Nonelective coronary artery bypass graft outcomes are adversely impacted by Coronavirus disease 2019 infection, but not altered processes of care: A National COVID Cohort Collaborative and National Surgery Quality Improvement Program analysis

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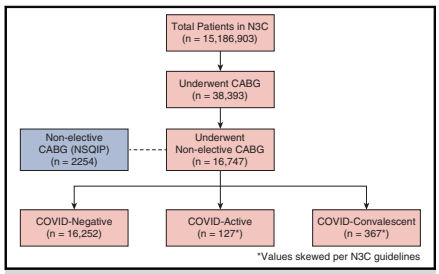
ABSTRACT

Objective: The effects of Coronavirus disease 2019 (COVID-19) infection and altered processes of care on nonelective coronary artery bypass grafting (CABG) outcomes remain unknown. We hypothesized that patients with COVID-19 infection would have longer hospital lengths of stay and greater mortality compared with COVID-negative patients, but that these outcomes would not differ between COVID-negative and pre-COVID controls.

Methods: The National COVID Cohort Collaborative 2020-2022 was queried for adult patients undergoing CABG. Patients were divided into COVID-negative, COVID-active, and COVID-convalescent groups. Pre-COVID control patients were drawn from the National Surgical Quality Improvement Program database. Adjusted analysis of the 3 COVID groups was performed via generalized linear models.

Results: A total of 17,293 patients underwent nonelective CABG, including 16,252 COVID-negative, 127 COVID-active, 367 COVID-convalescent, and 2254 pre-COVID patients. Compared to pre-COVID patients, COVID-negative patients had no difference in mortality, whereas COVID-active patients experienced increased mortality. Mortality and pneumonia were higher in COVID-active patients compared to COVID-negative and COVID-convalescent patients. Adjusted analysis demonstrated that COVID-active patients had higher in-hospital mortality, 30- and 90-day mortality, and pneumonia compared to COVID-negative patients. COVID-convalescent patients had a shorter length of stay but a higher rate of renal impairment.

Conclusions: Traditional care processes were altered during the COVID-19 pandemic. Our data show that nonelective CABG in patients with active COVID-19 is associated with significantly increased rates of mortality and pneumonia. The equivalent mortality in COVID-negative and pre-COVID patients suggests that pandemic-associated changes in processes of care did not impact CABG outcomes. Additional research into optimal timing of CABG after COVID infection is warranted. (JTCVS Open 2023;16:342-52)



Patient selection criteria from the N3C and NSQIP datasets.

CENTRAL MESSAGE

Altered processes of care during the COVID-19 pandemic did not worsen outcomes for COVID-negative patients. However, CABG in COVID-active patients is associated with significantly increased mortality.

PERSPECTIVE

Little is known about cardiac surgical outcomes during the COVID-19 pandemic. We found increased mortality for COVID-active patients, but not for COVID-convalescent patients. Additional work is needed to determine optimal timing of CABG after acute COVID-19 infection.

See Discussion on page 353.

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Abbreviations and Acronyms

CABG = coronary artery bypass graft
CI = confidence interval
COVID-19 = Coronavirus disease 2019
COVID-conv = COVID convalescent
CVA = cerebrovascular accident
EM = estimated means
LOS = length of stay
N3C = National COVID Cohort Collaborative
NCATS = National Center for Advancing Translational Sciences
NSQIP = National Surgery Quality Improvement Program
OR = odds ratio
STROBE = Strengthening the Reporting of Observational studies in Epidemiology

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The Coronavirus disease 2019 (COVID-19) pandemic significantly impacted healthcare delivery and care processes worldwide. Emergency rooms and hospitals were inundated with patients, forcing reallocation of resources away from some hospital operations, particularly elective surgery.[1-3] The National Health Service introduced provisional changes that reduced surgical and endoscopic activity and promoted only essential emergency procedures.[3-5] These changes were implemented to reduce viral nosocomial transmission, preserve supplies of personal protective equipment, make room for extra patient beds in wards and critical care units, and even allow the repurposing of surgical theatres into makeshift intensive care units.[2,3,6] Additionally, surgeons and their teams were relocated to support understaffed areas of the hospital.[3] As a result, access to surgical care was limited, likely with negative impacts to patients and global healthcare systems.[7]

