

was reported to be around 1.4% from 277 cardiac autopsies from 22 studies. Myocardial fibrosis (80-100%) of cases is the most common histo- pathological finding. A specific interstitial macrophage infiltration has been reported in 86% of cases and 14% of patients have multifocal lymphocytic myocarditis [27]. These studies are suggestive of fact that direct invasion by virus is not that frequent compared to dys-regulated inflammatory response resulting in myocardial inflammation and myocarditis.

Cardiac arrest among COVID-19 patients with heart failure can be multi-factorial including QTc interval prolongation resulting in Torsades de pointes, result of multi-organ dysfunction, hypoxia resulting in P.E.A, Hyper-coagulable status resulting in macrovascular thrombosis resulting in ACS and V fib arrest. QT interval prolongation among COVID patients depends on various factors including the use of QT prolonging medications like Hydroxy-chloroquine, Azithromycin, electrolyte disturbances, older age, risk of cardiovascular disease and bradycardia [28].

There is no direct study available on literature review evaluating the patho-physiology of Cardiac arrest among COVID 19 patients with underlying heart failure. Various studies have shown the impact of heart failure on COVID 19 mortality, length of mechanical ventilator stay and influence of multi organ failure, renal dysfunction and sepsis on the mortality among COVID 19 patients.

We have designed our study to evaluate these clinical predictors along with few other chronic co morbidities as risk factors for cardiac arrest among patients admitted to the hospital with COVID 19 and heart failure.

Methods

The study does not require I.R.B. approval, and informed consent was waived due to the de- identified nature of this administrative dataset. International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10 CM) codes (provided in supplementary appendix) were used to identify all patients over the age of 18 years with a discharge diagnosis of heart failure, COVID-19, cardiac arrest and other co morbidities.

Main Data Source

We have used the National Readmission Data from 2020 for the analysis of data. The database contains discharge-level data without any patient identifier and has around 100 clinical and non- clinical variables for each hospital stay. Major limitation of the study is dependency on ICD 10 codes for the diagnoses and inability to verify the severity of disease by reviewing the labs, charts and may not have complete list of all the co-morbidities which can influence the outcome.

Study Population

This observational study was conducted by extracting

the data for the year 2020. We have used the following ICD 10 codes for the heart failure: I50.20,I50.21,I50.22,I50.23 & I50.30,I50.31,I50.32,I50.33 and got 2882435 discharge data after applying these codes.

After getting this data of 2882435 discharges, we have used U07.1 & U07.3 for inpatient COVID 19 admissions and got 148916 admissions for our analysis. There was uncertainty regarding accurately diagnosing the inpatient COVID 19 admissions during the early pandemic. We have reviewed the literature and came across a Canadian study reviewing the admissions between March 1, 2020 to February 28, 2021 and has shown that U07.1 & U07.3 has PPV of 92.9% in accurately identifying the inpatient and ER admissions with COVID 19 [29].

There were 148916 patient admissions with COVID-19 using above mentioned ICD codes out of which 17 patients had age 18 or less than 18, and we used 148899 patient admissions for analysis. We have used I46.2, I46.8, I46.9 codes for identifying the cardiac arrest. Out of 148899, 6703 patients were found to have cardiac arrest, and 5783 died.

Study outcome: The primary objective is to find a correlation between end-organ dysfunction and co-morbidities with cardiac arrest from COVID-19 in heart failure patients. The secondary objectives are to evaluate the cardiac arrest and mortality percentage with respect to age groups, time on mechanical ventilator, and total length of stay among various groups.

Statistical analysis

Categorical data are represented by numbers and percentages. Continuous variables are expressed as means with S.D.s or medians and inter-quartile ranges. For each analysis, the null hypothesis was evaluated at a 2-sided significance level of 0.05 and calculated 95% C.I.s using standard errors. The statistical significance of the model was determined by Chi-Square and $p < 0.05$, suggesting that it could distinguish between patients with cardiac arrest and non cardiac arrest patients. Binary Logistic Regression was used to examine whether predictors were associated with the likelihood of having cardiac arrest among COVID 19 patients. We have used SAS 9.4 and SPSS statistics-28 for the analysis.

