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Clinical outcomes following hospitalization for COVID-19 in patients with cardiac sarcoidosis in the United States: a propensity-matched analysis from national inpatient sample database from April 2020 to December 2021

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Background: The highly arrhythmogenic nature of cardiac sarcoidosis (CS) leads to high morbidity and mortality, the rates of which may be higher in COVID-19 patients. This study aimed to evaluate the outcomes of CS patients admitted to hospitals with COVID-19.
Methods: The study utilised the 2020–2021 National Inpatient Sample database, examining primary COVID-19 cases in adults aged older than or equal to 18 years. Those with CS were identified using ICD-10 code "D86.85" and compared with and without propensity matching (1:10) to those without CS for baseline characteristics and primary outcomes of acute kidney injury (AKI), use of mechanical ventilation, cardiac arrest and mortality.
Results: In total, 2 543 912 COVID-19 cases were identified. Before propensity matching, CS patients were more likely to be younger (58.0 vs. 64.0 years, $P < 0.01$), male (64.0% vs. 52.6%, $P = 0.011$), of Black ethnicity (60.0% vs. 15.9%, $P < 0.01$), exhibit higher Charlson Comorbidity Index (CCI) scores (3.00 vs. 1.00, $P < 0.01$) and had a higher incidence of in-hospital cardiac arrest (aOR 2.649, 95% CI 1.366–5.134, $P = 0.004$). After propensity matching (CS, $N = 95$; non-CS, $N = 875$), those with CS were at a statistically significant reduced risk of AKI (aOR 0.484, $P = 0.01$); however, the outcomes of death, cardiac arrest, mechanical ventilation, length of stay (LOS) and healthcare costs did not reach significance.
Conclusion: In a propensity-matched cohort admitted with COVID-19, CS patients had a reduced risk of AKI, but comparable LOS, rates of cardiac arrest, mechanical ventilator use, and mortality. Future research is warranted to develop evidence-based guidelines for managing COVID-19 in patients with CS.

Keywords cardiac sarcoidosis, covid-19, NIS, propensity matching, sarcoidosis

Introduction

Sarcoidosis is a condition characterised by the development of non-necrotising granulomas, which have the potential to impact various organs across the body[1]. It can affect individuals across all age groups but is most commonly seen in females between the ages of 40–60 years, and males between the ages of 30–50 years[2]. Although sarcoidosis primarily affects the lungs and lymph nodes, it may be classified as cardiac sarcoidosis (CS) when there is involvement of the myocardium. Although there are vast swathes of patients who are asymptomatic, CS may manifest as conduction abnormalities, ventricular arrhythmias, and congestive heart failure in up to 30% of cases[3,4]. Furthermore, there are presentations of CS isolated to the myocardium, which occur in the absence of sarcoidosis affecting other areas of the body[5].

