 10–20 days.

Is there a correlation between specific CHD and COVID-19 outcomes?

The studies in the analysis do not include enough patients with specific CHDs; hence, there is not enough evidence to infer a correlation between specific congenital defects and disease severity.

However, patients with more severe CHDs could be at higher risk of COVID-19 complications due to functional incapacity. The severity of ACHDs is dependent on the status of surgical repair, their anatomical complexity, and the presence of other physiological conditions, such as cyanosis and pulmonary hypertension.[29] Although, Ferrero et al demonstrated how the clinical course of COVID-19 can vary in patients with similar physiology and anatomy.[14]

A study outlined the categories of children with CHD that would be at increased risk of severe illness if they acquired a COVID-19 infection. These included patients with a large VSD, "single heart physiology" such as hypoplastic left heart syndrome and tricuspid atresia, and patients who had an upcoming surgical procedure or had already undergone one, including the Fontan procedure.[30] Although this paper did neither justify how the authors came to this conclusion, nor can we support it with our own findings, it does align with the statements made in other studies.[29,30] Other factors outlined in the literature that could increase the risk of CHD patients can be found in Table 3.

Evidence-based recommendations

Currently, patients with CHD are encouraged to follow strict distancing guidelines, and individual risk being assessed by healthcare professionals. Whilst there are no specific guidelines, some papers have proposed recommendations that seem plausible. Most papers agree that baseline cardiac status should dictate treatment; in order to assess this, oxygen saturation, Right Heart Failure (RHF) phenotype, intracardiac shunt, and cardiac preload are focussed on. If a patient deteriorates and goes into cardiogenic shock, mechanical ventilation and vasoactive medication have proven to be useful in maintaining oxygenation and organ perfusion.[33,34]

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Table 2. Summary of included articles