The resulting changes in surgical volume and outcomes during the pandemic remain mixed. Although some studies reported minimal changes in complication rates during the pandemic, other studies found increased 30-day mortality despite decreased daily admissions.[5,8] Comparing the pandemic time frame to pre-COVID controls, D'Urbano and colleagues[1] found a 41.3% reduction in the number of patients who underwent emergency surgery but increased rates of surgical complications during this period. In the realm of cardiac surgery, most of the literature reports no significant pandemic changes in surgical outcomes[9]; however, although recent research has evaluated the impact of the COVID-19 pandemic on various surgical procedures, the postoperative outcomes of nonelective coronary artery bypass grafting (CABG) has yet to be studied. Specifically, clinical outcomes associated with active viral infection, viral convalescence, and altered care processes are unknown.

We hypothesized that patients with COVID-19 infection would have longer hospital lengths of stay and higher mortality compared with COVID-negative patients, but that these outcomes would not differ between COVID-negative and pre-COVID controls.

METHODS

The National COVID Cohort Collaborative (N3C) within the National Center for Advancing Translational Sciences (NCATS) and the National Institutes of Health (NIH) is a large-scale, national, centralized database that aggregates electronic health record data for all patients tested for COVID-19 from multiple health systems across the United States. It contains deidentified patient-level data for more than 19 million total patients and more than 6 million COVID-positive patients. The N3C Data Enclave provides a centralized repository that systematically collects data from participating institutions and harmonizes these data to allow for collaborative research.

This study was approved by the local Institutional Review Board (STUDY003656; approved January 24, 2022) as N3C project ID RP-75E880. The N3C Publication Committee confirmed that this manuscript is in accordance with N3C data use and attribution policies; however, the content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or the N3C program. The analyses reported herein were conducted using the NCATS N3C Data Enclave supported by NCATS U24 TR002306 and made possible because of the patients whose data was contributed by partner organizations (covid.cd2h.org/dtas). We gratefully acknowledge the scientists who have contributed to the ongoing development of this community resource (covid.cd2h.org/acknowledgements). This study is reported following the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) guideline and CHAMP (Checklist for statistical Assessment of Medical Papers) statement. To comply with N3C guidelines, any outcome measure for which the number of patients was <20 was blinded, and to prevent back-calculation, at times counts were skewed by up to 5. All analyses were performed with the nonskewed counts. Skewed counts are denoted by ¥ in text and tables.

Effects of COVID-19 Infection

Adult patients (age ≥18 years) who underwent coronary artery bypass surgery under a nonelective scenario (see Table E1 for included OMOP-CDM concepts) were queried from the N3C enclave using level 3 data from 2020 to 2022. Patients defined as "nonelective" included those who were admitted through the emergency room or were admitted to the hospital and then subsequently underwent CABG during the same admission. We excluded scheduled elective patients whose inpatient encounter began with surgery, as well as those scheduled as an outpatient encounter. Patients were defined as COVID-negative if their COVID test on admission was negative, as COVID-active if they had a positive test ≤2 weeks before their CABG, and as COVID-convalescent (COVID-conv) if they had a positive test >2 weeks before their CABG. The COVID-active and COVID-conv time frames were based on the 2022 Guidance Statement by the Society for Thoracic Surgeons for surgical timing in patients with COVID-19.[10]

Primary outcomes were hospital length of stay (LOS), in-hospital mortality, and 30- and 90-day postoperative mortality. Secondary outcomes

included 30- and 90-day individual complications including renal impairment, infection, cerebrovascular accident (CVA), post-operative bleeding, and pneumonia. In addition, we tabulated the yearly in-hospital and 30-day mortality for patients of each COVID status to evaluate the trend in mortality over time.