Results

Total 148899 patients were found to be admitted to hospitals with COVID-19. 6703 patients had cardiac arrest and 5783 died during the hospitalization. Incidence of Cardiac arrest was 4.5% consistent with previous studies reporting the incidence of cardiac arrest ranging between of 3% to 7% as discussed above [7,8].

Mechanical Ventilator use was found to be the most significant determinant for cardiac arrest with an odd ratio of 14.443 (Confidence Interval 13.67-15.26) & P value

(<.001), followed by septic shock with an odd ratio of 5.62 (Confidence Interval 5.34-5.92) & P value (<.001).

Spontaneous tension pneumothorax has an odd ratio of 4.92 (Confidence Interval 3.82-6.34) & P value (<.001). Acute renal failure has an odd ratio of 2.45 (CI 2.32-2.57) & P value (<.001).

Sepsis has an odd ratio of 2.27(CI 2.11-2.44) & P value (<.001), Complete heart block has an odd ratio of 1.90 (CI 1.55-2.33) & P value (<.001). ESRD has an odd ratio of 1.59 (CI 1.49-1.71) & P value (<.001), followed by acute pulmonary embolism with an odd ratio of 1.53 (CI 1.35-1.73) & P value (<.001).

Type 2 MI with an odd ratio of 1.50(1.37-1.63) & P value (<.001). Diabetes Mellitus is associated with an increased risk of cardiac arrest and an odd ratio of 1.29(CI 1.23-1.36) & P value(<0.001). Atrial fibrillation with an odd ratio of 1.13 (CI 1.08-1.19) & P value (<.001). These results have been shown in the Table 1.

We have reported the mortality & cardiac arrest distribution across the age groups among COVID-19 patients. There is 57.14% mortality in the age group between 19-29, 70.11% for 30-39, 73.98% for the age group 40-49 with a steady increase in mortality with 50-59 reporting 80.39%, 60-69 reporting 83.19%,70-79 reporting 88.70%, 80-89 reporting 90.92% and 90-99 reporting 94.55% mortality among cardiac arrest patients with Acute COVID 19. These results have been shown in Table 2 and Figure 1

Mechanical ventilator uses duration and mortality percentage has a direct correlation with mechanical vent hours with (< 24 hours) use, reported a 17.07% cardiac arrest and 15.79% mortality and increased to 20.68% cardiac arrest and 22.65% mortality with 24-96 hours of mechanical ventilator use. Patients on mechanical ventilators for more than 96 hours have 33.09% cardiac arrest and 30.75% mortality. Results have been shown in the Table 3 and Figure 2 as well.

Table 1: Binary Logistic Regression and odd ratio for the Cardiac Arrest vs Non Cardiac Arrest Patients with COVID 19.

Variable	B	S.E.	DF	P-value	OR	95% CI
Atrial fibrillation	0.124	0.026	1	<0.001	1.132	1.076-1.192
Acute Pulmonary Embolism	0.423	0.064	1	<0.001	1.526	1.347-1.729
Spontaneous Tension Pneumothorax	1.593	0.13	1	<0.001	4.92	3.816-6.343
Sepsis	0.82	0.037	1	<0.001	2.27	2.113-2.439

Table 2: Age Group Distribution by Cardiac Arrest and Mortality.