Author and country	Study design	Patients	Congenital defect(s)	Past treatment for CHD	Other co-morbidities	Current cardiac dysfunction	CV complications	ICU (%)	Outcome
Ahluwalia et al, USA[11]	Case report	Total: 1 Age and sex: 29M	Tricuspid atresia with single ventricle physiology	Yes	Fontan-associated liver disease under investigation	Tricuspid atresia, single ventricle S/P Fontan circulation	Nil	0	Recovery, discharged on day 10
Bezerra RF et al, Brazil[12]	Case report	Total: 1 Age and sex: 35 months F CHD-COVID-19+: 9 SuspCHD-COVID-19: 67	Hypoplastic left heart syndrome	Yes	Nil	Hypoxaemia	Complete AV block	1 (100)	Recovered, discharged on POD 24
Eghbali et al, Iran[13]	Case series	Total: 4 CHD patients: 1 Age and sex: 13M	Cyanotic heart disease (single ventricle, cyanosis, and PH)	Nil	Nil	Cyanotic heart disease and PH	Nil	0	Still hospitalised at time of report
Ferrero et al, Italy[14]	Case series	Total: 3 Age and sex: Pt 1: 30M Pt 2: 48M Pt 3: 48M	Pt 1: TGA, pulmonary stenosis Pt 2: TGA Pt 3: TGA	Pt 1: Yes Pt 2: Yes Pt 3: Yes	Pt 1: Chronic lung disease with multiple bronchiectasis, palpitations Pt 2: HF, CKD, diabetes Pt 3: Nil	Pt 1: Systemic RV mild dysfunction and moderate tricuspid regurgitation Pt 2: Severe dysfunction of the systemic RV with significant tricuspid regurgitation Pt 3: RV moderate dysfunction with mild tricuspid regurgitation	Pt 1: Palpitations Pt 2: Nil Pt 3: Nil	0	Pt 1: Discharged and clinically normal after 8 days Pt 2: Progressive clinical improvement after 1 week and CXR normalised Pt 3: Isolated and symptoms improved after 10 days
Krishnan US et al, USA[15]	Case series	Total: 3 Age and sex: Pt 1: 3M Pt 2: 25F Pt 3: 21M	Pt 1: AVSD Pt 2: AVSD with Eisenmenger physiology Pt 3: Partial AVSD with a small primum atrial shunting	Pt 1: Yes Pt 2: Nil Pt 3: Yes	Pt 1: Down syndrome, PH, OSA with dependence on CPAP, hypoxic ischaemic encephalopathy with seizures, chronic lung disease Pt 2: OSA, dependent on CPAP Pt 3: Obesity and OSA	Pt 1: PH Pt 2: Unrepaired AVSD with eisenmenger physiology Pt 3: PH	Pt 1, 3: QTc prolongation secondary to drug therapy Pt 2: Nil	2 (67)	Recovered and discharged home
Linnane et al, Ireland[16]	Case Report	Total: 1 Age and sex: 10M	DILV, pulmonary atresia, ASD, right aortic arch	Yes	Nil	Nil	Nil	0	Discharged home
Moazenzadeh et al, Iran[17]	Case Report	Total: 1 Age and sex: 48M	Untreated suspected TOF	Nil	Cardiomegaly	Same as CHD	Central cyanosis	0	Recovered and discharged on POD 14
Olfe et al, Germany[18]	Case Report	Total: 1 Age and sex: 16F	Severe MV insufficiency and mild MV stenosis	Yes	PH, atrial flutter, and fibrillation	Severe stenosis and insufficiency of the MV prosthesis	Mild cardiac distress	0	Recovered, discharged on day 10. Planned mitral valve replacement postponed
Sabatino et al, Italy[19]	Cross-sectional Study	Total (adults + children): 76 CHD-COVID-19+: 9 SuspCHD-COVID-19: 67 Total children: 4 Age range: 2 months to 2 years Sex: 2M, 2F Total adults: 72 Age range: 21 to 76 years Sex: 38M, 34F	CHD-Covid-19+: TGA (33%), Pulm atresia (22%), VSD (22%), CoA (11%), AVSD (11%), TCPC (11%), AS/BAV (11%) SuspCHD-COVID-19: TOF (13%), CoA (12%), TCPC (10%), VSD (12%), ASD (10%), Pulm atresia (9%), AS/BAV (9%)	CHD-COVID-19+: Yes (2 pts) SuspCHD-COVID-19: N/A	In adults: Obesity (9%), and diabetes (1%) In children: Nil	Atrial tachycardia/Atrial fibrillation (9%), PH (3%), hypertension (7%)	CHD-Covid-19+: HF (55%), palpitations/ arrhythmias (22%), stroke/TIA (22%), PH (22%), chest pain (11%), MI (11%), pericardial effusion (11%) SuspCHD-COVID-19: Nil	CHD-Covid-19+: 2 (22) SuspCHD-COVID-19: 0	Rate of discharge 100% with no deaths reported