Exploratory analysis was undertaken by visually exploring all variables to evaluate for frequency, percentage, near-zero variance (for categorical variables), distribution (for numeric variables), and corresponding missing value patterns. Missing data from N3C are noted in Table 1 next to each variable name [# missing] and were not imputed for unadjusted results. For multivariable adjusted analysis, missing data for age, sex, race, and Q-score were imputed. Imputation was via fully conditional specification, where each incomplete variable was imputed by a separate multivariable model.[11] A subsequent sensitivity analysis was undertaken to compare results of models with and without imputed data. Univariable analysis was performed with the t test or χ^2 test with pairwise comparison or analysis of variance with the Tukey post hoc test, as applicable; P values $< .05$ were considered statistically significant. Bonferroni adjustment was used when performing multiple comparisons, to control for the risk of false-positive findings. Specifically, we used a conservative Bonferroni correction, in which the new significance level is obtained by dividing 0.05 by the number of tests performed.[12]

Adjusted analysis via generalized linear models with binomial distribution family (logistic regression) for dichotomous outcomes was performed for the COVID-negative (referent group), COVID-active, and COVID-conv groups. As an outcome variable, LOS was categorized as less than or greater than median. We chose possible confounders using a combination of clinical judgment and literature-based evidence, as these joint criteria have been shown to perform better than separately selecting clinical or evidence-based variables.[13] Specifically, each outcome was adjusted for age,[14-16] sex,[15,17,18] race,[15,18-20] and Quan-Charlson Comorbidity Index,[2,18,21] based on supporting literature. Results are reported as odds ratios (ORs) with 95% confidence interval (CIs). Data gathering and cleaning were performed in the N3C Enclave, and all analyses were performed using R.[22]

Effects of COVID-19 Pandemic

Pre-COVID controls were compared with the established N3C COVID-negative patients to determine the effect of the altered care processes seen during the COVID-19 pandemic. The American College of Surgeons National Surgical Quality Improvement Project (NSQIP) database from 2016 to 2018 was queried for adult patients who also underwent nonelective CABG (see Table E1 for Current Procedural Terminology codes) to create a pre-COVID control group. Nonelective was defined as the elective surgery variable being "no;" patients were excluded if elective surgery was "unknown" or "yes." Additionally, patients were excluded whose visit was denoted as "outpatient." Exploratory analysis was undertaken by visually exploring all variables to evaluate for frequency, percentage, near-zero variance (for categorical variables), distribution (for numerical variables), and corresponding missing value patterns. There were no missing data values from the NSQIP. Univariable analysis was performed with the t test or χ^2 test with pairwise comparison or ANOVA with Tukey's post-hoc test, as applicable; P values $< .05$ were considered statistically significant.

Primary outcomes were LOS, in-hospital mortality, and 30-day mortality. Ninety-day mortality could not be obtained for the pre-COVID group owing to database limitations. Additionally, individual complication rates could not be compared between pre-COVID and COVID groups, because of database differences between the N3C and NSQIP.

RESULTS

A total of 15,186,903 patients were available for review in the N3C. Patients who did not meet CABG inclusion criteria (n = 15,148,510), did not meet inpatient-type visit criteria (n = 14,597), did not meet criteria of 1 of the 3 defined COVID-19 groups (n = 7040), or were age <18 years (n = 9) were excluded. A total of 17,293 patients were identified as having undergone urgent or emergent CABG and were included in our analysis. The N3C cohort included 16,747 patients: 16,252 COVID-negative, 127¥ COVID-active, and 367¥ COVID-conv. A total of 2254 patients were included from the NSQIP pre-COVID control group (Figure 1). Baseline patient characteristics are reported in Table 1. There were no differences among the groups with respect to age or sex. There were more white patients in the pre-COVID group and more black patients in the COVID groups ($P < .01$). Each COVID group had a significantly different distribution of Q-scores (all $P \leq .01$).