Mechanical Ventilator	2.67	0.028	1	<0.001	14.443	13.673-15.257
Type 2 MI	0.402	0.044	1	<0.001	1.495	1.371-1.631
Acute Renal Failure	0.895	0.026	1	<0.001	2.446	2.323-2.577
Septic Shock	1.727	0.026	1	<0.001	5.622	5.343-5.917
ESRD	0.466	0.035	1	<0.001	1.593	1.486-1.708
Complete Heart Block	0.642	0.105	1	<0.001	1.899	1.547-2.331
DM	0.255	0.026	1	<0.001	1.29	1.227-1.357

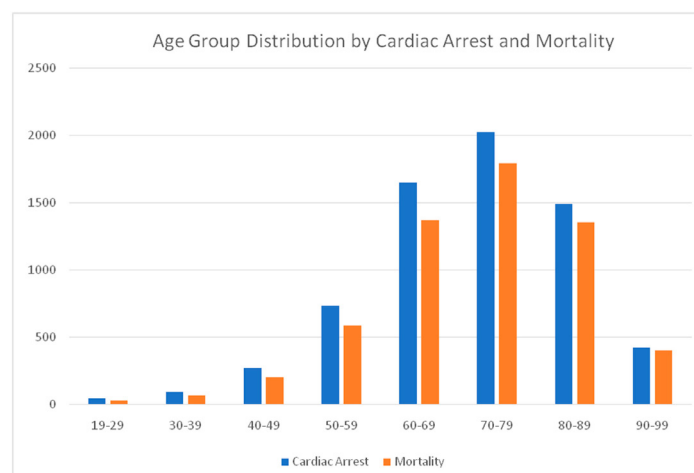


Figure 1: Cardiac Arrest & Mortality Distribution Across the Age Groups.

Incidence of Cardiac arrest has impacted the length of stay for patients as well with 13.47 days vs 10.25 days. We have shown the frequency distribution of all the co-morbidities among cardiac arrest patients in Figure 3.

Table 3: Frequency distribution of Cardiac Arrest and Mortality with respect to time on Mechanical Ventilator.

Mechanical Vent Hours	Cardiac Arrest (N= 6703) Frequency (Percent)	Mortality (N = 5783) Frequency (Percent)
<24	1144 (17.07)	913 (15.79)
24-96	1386 (20.68)	1310 (22.65)
>96	2218 (33.09)	1778 (30.75)

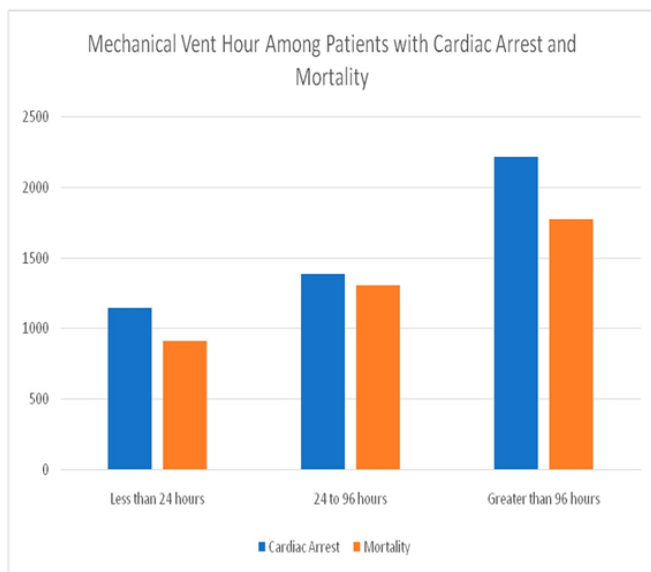


Figure 2: Mechanical Ventilator Use & Incidence of Cardiac Arrest & Mortality.