Simpson et al, USA[20]	Case series	Total: 7 Age and sex: Pt 1: 3-month M Pt 2: 3-month F Pt 3: 6-month M Pt 4: 6-month M Pt 5: 9-month M Pt 6: 18F Pt 7: 19M	Pt 1: CAVC defect with marginally compensated HF Pt 2: unrepaired CAVC defect with compensated HF Pt 3: Repaired ALCAPA and post-operative supravalvular AS, and severe LV dysfunction with compensated HF Pt 4: LV non-compaction/DCM with depressed biventricular function with compensated HF Pt 5: right dominant CAVC with parachute left AV valve, and PH Pt 6: HCM Pt 7: DILV	Pt 1, 2, 4, 6: Nil Pt 3: Yes Pt 5: Yes Pt 7: Yes	Pt 1: Trisomy 21, Ex 35 week Pt 2: Trisomy 21, Acute respiratory failure, staphylococcal scalded skin syndrome, AKI secondary to HF, and medical NEC Pt 3: Nil Pt 4: Ex 36 week Pt 5: Trisomy 21, OSA, hypothyroidism, TOF Pt 6: Metabolic syndrome, type II diabetes, chronic HTN Pt 7: Type II diabetes, stage II CKD, asthma	Pt 1: same as CHD Pt 2: mild to moderate common AV valve regurgitation with mildly dilated and hypertrophied RV Pt 3: cardiomegaly, severe LV dysfunction and moderate supravalvar AS Pt 4: Dilated LV, depressed LV systolic function and impaired LV diastolic function Pt 5: residual CHD Pt 6: preserved biventricular systolic function, and LV hypertrophy Pt 7: dilated RV	Pt 1, 4, 5: Nil Pt 2: worsening HF Pt 3: PH, RV dysfunction, worsening HF Pt 6: acute decompensated HF, VT Pt 7: 1st degree AV block	5 (71)	Pt 1, 3, 4, 7: Discharged home Pt 2: Improved after complete surgical repair, remains inpatient Pt 5: Death from unknown causes 2.5 months after initial admission Pt 6: Death due to recurrence of VT
Xia et al, China[21]	Retrospective cross-sectional study	Total: 20 CHD patients: 2 Age and sex: Unknown	ASD	Yes	N/A	N/A	N/A	0	N/A
Zheng et al, China[22]	Retrospective Cross-sectional Study	Total: 25 Patients CHD: 2 Age and Sex of CHD Patients: Pt 1: 8-month M Pt 2: 1-year M	Present but unspecified	Yes	Pt 1: Malnutrition, suspected hereditary metabolic diseases Pt 2: Nil	Nil	Nil	2 (100)	Pt 1: Partly alleviated Pt 2: Significantly alleviated

Abbreviations: AKI = acute kidney injury; ALCAPA = anomalous left coronary artery from the pulmonary artery; AS = aortic stenosis; ASD = atrial septal defect; AS/BAV = aortic stenosis/bicuspid aortic valve; AV = atrioventricular; AVSD = atrioventricular septal defect; CHD-COVID-19 positive = confirmed diagnosis of COVID-19,; CAVC = complete atrioventricular canal; CoA = coarctation of the aorta; CKD = chronic kidney disease; CPAP = continuous positive airway pressure; CXR = chest x-ray; DCM = dilated cardiomyopathy; DILV = double inlet left ventricle; F = female; HCM = hypertrophic cardiomyopathy; HF = heart failure; HTN = hypertension; LV = left ventricle; M = male; MV = mitral valve; NEC = necrotising enterocolitis; OSA = obstructive sleep apnoea; PH = pulmonary hypertension; POD = post-operative day; Pt = patient; QTc = corrected QT interval; RV = right ventricle; S/P = surgical procedure; SuspCHD-COVID-19 = clinically suspected COVID-19 (no confirmation tests done); TCPC = total cavopulmonary connection; TGA = transposition of the great arteries; TOF = tetralogy of Fallot; VSD = ventricular septal defect; VT = ventricular tachycardia

Table 3. Factors placing CHD patients in higher risk groups[31,32]

Age >70 or <3 months	Complex CHD
Medical problems, i.e. diabetes, hypertension, kidney disease, pulmonary hypertension, symptomatic heart failure	Persistent high fever (3–5 days)
Poor mental response/decreased consciousness	Co-infection with other viruses/bacteria
Immunosuppression	BMI > 40

COVID-19 in children and young patients

Although children can be infected by the coronavirus and become ill, they represent a small percentage of COVID-19 confirmed cases across the globe. According to the Centre for Disease Control and Prevention (CDC) report, as of 2 April, 2020, out of the 149,760 laboratory-confirmed cases of COVID-19 in the United States of America, only 1.7% of cases occurred in children under the age of 18, although they comprise about 22% of the population.[35] Similarly, the Chinese CDC report showed that out of 44,672 confirmed cases, 87% occurred in patients aged 30–79 years, whereas patients 19 years or younger only accounted for 2% of the cases. No deaths were reported in patients 9 years or younger, whereas the overall case fatality rate was 8.0% and 14.8% for 70–79 years and 80 years and older, respectively.[36] Adults are also more likely to report symptoms and signs, with 93% of adults in the United States of America experiencing at least one of the symptoms such as fever, cough, and shortness of breath compared to only 73% of the paediatric population.[35] Although critical cases in the paediatric population are infrequent, some data suggest infants may be more likely to have severe outcomes.[37]