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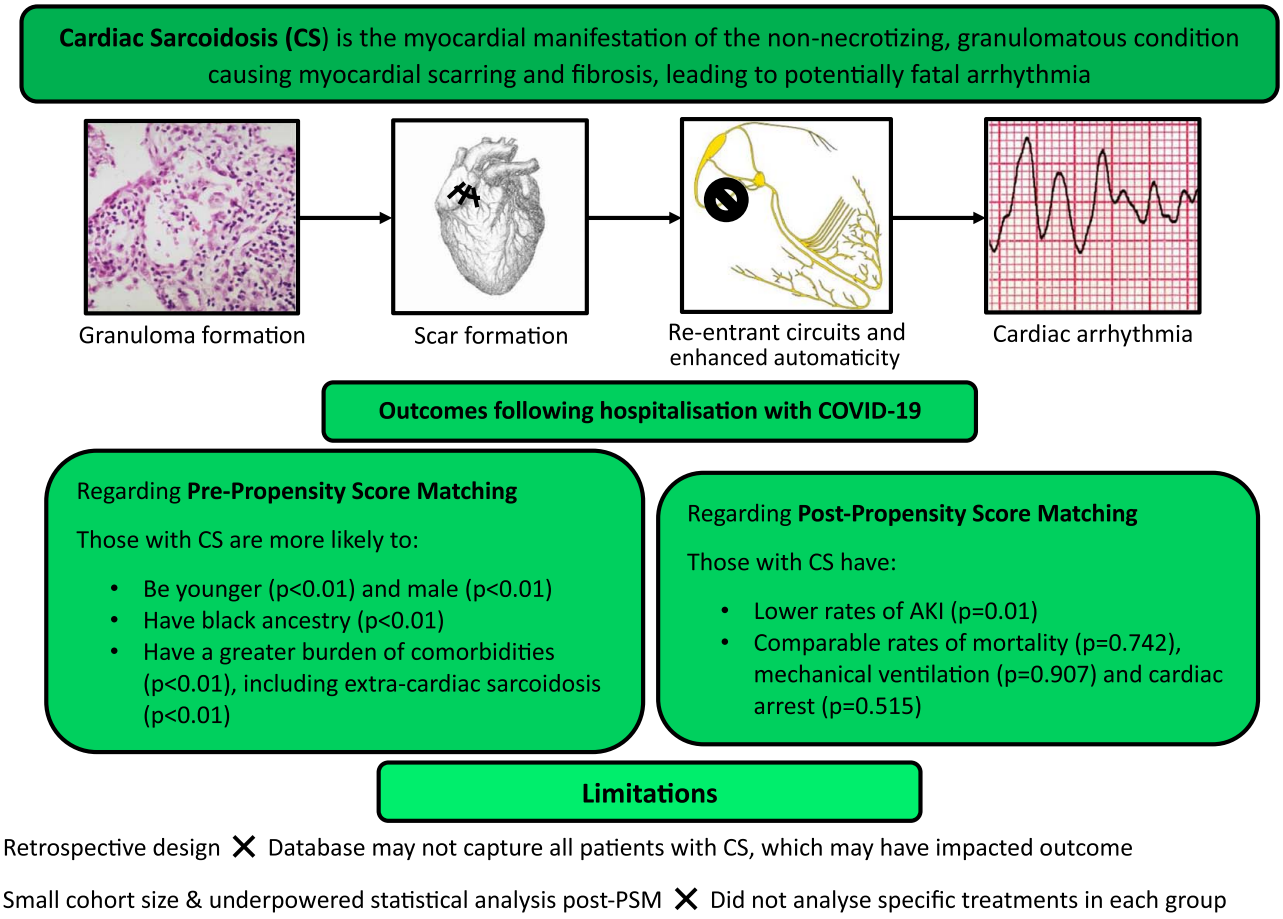

SARS-CoV-2, which is responsible for the outbreak of COVID-19, primarily affects the lung parenchyma. Although just one of an increasing number of zoonotic diseases, perhaps in part due to climate change, the global impact of its spread due to the risk to life has been colossal[6]. Individuals with comorbidities such as cardiovascular disease, diabetes and hypertension have been previously shown to be at greatest risk of adverse outcome, with further evidence to support those with underlying lung disease being particularly vulnerable[7,8]. Compounding with this, the widespread use of glucocorticoids or other immunosuppressive agents in the routine management of both systemic and cardiac manifestations of sarcoidosis may also amplify the effect of COVID-19[9].

Immunomodulation, including immunotherapy and vaccination regimes, particularly in patients within the 'vulnerable' category such as those with pre-existing lung disease, can play an important part in the management of COVID-19. However, little is known about the interaction between those with both sarcoidosis and COVID-19[10–14]. Previous studies have demonstrated higher rates of COVID-19 infection in those with sarcoidosis when compared to the average individual; however, the outcomes of SARS-CoV-2 infection in these individuals is less commonly reported within the literature[15]. Similarly, there is a paucity in current data relating to the outcomes of CS patients admitted to hospitals with COVID-19.

The primary aim of this study is to evaluate the clinical outcomes of individuals diagnosed with CS in the United States who were admitted to hospitals due to COVID-19, specifically the primary endpoint of mechanical ventilation, acute kidney injury (AKI), cardiac arrest and mortality, with the intent to help inform the management of the disease and mitigate unfavourable patient outcomes.