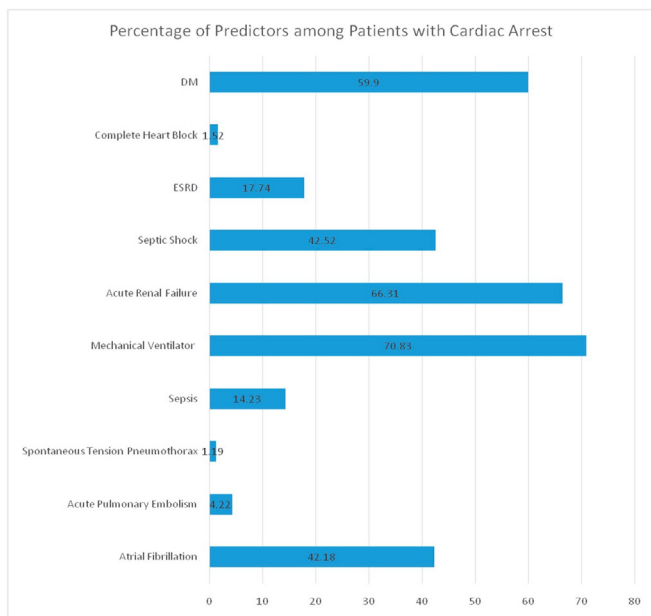


Figure 3: Predictors Distribution in the Population with Cardiac Arrest.

Discussion

In our study, we have tried to reveal the correlation and relevance of the following clinical variables in determining the impact on cardiac arrest, although no prior studies have been done to establish the causal relationship of these clinical predictors with cardiac arrest among COVID 19 and heart failure.

Mechanical ventilator and cardiac arrest

Critically ill COVID-19 patients have severe lung parenchyma injuries requiring mechanical ventilator support. Hypoxia and hypercapnia are well-known risk factors for cardiac arrest. Hypoxic cardiac arrest patients usually have poor outcomes [30]. Hypoxia has a detrimental impact on cardiac function and can lead to sodium-potassium (Na⁺/K⁺) ATP ase dysfunction and mitochondrial damage triggering energy failure and cell apoptosis [31].

In one of the rare studies done to understand peri mortem pathophysiology and co-correlation of hypoxia and cardiac arrest, it was found that after reaching threshold hypoxia, blood pressure starts falling almost 8 minutes prior to arrest, followed by a drop in heart rate 4 minutes prior to terminal circulatory arrest [32]. Suggesting the critical role of hypoxia in cardiac arrest.

Hypercapnia reduces the sensitivity of adrenergic receptors and adversely affects the expression of these receptors. Hypercapnia can induce metabolic acidosis, which can depress the cardiac contractility and response of the left ventricle to catecholamine [33]. In the literature, so far, no clear causal mechanism has been discovered to explain cardiac arrest among ventilated patients with COVID-19, but hypoxia and hypercapnia can partly explain the possible mechanism of cardiac arrest. In our sub-analysis, the mortality has been shown to worsen with a longer mechanical ventilator duration.

Pulmonary embolism and cardiac arrest

Venous thromboembolism, including pulmonary embolism, leads to significant morbidity and mortality in COVID-19 patients. This may be due to a combination of a hypercoagulable state due to epitheliopathy and a hyper-inflammatory state due to cytokine storm, which leads to venous and arterial thrombosis [34]. COVID-19 patients have a seven times higher risk of pulmonary embolism than non-COVID patients. Pulmonary embolism is seen in 2.6-8.9% of hospitalized COVID-19 patients, with one-third of them requiring intensive care unit admission, despite thromboprophylaxis use [35].

A propensity-matched analysis of the National Inpatient Sample (N.I.S.) database from 2020 showed COVID-19 patients with pulmonary embolism needed more vasopressor, mechanical ventilation, longer hospital stays, and higher in-hospital mortality when compared to COVID-19 patients

without pulmonary embolism[36]. In anecdotal cases, acute pulmonary embolism has been seen in young asymptomatic females with COVID-19 presenting as sudden death [37]. Pulmonary embolism is also reported as a sequela of long COVID-19, presenting as paroxysmal supra-ventricular tachycardia followed by cardiac arrest in a 31-year-old lady [38].

Type 2 MI in COVID-19 and cardiac arrest

Incidence of Type 2 MI incidence has been relatively high among COVID-19 patients, and a study based on a Nationwide inpatient sample database concluded that T 2MI had higher in-hospital mortality with an odds ratio of 1.4, sudden cardiac arrest with an odd ratio of 1.3 and cardiogenic shock with an odd ratio of 2.16 compared to one without T2MI in COVID 19 patients [39]. Type 2 MI in various analyses has shown poor outcomes in the long term. A prospective study with follow-up for 1. 8 years reported In-hospital mortality of 10% and 30% all-cause mortality for Type 2 MI [40]. In a multicenter study on COVID-19, myocardial injury was associated with a 2.31 times higher risk of mortality, although after adjusting for age, multi-organ dysfunction, and vasopressor requirement, the association was attenuated [41].