Effect of COVID-19 Infection

There was no difference in LOS between the COVID-active group (mean, 11.60 ± 12.10 days) and other COVID groups. Active COVID patients had higher in-hospital and 30-day mortality compared with all other groups ($P < .01$ for all comparisons).

Among the COVID groups, COVID-active patients experienced higher in-hospital, 30- and 90-day mortality than COVID-negative and COVID-conv cohorts ($P < .01$). COVID-active patients had higher rates of 30- and 90-day postoperative pneumonia compared to COVID-negative patients ($P < .01$), whereas COVID-conv patients experienced higher rates of 30- and 90-day postoperative renal impairment compared to COVID-negative and COVID-active patients ($P < .05$). There were no differences between COVID groups in the incidences of 30- and 90-day postoperative wound infection or cerebrovascular accident (Table 1).

Adjusted analysis between COVID groups using COVID-negative as the reference group demonstrated that COVID-active patients had higher in-hospital, 30-day, and 90-day pneumonia rates but no differences in LOS, renal impairment, or cardiovascular events. Compared with COVID-negative patients, COVID-conv patients experienced shorter LOS and higher rates of 30-day and 90-day renal impairment but no differences in mortality, stroke, or pneumonia (Table 2). Sensitivity analysis comparing models with and without imputed data did not differ significantly.

When examined year-by-year, in-hospital and 30-day mortality were higher during 2020 and 2021 compared with 2022 for each COVID status category. For COVID-negative patients, mortality was approximately the same during 2020 and 2021 but were decreased in 2022. Mortality rates for the COVID-active and COVID-conv groups were too low to report individually per year. For COVID-active patients, both in-hospital and 30-day mortality were highest in 2020 and lowest in 2022. For COVID-conv patients, mortality rates were highest in 2021 and lowest in 2022.