Materials and methods

We utilised the 2020–2021 National Inpatient Sample (NIS) database, which was compiled by the Health Care Utilisation and Project (HCUP) and funded by the Agency for Healthcare Research and Quality (AHRQ). The NIS is a highly extensive repository of inpatient medical records within the United States, encompassing a substantial proportion of hospitals, specifically 20% across 48 states. The database is publicly released in a de-identified format and includes a range of patient and hospital demographic information such as age, race, sex, and hospital location and teaching status. The International Classification of Diseases 10th Revision (ICD-10) codes enable users to identify and classify various diseases and processes.

Patient selection

Individuals aged 18 years and older who had been admitted to the hospital with a primary diagnosis of COVID-19, as indicated by the ICD-10 code "U071", were included in this cohort, retrospective study. The study was located in the United States of America, across multiple secondary/tertiary care settings. The inclusion of patients admitted between April 2020 and December 2021 in the data set

was guided by the implementation of the ICD-10 code on April 2020, as per the recommendations of HCUP. Cases of sarcoid myocarditis were identified using the ICD-10 code "D86.85"[16,17]. The investigation covered the examination of several factors, such as smoking, atrial fibrillation, dyslipidaemia, a history of previous myocardial infarction, chronic renal disease, obesity, and diabetes. Primary outcomes included in-hospital mortality, cardiac arrest, use of mechanical ventilation, incidence of AKI, length of stay and hospital costs[18–21].

The statistical techniques employed in this study to evaluate disparities in patient characteristics and outcomes across the two cohorts included χ^2 tests for categorical variables and given the non-parametric nature of the NIS, we used 'Mann–Whitney tests for continuous variables. Subsequently, propensity matching with 1:10 near-neighbour matching technique was employed, with a caliper width of 0.01, in order to account for variables such as age, CCI score, sex, lipid disorder, race, primary insurer, atrial fibrillation, hypertension, diabetes, smoking, obesity, chronic kidney disease (CKD), chronic obstruction pulmonary disease (COPD), prior stroke, prior myocardial infarction, pulmonary sarcoidosis, sarcoidosis involvement in other organs (excluding the lung and heart), and median income quartile between the two cohorts. The adjusted odds ratio (aOR) of primary outcomes between the two groups was estimated using multivariable logistic regression models in our pre-PSM and post-PSM samples.

The statistical analyses were conducted using SPSS 29.0 (IBM Corp) and R-Studio 2023.09.0 Build 463 (https://www.R-project.org). A two-tailed significance level of 0.05 was employed to determine statistical significance. Our work has been reported in line with the STROCSS criteria[22]. There was no patient or public involvement in this research.

Ethics clearance and registration

As the data provider releases the sample in de-identified form, without protected health information, the need for ethics clearance is waived.

Results

Pre-propensity matching

A total of 2 543 912 cases of COVID-19 infection, including 125 individuals with CS, were identified. As demonstrated in Table 1, CS patients admitted with COVID-19 were more likely to be younger (median age 58.0 vs. 64.0 years, $P<0.01$), male (64.0% vs. 52.6%, $P=0.011$), and have a greater comorbidity burden as per the Charlson Comorbidity Index (CCI) (Median: 3.0 vs. 1.0, $P<0.01$). They were also less likely to have Medicare (48.8% vs. 40.0%, $P=0.141$), and more likely to have private insurance (36.0% vs. 30.5%, $P=0.141$). Those with CS had greater prevalences of prior myocardial infarction (24.0% vs. 4.2%, $P<0.01$), atrial fibrillation (56.0% vs. 14.2%), chronic kidney disease (CKD) (36.0% vs. 18.0%, $P<0.01$), lipid disorders (68.0% vs. 39.8%, $P<0.01$), smoking (56.0% vs. 28.7%, $P<0.01$), obesity (48.0% vs. 30.2%, $P<0.01$) and diabetes (48.0% vs. 37.9%, $P=0.02$), but less likely to have a diagnosis of hypertension (16.0% vs. 40.2%, $P<0.01$). When compared to non-CS patients, those with CS had higher rates of sarcoidosis involvement in other organs, including pulmonary sarcoidosis (36.0% vs. 0.1%, $P<0.01$) as well as manifestations of sarcoidosis affecting organs outside of the cardiac or pulmonary systems (12.0% vs. 0.2%, $P<0.01$).