Spontaneous tension pneumothorax, COVID-19 and cardiac arrest

Critically ill COVID-19 patients require mechanical ventilation, and there is a high risk of tension pneumothorax. Tension pneumothorax can lead to compression of mediastinal structures, lung parenchyma, and a decrease in cardiac output, possibly by compression of great vessels, hypoxia, and poor venous return. It manifests clinically in the form of a progressive decrease in Spo2 and reduction in cardiac output, which can precipitate cardiac arrest [42]. In the retrospective investigation of 21 COVID patients, there is (42.9%) mortality rate among patients with spontaneous tension pneumothorax [43].

Sepsis and septic shock, COVID-19 and cardiac arrest

Sepsis is one of the leading causes of death in critically ill patients [44]. In a large meta-analysis based on 170 studies across North America, Europe, and Australia, septic shock has a mortality of 34.7% over 30 days time period [45]. The most common cause of cardiac arrest includes pulseless electrical cardiac activity triggered by hypoxemia, hypovolemia, hypokalemia, hyperkalemia, and acidosis, which can occur concomitantly with sepsis [46]. Finally, Altered cardiac contractility and pre and after-load changes can induce pulseless electrical activity [47].

In a retrospective analysis of 30 patients with COVID-19 septic shock, the mortality rate was reported to be 96.7% [48], whereas another study reported in the European Heart Journal reported a mortality rate of 56% among septic shock

patients and 4.44% among sepsis patients with COVID- 19 [49]. Multiple co-morbidities and end-organ dysfunction impact cardiac arrest. Acute Respiratory failure with an odd ratio of 2.96, G.I. bleeding with a ratio of 1.26, RCRI index of 1.07, and male gender with a ratio of 1.32 are significant determinants of In hospital cardiac arrest with sepsis noticed in a retrospective study [50].

Diabetes mellitus, COVID-19 and cardiac arrest

A large meta-analysis of 18 studies to evaluate the impact of D.M. on COVID-19 severity and mortality reported 2.5 fold increase in mortality among diabetic patients [51]. There are limited studies in the literature elucidating the pathophysiological impact of diabetes mellitus on COVID-19. Hyperglycemia can lead to increase SARS-CoV 2 replication, and glycolysis sustains this replication [52]. Endothelial damage by inflammation, glucotoxicity, and accelerated atherosclerosis can contribute to an increased risk of thromboembolic complications impacting the end organs in patients with diabetes and contribute to adverse outcomes [53]. In a retrospective analysis of more than 10000 hospital cardiac arrest patients, the higher non-shock-able rhythm was reported in diabetic patients compared to the rest of the cohort, and poor survival to discharge independent of other risk factors [54].

Renal dysfunction, COVID-19, and cardiac arrest

CKD, ESRD, and A.K.I. have been found to have a significant impact on mortality among COVID-19 in various studies. In a retrospective administrative data set based on 17 million patients, a hazard ratio of 3.7 was reported for haemodialysis(H.D.) patients and 2.5 for CKD 4 patients and were among the top four co-morbidities with the highest mortality from COVID-19 [55]. In a large meta-analysis of 69 reviews and 66 primary studies, the pooled hazard ratio of mortality for the CKD 3 stage is 1.46, the hazard ratio of 2.84 for CKD 4, and the hazard ratio of 1.92 for ESRD patients on the H.D. among COVID-19 [56].