TABLE 1. Baseline cohort demographics and patient characteristics

Variable [no. missing]	Pre-COVID (N = 2254)	COVID-negative (N = 16,252)	COVID-active (N = 127¥)	COVID-conv (N = 367¥)	*P* value
Age, y, mean ± SD [1008]	64.75 ± 10.20	65.20 ± 10.65	64.33 ± 10.00	64.90 ± 10.63	.29
Sex, n (%) [7]					.75
Male	1742 (77.3)	12,410 (76.4)	98 (78.4)	285 (77.0)	
Female	512 (22.7)	3835 (23.6)	29¥ (21.6)	82¥ (23.0)	
Race, n (%) [1700]					<.01
White	1893 (84.0)	12,330 (84.5)	80 (80.0)	292 (84.1)	
Black	160 (7.1)	1507 (10.3)	<20	40 (11.5)	
Asian	84 (3.7)	526 (3.6)	<20	<20	
Other	117 (5.2)	237 (1.6)	<20	<20	
Ethnicity, n (%) [1879]					<.01
Hispanic	316 (14.0)	1020 (7.1)	<20	24 (7.1)	
Not Hispanic	1938 (86.0)	13,398 (92.9)	102 (91.1)	314 (92.9)	
Quan CCI, n (%)					<.01
0	NA	8081 (49.7)	79 (63.2)	128 (34.6)	
1-2	NA	4488 (27.6)	27 (21.6)	121 (32.7)	
3-15	NA	36,834 (22.7)	<20	121 (32.7)	
Comorbidities, n (%)					
Myocardial infarction	NA	3514 (21.6)	22 (17.6)	121 (32.7)*	<.01
Congestive heart failure	NA	3844 (23.7)	20 (16.0)	124 (33.5)*	<.01
PVD	NA	3622 (22.3)	21 (16.8)	97 (26.2)	.07
Cerebrovascular disease	NA	3476 (21.4)	21 (16.8)	97 (26.2)	.05
Dementia	NA	119 (0.7)	<20	<20	.09
Chronic lung disease	NA	2597 (16.0)	<20	84 (22.7)*	<.01
Rheumatic disease	NA	650 (4.0)	<20	23 (6.2)	.07
Peptic ulcer disease	NA	267 (1.6)	<20	<20	.06
Mild liver disease	NA	923 (5.7)	<20	33 (8.9)†	.03
Severe liver disease	NA	147 (0.9)	<20	<20	.93
Uncomplicated diabetes	NA	5797 (35.7)	43 (34.4)	196 (53.0)*	<.01
Complicated diabetes	NA	3016 (18.6)	<20	103 (27.8)*	<.01
Hemiplcia/paraplegia	NA	154 (1.0)	<20	<20	.54
Renal disease	NA	2700 (16.6)	<20	92 (24.9)†	<.01
Any cancer	NA	1420 (8.7)	<20	40 (10.8)‡	.03
Metastatic cancer	NA	196 (1.2)	<20	<20	.89
LOS, d, mean ± SD[35]	11.44 ± 6.61§	9.76 ± 12.92	11.60 ± 12.10	8.59 ± 8.35	<.01
Death in hospital, n (%)	65 (2.9)	494 (3.0)	<20‖	<20	<.01
Death, 30 d, n (%)	75 (3.3)	600 (3.7)	<20‖	<20	<.01
Death, 90 d, n (%)	NA	695 (4.3)	<20¶	<20	<.01
Renal impairment, 30 d, n (%)	NA	1890 (11.6)	<20	64 (17.3)#	<.01
Renal impairment, 90 d, n (%)	NA	2601 (16)	24 (19.2)	78 (21.1)#	.02
Infection, 30 d, n (%)	NA	<20	<20	<20	.94
Infection, 90 d, n (%)	NA	<20	<20	<20	.89
CVA, 30 d, n (%)	NA	26 (0.2)	<20	<20	.67
CVA, 90 d, n (%)	NA	48 (0.3)	<20	<20	.83
Pneumonia, 30 d, n (%)	NA	273 (1.7)	<20#	<20	<.01
Pneumonia, 90 d, n (%)	NA	447 (2.8)	<20#	<20	<.01

Quan-CCI, Quan-Charlson Comorbidity Index; *NA*, not applicable; *PVD*, peripheral vascular disease; *LOS*, length of stay; *CVA*, cerebrovascular accident. ¥To comply with National COVID Cohort Collaborative guidelines, this cell number was skewed by up to 5 points. *$P = .01$ versus COVID-negative and COVID-active. †$P = .03$ versus COVID-negative. ‡$P < .05$ versus COVID-active. §$P < .01$ versus COVID-negative and COVID-convalescent (conv). ‖$P < .01$, COVID-active versus pre-COVID, COVID-negative, and COVID-conv. ¶$P < .02$ versus COVID-negative, COVID-conv. #$P < .01$ versus COVID-negative.