In terms of pre-PSM outcomes, CS patients were more likely to have in-hospital cardiac arrest [adjusted odds ratio (aOR) 2.649, 95% CI 1.366–5.134, $P=0.004$]. Death, AKI and mechanical ventilation use were comparable between the two cohorts (Table 2).

Post-propensity matching

Post-propensity matching there were 95 CS patients and 875 non-CS patients, the characteristics of which are demonstrated in Table 3. There now remained no statistical difference between non-CS and CS groups with regard to age (60.0 vs. 57.0 years, $P=0.449$), CCI (2.0 vs. 3.0, $P=0.249$), sex (36.8% vs. 33.3%, $P=0.468$) or Black ethnicity (57.9% vs. 61.7%, $P=0.468$). The only statistically significant variables identified were the lower rates of Medicare and higher rates of private insurance in those with CS (36.6% vs. 42.1% and 30.3% and 37.4%, respectively, $P<0.01$ for both), higher comorbidities of obesity (47.4% vs. 36.6%, $P=0.039$) and pulmonary sarcoidosis (15.8% vs. 6.3%,

Table 1

Pre-propensity-matched sample of COVID-19 patients with and without cardiac sarcoidosis

	COVID-19 cases without cardiac sarcoidosis ($n=2\,543\,787$) (%)	COVID-19 cases with cardiac sarcoidosis ($n=125$) (%)	*P*
Patient characteristics			
Median age (IQR)	64.00 (52.00–76.00)	58.00 (55.00–64.00)	<0.01
Median CCI (IQR)	1.00 (0.00–3.00)	3.00 (2.00–5.00)	<0.01
Female	47.4	36.0	0.011
Insurance form			0.141
Medicare	48.8	40.0	
Private	30.5	36.0	
Race			<0.01
Others	84.1	40.0	
Black	15.9	60.0	
Median income quartile			0.551
0–25	33.2	33.3	
26th–50th	27.7	25.0	
51st–75th	22.9	20.8	
76th–100th	16.2	20.8	
Comorbidities			
Lipid disorder	39.8	68.0	<0.01
Atrial fibrillation	14.2	56.0	<0.01
Hypertension	40.2	16.0	<0.01
Diabetes	37.9	48.0	0.020
Smoking	28.7	56.0	<0.01
Obesity	30.2	48.0	<0.01
Chronic kidney disease	18.0	36.0	<0.01
COPD	15.0	24.0	<0.01
Previous stroke	5.4	n/a	n/a
Previous MI	4.2	24.0	<0.01
Pulmonary sarcoidosis	0.1	36.0	<0.01
Sarcoidosis involvement in other organs (excluding the lung and heart)	0.2	12.0	<0.01

CCI, Charlson Comorbidity Index; COPD, chronic obstruction pulmonary disease; IQR, interquartile range; MI, myocardial infarction.

Table 2

Pre-propensity-matched analysis of outcomes in COVID-19 patients with cardiac sarcoidosis

		95% CI		
	aOR	Lower	Upper	*P*
Death	0.712	0.369	1.374	0.311
Acute kidney injury	0.910	0.600	1.381	0.659
Cardiac arrest	2.649	1.366	5.134	0.004
Mechanical ventilation	1.003	0.574	1.751	0.992

aOR, adjusted odds ratio.

$P < 0.01$) in those with CS, and lower incidences of diabetes (31.6% vs. 45.1%, $P = 0.011$) and smoking (57.9% vs. 69.1%, $P = 0.026$).