A link between Kawasaki disease and SARS-CoV-2 has been established by a few studies as children who tested positive for COVID-19 began developing symptoms of Kawasaki-like disease. A 30-fold increase in the incidence of Kawasaki-like disease was observed in an Italian study with these patients going on to develop serious complications like Kawasaki disease shock syndrome and macrophage activation syndrome, which required adjunctive steroid therapy.[38] Similarly, another study evaluated the link between inflammatory multi-system syndrome and exposure to SARS-CoV-2. About 100% of the patients showed cardiac involvement with the main abnormalities being left ventricular dysfunction, valve regurgitation, and coronary artery complications.[39] With very limited evidence, it is too early to make any firm conclusions.

Why do children react differently to adults?

2019-nCoV gains access into the cells by binding to the same receptor, angiotensin-converting enzyme II (ACE2), as SARS-CoV.[40] SARS-CoV-2 downregulates the expression of ACE2 once inside the cells in which ACE2 is responsible for converting angiotensin II to angiotensin 1–7.[41] Angiotensin II has a pro-inflammatory and pro-fibrotic role as well as being a vasoconstrictor, whereas angiotensin 1–7 play an important anti-inflammatory and antioxidant role as well as causing mild vasodilation, protecting the heart and lungs from injury.[42] Angiotensin II levels are found to be notably increased in the plasma of those infected with SARS-CoV-2 whilst high ACE2 levels were seen in those less affected by the virus and these levels reportedly decrease with age.[43,44] Decreasing levels of ACE2 may explain why the elderly are at a higher risk of severe illness from COVID-19 compared to the paediatric population. High ACE2 levels seen in the younger population can be protective as it leads to increased conversion of angiotensin II to angiotensin 1–7 to counteract any vasoconstriction, downregulate cytokines, leukocytes, and fibrosis.[45] On the other hand, in those with low levels of ACE2, angiotensin II accumulates and can lead to pro-inflammatory effects resulting in severe cases. Another factor that could contribute to the reduced cases and a better prognosis in the paediatric population may be the absence of co-morbidities and fewer risk factors such as smoking and obesity.

SARS-CoV-2 is a single-stranded RNA virus and live vaccines such as BCG have been proven to lower the severity of infections caused by these viruses in multiple trials. A retrospective study carried out in Spain showed a 40% reduction in rates of paediatric admissions due to respiratory infections in children who were vaccinated against the non-BCG-vaccinated children due to heterologous protection that the BCG vaccine provides.[46] The non-specific production of T helper 1 and T helper 17, and their effects on innate trained immunity remain pronounced until 1 year after the vaccination.[47] As well as that, total lymphocyte, T lymphocyte, and B cell counts decrease with age suggesting a decline in immunity.[48] High lymphocyte count in the younger population could also be put down to frequent viral infections experienced in childhood.[49] Finally, early school closures meant children were not as likely to be exposed to the virus as adults. Innate trained immunity, high lymphocyte count, and reduced exposure could all be possible explanations for why children may fare better than adults.

Pathophysiology of COVID-19 and cardiovascular system

Whilst the aetiology of cardiovascular complications due to SARS-Cov-2 infection is not clear, it has been proposed that ACE2 receptors could be used as a mode of entry into myocytes and cause myocardial injury through various mechanisms. One such mechanism is via increased myocardial oxygen demand in response to severe hypoxia.[50] Coronavirus may also cause myocardial injury via the cytokine storm that occurs in response to a possible large immune response during the infection.[51,52] Cardiac involvement such as right ventricular failure and congestion can either be a result of respiratory distress or direct cardiac injury caused by the virus, as suggested by the raised cardiac troponin I in critical patients compared to non-critical patients.[53,54] It is also important to keep in mind that COVID-19 may mimic symptoms of exacerbation of cardiac conditions such as endocarditis or heart failure which can be a serious issue when dealing with patients with CHD.[7]

Service provision and telemedicine for CHD patients

The COVID-19 pandemic has placed an unprecedented stretch on the healthcare system and demands have been increased dramatically. Healthcare systems had to completely reshape and redesign to accommodate for the vast increase in patients infected with SARS-CoV-2.[7] All patients with heart disease are classed as being at high risk of being infected with SARS-CoV-2.[31] Due to this, it was essential for healthcare services to put provisions in place for those with underlying CHD.