The pathophysiology of the impact of COVID on renal function is still under investigation. Renal parenchyma cells, especially proximal tubular cells, express high levels of A.C.E. 2 receptors promoting the entry of SARS-CoV- 2 viral particles [57]. In a study on 62 patients with COVID-19, all the patients were found to be tested positive for SARS-CoV-2 in the kidney specimens. It was detected in tubular cells and podocytes, and cells infected with viral R.N.A. had increased expression of genes involved in inflammation, injury, and fibrosis [58]. The systemic impact of volume depletion, cytokine-induced systemic inflammatory response, and downstream consequences of infection, including rhabdomyolysis, ischemic thrombi, inflammation, complement dysregulation, and hemodynamic instability, may contribute towards the end organ dysfunction and mortality [59].

Complete heart block, COVID-19, and cardiac arrest

Cardiac arrhythmias are frequently seen in severe coronavirus disease 2019 (COVID-19). Some studies have cited arrhythmias occurring in up to 44% of patients and bradycardia (sinus bradycardia and A.V. block) occurring in up to 24.9% of patients [60,61]. There are several anecdotal records of patients who have a sudden cardiac arrest from pulse-less electrical activity or complete heart block while being either evaluated for or treated for COVID-19 infection.

In certain case reports, the complete heart block was transient and recovered within 24-48 hours [61]. On the other hand, there are several case reports where the complete heart block resulted in C.P.R.; eventually, the rhythm converted to ventricular fibrillation (V.F.) needing cardio-version, which was mostly unsuccessful [62]. The duration and consequences of atrioventricular (A.V.) nodal blockade were not consistent among the cases reported, analogous to most pathologies involving a spectrum of diseases.

In the literature so far, no clear causal mechanism has been discovered for the development of C.H.B. associated with this virus. Complete A.V. block can be caused by increased vagal tone, cardiac conduction system disease (fibrosis), ischemia and local inflammation, cardiomyopathies, or viral myocarditis. Some reversible causes can be hyperkalemia, thyroid disease, or medications used in the treatment of COVID. It has been suggested that direct viral infiltration of cardiomyocytes through the angiotensin-converting enzyme-2 receptors and subsequent systemic inflammation may be one mechanism of cardiac injury [60].

Atrial fibrillation, COVID-19, and cardiac arrest

Atrial fibrillation is the most common cardiac arrhythmia among COVID-19 patients. It was found that the incidence of New-onset atrial fibrillation (AFib) was 1 in 20 among patients hospitalized with COVID-19 [63]. Using data from the American Heart Association's COVID-19 Cardiovascular Disease Registry, researchers examined nearly 28,000 patients without a history of A Fib who were hospitalized for COVID-19. In this study, new-onset A Fib was strongly associated with increased in-hospital mortality and major adverse cardiovascular events. They also had longer hospital stays and a greater need for I.C.U. Care and intubation. Also of note, approximately 45% died in the hospital.

Limitation of the Study

It is based on administrative data base with limitations due to the nature of study including but not limited to accuracy and completeness of data entered by professionals with limited medical knowledge. Multivariate analysis has been done but confounding factors cannot be completely eliminated. In order to include all the heart failure admissions, we have used all the ICD 10 codes, but has led to inclusion of stable chronic

heart failure diagnoses and patients with recovered ejection fraction as well without exacerbation, which may have led to dilution of severity and its impact on COVID 19 patients. We do not have access to verify the accuracy, evaluate the NYHA class of heart failure and lab values which can influence the mortality and outcome. Despite these limitations, it is one of the largest studies to evaluate the predictors of cardiac arrest among COVID 19 patients.

Conclusions

In this observational study, we have concluded that the use of a mechanical ventilator, a reflector of the severity of the disease, is the strongest risk factor for cardiac arrest, followed by septic shock among COVID-19 patients with history of heart failure. Future prospective studies in critically ill patients can advance our knowledge and address these risk factors for improving mortality.

Funding: This research received no external funding.

Institutional Review Board Statement: It is an administrative data set without identifiable patient information.

Informed Consent Statement: It is an administrative data set without identifiable patient information.

Data Availability Statement: The data that support the findings of this study are available from NRD 2020, but restrictions apply to the availability of the raw data in compliance with NRD policies.

Conflicts of Interest: All the authors declare that they have no competing interests.

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