The outcomes following multivariable regression analysis, as shown in Table 4, demonstrate a statistically significant reduced risk of AKI in those with CS and COVID-19 (aOR 0.484, 95% CI 0.279–0.839, $P = 0.01$). Those within the CS group were shown to have comparable rates of mechanical ventilation (aOR 0.951, 95% CI 0.407–2.222, $P = 0.907$), mortality (aOR 1.15, 95% CI 0.501–2.641, $P = 0.742$), incidence of cardiac arrest (aOR 1.654, 95% CI 0.363–7.536, $P = 0.515$), median length of hospital stay (LOS) (5.0 vs. 5.0 days, $P = 0.649$) and median hospital charge (42 381 vs. 49 428 USD$, $P = 0.613$).

Discussion

There were three main findings in this contemporary real-world study, which analysed both CS and non-CS individuals who were admitted to hospital with a primary diagnosis of COVID-19. Firstly, prior to PSM, those with CS tended to be younger, more comorbid, and more likely to be of Black ancestry when compared to those without CS. Secondly, the incidence of in-hospital cardiac arrest was higher in those with CS pre-PSM. Finally, when analysing post-propensity matching, CS patients with COVID-19 experienced lower rates of AKI. Rates of mortality, mechanical ventilation, cardiac arrest, length of stay and hospital charge did not reach statistical significance.

Patient characteristics

This study revealed significant disparities in patient characteristics between the two groups. Overall, there were more male patients admitted with COVID-19 in both CS and non-CS cohort which can be attributed to the reported difference in the prevalence of COVID-19 between sexes in the literature[23]. However, a higher proportion of males were seen in the cardiac sarcoidosis group compared to the non-cardiac sarcoidosis group. This finding is consistent with the previous study conducted by Arkema *et al.*[2]. It is pertinent to mention here that males have an increased risk of COVID-19 death and severity compared to females[24]. The authors postulate that this factor along with the higher CCI may well be the reason for higher in-hospital cardiac arrests observed in the pre-PSM CS cohort.

The analysis also demonstrated that CS patients admitted with COVID-19 were younger. Several factors including the presence of granulomatous inflammation, comorbidities owing to long-term steroid use, and a compromised immune system following the administration of immunosuppressive medications such as methotrexate, azathioprine, and tumour necrosis factor alpha inhibitors may account for this finding, and potentially explain the earlier contraction of COVID-19 in CS patients[25,26].

Table 3

Propensity-matched sample of COVID-19 patients with and without cardiac sarcoidosis

	COVID-19 cases without cardiac sarcoidosis ($n = 875$) (%)	COVID-19 cases with cardiac sarcoidosis ($n = 95$) (%)	*P*
Patient characteristics			
Median age (IQR)	60.00 (48.00–68.00)	57.00 (55.00–65.00)	0.449
Median CCI (IQR)	2.00 (1.00–5.00)	3.00 (2.00–4.00)	0.249
Female	33.3	36.8	0.468
Insurance form			< 0.01
Medicare	36.6	31.6	
Private	30.3	47.4	
Race			0.468
Others	38.3	42.1	
Black	61.7	57.9	
Median income quartile			0.827
0–25th	29.7	31.6	
26th–50th	26.9	26.3	
51st–75th	24.0	26.3	
76th–100th	19.4	15.8	
Comorbidities			
Lipid disorder	70.3	78.9	0.077
Atrial fibrillation	57.7	47.4	0.053
Hypertension	26.9	21.1	0.222
Diabetes	45.1	31.6	0.011
Smoking	69.1	57.9	0.026
Obesity	36.6	47.4	0.039
Chronic kidney disease	28.6	36.8	0.093
COPD	18.3	15.8	0.548
Previous stroke	12.6	n/a	> 0.05
Previous MI	30.3	26.3	0.422
Pulmonary sarcoidosis	6.3	15.8	< 0.01
Sarcoidosis involvement in other organs (excluding the lung and heart)	3.4	n/a	< 0.01
Outcomes			
Median length of stay (LOS)	5.00 (3.00–9.00)	5.00 (3.00–9.00)	0.649
Median hospital charge (USD$)	42 381 (25 059–83 431)	49 428 (28 402–73 400)	0.613

CCI, Charlson Comorbidity Index; COPD, chronic obstruction pulmonary disease; IQR, interquartile range.