The abrupt changes that were introduced instilled fear in many patients with CHD, notably chronic cardiac patients who had heart failure and were advised to self-isolate. The uncertainty behind social distancing guidelines, fear of getting infected, and concerns

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regarding the availability of healthcare services had a negative impact on the mood of these patients. It was found that the COVID-19 pandemic resulted in a severe mood change in 18.9% and moderate in 51.6%.[55] This has specifically affected patients with CHD who require regular follow-ups. A lack of these could potentially result in delayed diagnosis of CHD complications and loss of follow-up during the transition from paediatric to adult care.

In order to aid the management of ACHD patients, an abbreviated triage algorithm was proposed to help staff identify the "ACHD phenotype and baseline cardiac status." This allows staff members to classify patients according to their compensation status and provide appropriate management to those with moderate or severe CHD. The triage algorithm includes five "ACHD phenotypes": CHD with pulmonary hypertension (CHD-PAH), cyanotic CHD, single ventricle/Fontan anatomy, right heart failure, and systemic right ventricle.[33]

Furthermore, regular outpatient clinics for patients with CHD were cancelled and there was a huge drive to move towards telemedicine. Online consultations have the advantage of allowing both parties to shield, whilst also ensuring patients are receiving appropriate care. A wide range of clinical data can be transmitted through telehealth, thus allowing for adequate patient examination, diagnosis, and management decisions. It also promotes access to specialist opinion. Virtual risk stratification has also been implemented to ensure the allocation of resources and safety of staff members.[6,34]

Overall, there have been many positive changes in the care of patients with CHD. The use of telemedicine has proven to be beneficial in alleviating concerns and educating patients on their condition. The introduction of a new triage algorithm is also a positive move forward in guiding treatment and increasing quality of care. Development of these innovative changes was essential to protect patients from being infected whilst still providing great care throughout the pandemic.[56] However, a balance between managing the exposure of both patients and staff, and providing adequate care has to be reached. Telemedicine has been proven useful in these times and could be implemented to provide personalised care beyond the coronavirus pandemic.

Limitations

First, there is a paucity of the data regarding COVID-19 in patients with CHD. This is perhaps due to the novelty of the virus at this time, but also due to CHD patients being considered high risk and having less exposure compared to the general population. As a result, most publications are case studies, which carry a significant amount of bias in patient selection.

Second, since there are no clear guidelines regarding the management of COVID-19 in patients with CHD, decisions had to be made on a case-by-case basis and most patients received different care. Therefore, strong conclusions cannot be drawn regarding the causality between CHD and outcome of patients.

Future research

The risk associated with SARS-CoV-2 infection in patients with CHD is a topic that still requires extensive research. Future multi-centre studies should be done to validate findings in a larger cohort of patients and to avoid the selection bias in case studies. These should aim to quantify the isolated effect of COVID-19 on these patients, whilst adjusting for significant covariates such as age, co-morbidities, and treatment given, which have a large effect on disease severity and progression. More research could also investigate a possible correlation between degree of cardiovascular impairment and COVID-19 prognosis.

Conclusion

Patients with CHD are more likely to be at an increased risk of developing complications due to SARS-CoV-2 infection, consequently being admitted to ICU. However, the paediatric patients may be less susceptible to COVID-19 due to multiple reasons such as the high levels of ACE2, innate trained immunity, and absence of co-morbidities. The variety of defects and differences in clinical manifestations makes it difficult to predict the clinical outcomes and thus manages CHD-COVID-19-positive patients. Further studies with a larger sample size should be conducted to clarify the association between the type and severity of CHD and the prognosis in COVID-19 patients.

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