Although only statistically significant within our pre-propensity-matched cohorts, Black ethnicity was a variable that was shown to be greater in the COVID-19 cohort with CS. Early anecdotal findings from the COVID-19 pandemic, which were subsequently confirmed by larger-scale research, demonstrated Black and Asian groups to be disproportionately affected by COVID-19[27]. Similarly, racial disparities in those with CS have been previously demonstrated to lead to adverse outcomes, highlighting the need for ongoing public health initiatives and increased clinician awareness to identify those populations at greatest risk of negative outcomes[18,28].

Medicare is the federal health insurance program for individuals in the US who are aged older than or equal to 65 years,

Table 4

Multivariable regression analysis of outcomes in COVID-19 patients with cardiac sarcoidosis

		95% CI		
	aOR	Lower	Upper	*P*
Death	1.15	0.501	2.641	0.742
Acute kidney injury	0.484	0.279	0.839	0.01
Cardiac arrest	1.654	0.363	7.536	0.515
Mechanical ventilation	0.951	0.407	2.222	0.907

aOR, adjusted odds ratio.

individuals with end-stage renal disease, and selected individuals with disabilities aged younger than 65 years[29]. In both pre- and post-propensity matching, individuals with CS were at greater likelihood of holding private insurance, therefore insurance-based disparities are unlikely to have restricted the care in both cohorts.

Comorbidities

Variations in the lipid profile are frequently observed in CS patients, with our study demonstrating lipid disorders to be higher in COVID-19 individuals with CS compared to those without CS[30]. This association between sarcoidosis and dyslipidaemia has been documented by a previous study, and could be plausibly linked with increased oxidative stress[31]. Decreased HDL-cholesterol (HDL-c) without any significant change in LDL-cholesterol (LDL-c), total cholesterol (TC), and triglycerides have been detected in untreated sarcoidosis patients[32]. Several studies have sought to investigate correlations between lipid levels and COVID-19, with most showing that decreasing HDL-c levels are seen in acute COVID-19 infection and that, furthermore, the patients with most severe COVID-19 infection show the lowest levels of HDL-c. Analysis of outcomes in these groups demonstrates low levels of HDL-c at admission to be positive predictors of morbidity and mortality, potentially complicating the treatment of infection in those with dyslipidaemia[33]. Although it is unclear from our analysis whether this variable has resulted in changes in our primary outcomes, we feel this relationship between CS, dyslipidaemia and COVID-19 infection warrants further investigation.

The link between CS and atrial fibrillation can be expected owing to the highly arrhythmogenic nature of CS. Before propensity matching, the analysis demonstrated a significant association between atrial fibrillation and CS patients- a finding which aligns with the study conducted by Desai *et al.*[34] showing atrial fibrillation in over 1 in 10 sarcoidosis patients. A more recent meta-analysis conducted by Mahmoud *et al.*[35] revealed that unspecified arrhythmias were found to be the third most prevalent cardiac comorbidity in sarcoidosis patients.

The systemic inflammatory nature of sarcoidosis and its potential for granulomatous infiltration into any organ likely accounts for the higher incidence of both the pulmonary and also combined "non-cardiac, non-pulmonary" manifestations, which were seen more frequently in the CS cohort. It is prudent to note the potential screening bias which we anticipate in those with pre-existing cardiac involvement due to the more extensive investigations those with CS will get when compared to those without a prior history of sarcoidosis. That being said, a proportion of those with CS may have disease isolated to the myocardium[5]. The impact of COVID-19 infection on "isolated" cardiac sarcoidosis (iCS) patients may differ from those with systemic cardiac sarcoidosis (sCS); however, this relationship was not explored within this study.

There is inconclusive data from several previous studies with respect to smoking, with some documenting a decreased incidence of sarcoidosis among smokers[36,37]. In contrast, others studies have not drawn this same conclusion, finding higher rates of smoking in those with CS - similar to our pre-propensity-matched cohort[38,39]. The mixed results can be attributed to limited medical evidence resulting in unclear understanding of the relationship between smoking and sarcoidosis so far. The significantly higher prevalence of smoking in CS patients in our pre-propensity match analysis could be explained by the strong genetic predisposition of sarcoidosis with smoking triggering an abnormal immune response in genetically susceptible individuals[40]. However, this postulation is merely a hypothesis and further investigation is necessary to develop an accurate narrative. Similarly, CKD—another comorbidity variable that reached significance in the pre-matched CS cohort—could be linked with the tendency of sarcoidosis to affect renal function[41]. The association between sarcoidosis and chronic renal disease is not well discussed in the literature.

Old MI demonstrated a significantly higher prevalence in the pre-matched cardiac sarcoidosis group. Although no definite connection has been documented between sarcoidosis and old MI, several potential connections can be deduced from the available literature. The sarcoid granulomas can infiltrate the myocardium and compress the coronary vessels, leading to scarring and reduced blood flow to the myocardium, respectively, predisposing individuals to MI or exacerbating prior MI[42]. Notably, severe arrhythmias can also reduce myocardial blood flow. Hypertension is a significant health concern that is particularly common in older adults[43]. The decreased prevalence of hypertension in the CS cohort could be attributed to the younger population contrary to the older in the non-CS cohort.

Prior studies have recorded a statistically significant association between sarcoidosis and both diabetes and obesity, a finding consistent with our pre-propensity match analysis results[44,45]. The increased secretion of leptin, an immunomodulatory hormone, in obese individuals could explain the relationship between sarcoidosis and obesity. Leptin, then stimulates immune cell proliferation particularly naive T-cells triggering a shift towards Th1 immunity- a phenomenon that may contribute to the development of sarcoidosis[46]. Although statistically greater in both the pre- and post-propensity-matched cohorts, the exact reason for the higher incidence of obesity seen in the CS group could not be ascertained in our study; further investigation is required to draw a meaningful conclusion in this regard.

Regarding comorbidity burden, our results before propensity match analysis demonstrated significantly increased CCI score in CS individuals. These results align with the previous studies[47,48]. Pohle *et al.*[49] found a higher mean number of comorbid diseases in sarcoidosis individuals compared to control group. Similarly, Nowinski *et al.*[50] reported a significantly higher mean number of comorbidities in sarcoidosis patients who died compared to survivors. Persistent inflammatory organ damage coupled with side effects of chronic glucocorticoid use may account for increased mean CCI score in the CS cohort. Care management become considerably more complex and requires a

multidisciplinary approach due to the burden of associated chronic disease in sarcoidosis patients.

Outcomes

Mechanical ventilation is a crucial intervention in the management of COVID-19 patients especially in the setting of acute respiratory distress syndrome (ARDS) or respiratory failure. It is well-documented that more than 90% of sarcoidosis patients have pulmonary involvement[51]. Although we hypothesised those with CS to have an increased rate of mechanical ventilation due to ongoing granulomatous inflammation and compounding respiratory effects of SARS-CoV-2, the risk in the two COVID-19 cohorts were similar. As we go on to discuss within the limitations of the study, we suspect this similarity between the two groups may be due to our inability to discern between varying severities of COVID-19 due to the nature of the ICD codes.

Previous studies have highlighted links between sarcoidosis and kidney disease; however, rates of AKI in cardiac manifestations are less commonly reported[52,53]. We expected that sarcoidosis-related granulomatous interstitial nephritis coupled with COVID-19-induced kidney damage would contribute to a higher occurrence of AKI in the CS group. However, our results showed that AKI was actually lower in those with CS than without cardiac involvement A possible reason for this may be sarcoidosis-associated Vitamin D level changes or pre-existing immunosuppressive medications taken by those with CS, for example corticosteroids or steroid-sparing immunosuppressants, may in fact modulate and dampen the cytokine storm associated with SARS-CoV-2, which prevent kidney damage and a prothrombotic state which may give rise to clot formation[54–57].

As a consequence of its pathophysiology, CS patients are at risk of ventricular arrhythmia, which may result in cardiac arrest. As such, the prevention of sudden cardiac death in these patients is understandably a priority for clinicians who look after those with sarcoidosis[3,58,59]. A prior study using the Swedish Registry for Cardiopulmonary Resuscitation demonstrated greater mortality rates in those infected with COVID-19 who have a cardiac arrest[60]. Although our data relating to the outcomes of cardiac arrest and mortality did not reach significance, the results tended towards a greater risk of cardiac arrest in those with CS and COVID-19, which may be as a consequence of the compounding impact of COVID-19 infection with the greater burden of arrhythmia in CS patients. As such, exercising caution in those with both of these is advisable, and may prompt clinicians to lower the threshold as when to consider active treatment of COVID-19.

Strengths and limitations

The key strength of our study is the large sample size without any selection bias associated with the selective publication of results from specialized centres and clinical trials. There is a broad representation of the United States population in our study. These findings are also reflective of the real-world impact of COVID-19 on patients with and without CS.

Due to the innate rarity of CS, using a large database such as the NIS to capture a large group of cases and eliminate error was pivotal. However, the retrospective design means that all potential confounding factors which may influence outcome will not be accounted for. Additionally, there is a possibility not all instances of CS are accurately recorded, which would result in an underestimation of the actual prevalence and severity of the condition. Furthermore, as already highlighted, differentiating between the varying severities of COVID-19 infections in patients was not possible in this study.

The single-nation nature of the data from our study renders drawing conclusions in different regions more challenging. Although a nationwide study, the objectively low number of CS patients with COVID-19 that were identified limited our ability to draw high-powered conclusions. Further research with a larger and more diverse population is needed to corroborate these findings and better understand the intricate relationship between cardiac sarcoidosis, COVID-19, and associated clinical outcomes. Using this, the development of evidence-based guidelines for managing COVID-19 in patients with cardiac sarcoidosis can be formulated to improve overall prognosis.

Conclusion

This study hypothesised that those with CS would be at greater risk of adverse outcomes when infected with COVID-19, namely AKI, mechanical ventilator use, cardiac arrest and mortality. Although the study demonstrated that those with CS had a greater burden of comorbidity and greater incidence of in-hospital cardiac arrest before propensity matching, it was only after propensity matching that the study demonstrated a lower incidence of AKI in CS cohort, with mortality, cardiac arrest, mechanical ventilator use, length of stay and in-hospital charges being comparable between CS and non-CS cohorts.

Ethical approval

Ethical approval is waived due to nature of National Impatient Sample (NIS) database used in this study. NIS data are released publicly in de-identified form. It is compiled by the Health Care Utilisation and Project and funded by the Agency for Healthcare Research and Quality. More information can be found on: https://hcup-us.ahrq.gov/DUA/dua_508/DUA508version.jsp.

Consent

Given the retrospective nature of this publicly available database, consent from patient is not required. Please refer to: https://hcup-us.ahrq.gov/DUA/dua_508/DUA508version.jsp.

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Author contribution

S.M., R.A.: conceptualization, writing—original draft, writing—review and editing. A.R., S.T., H.S., M.B., Y.J., M.S.D., A.L., M.A., P.K.P.-B., A.A., A.W., V.K.: writing—review and editing. K.R.: data curation, formal analysis, investigation. A.C., R.S.: supervision, writing—review and editing.

Conflicts of interest disclosure

The authors declare no conflicts of interest.

Research registration unique identifying number (UIN)

The work was registered using the Research Registry (UIN researchregistry10311)[61].

Guarantor

Anwar Chahal.

Data availability statement

Data made available by Health Care Utilisation and Project (HCUP) and funded by the Agency for Healthcare Research and Quality (AHRQ). Anyone interested in the database has to make a formal request to get the access directly through HCUP.

Provenance and peer review

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