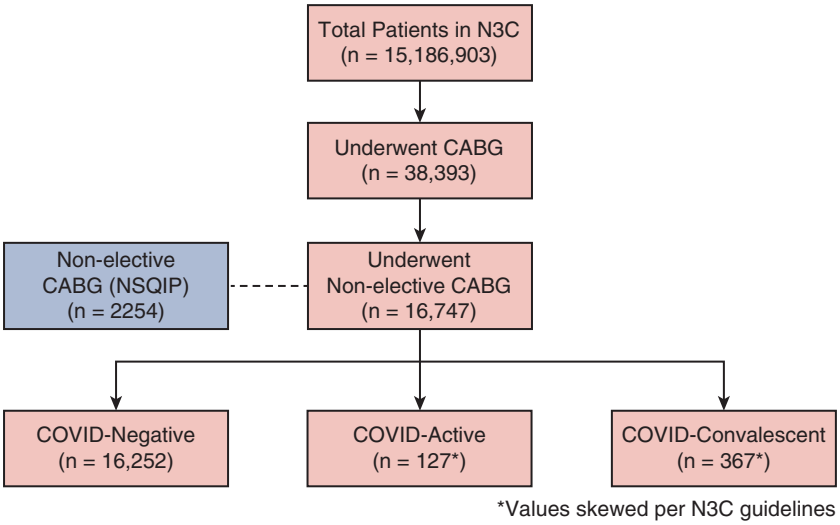


FIGURE 1. Patient selection criteria from the National COVID Cohort Collaborative (*N3C*) and National Surgery Quality Improvement Program (*NSQIP*) datasets. *CABG*, Coronary artery bypass grafting.

Effect of the COVID-19 Pandemic

Pre-COVID patients experienced significantly longer hospital LOS than COVID-negative ($P < .01$) and COVID-conv ($P < .01$) patients. There was no difference in in-hospital or 30-day mortality between the COVID-negative and pre-COVID groups (Table 1).

DISCUSSION

The COVID-19 pandemic significantly altered hospital processes of care and healthcare delivery in the United States. This retrospective cohort study sought to evaluate outcomes of patients undergoing CABG performed on an urgent or emergent basis before and during the COVID-19 pandemic using a large, nationally representative database. This study found no difference in mortality between COVID-negative and pre-COVID nonelective CABG patients, which suggests that changes in care processes during the pandemic did not negatively affect patient outcomes when CABG was performed nonelectively. However, mortality and complication rates were higher in COVID-active CABG patients, indicating that active COVID-19 infection contributes significantly to morbidity in patients requiring nonelective CABG. Additionally, postoperative renal impairment was significantly higher in the COVID-conv group compared with the COVID-negative group, suggesting that prolonged organ dysfunction may be a notable sequela of COVID-19 infection.

The COVID-19 pandemic has had a significant impact on hospital systems' abilities to perform elective surgical cases, schedule routine clinic visits, and provide the full breadth of care usually associated with inpatient hospital stays. These changes in care processes were initially necessary to appropriately triage and care for those affected by COVID-19, ensure adequate staffing and supply levels,

TABLE 2. Association between COVID-19 status and each outcome, adjusted for age, sex, Q-score, and race

Outcome	COVID-active, OR (95% CI)	*P* value	COVID-conv, OR (95% CI)	*P* value
Length of stay	1.38 (0.97-1.97)	.08	0.73 (0.59-0.90)	<.01
Death in hospital	4.27 (2.26-7.40)	<.01	0.84 (0.41-1.50)	.59
Death, 30 d	4.46 (2.51-7.43)	<.01	0.82 (0.43-1.40)	.50
Death, 90 d	4.44 (2.57-7.23)	<.01	0.82 (0.45-1.35)	.47
Renal impairment, 30 d	1.48 (0.91-2.32)	.10	1.39 (1.03-1.83)	.03
Renal impairment, 90 d	1.25 (0.78-1.92)	.33	1.20 (0.91-1.56)	.19
CVA, 30 d	0 (0-infinity)	.99	0 (0-infinity)	.99
CVA, 90 d	0 (0-infinity)	.99	0.93 (0.05-4.28)	.94
Pneumonia, 30 d	4.88 (2.27-9.21)	<.01	1.54 (0.76-2.78)	.18
Pneumonia, 90 d	4.07 (2.11, 7.15)	<.01	1.28 (0.71-2.13)	.37

COVID-negative is the referent group. Adjusted via generalized linear models based on age, sex, race, and Q-score. *COVID*, Coronavirus disease; *OR*, odds ratio; *CI*, confidence interval; *COVID-conv*, COVID-convalescent; *CVA*, cerebrovascular accident; *COVID-19*, Coronavirus disease 2019.

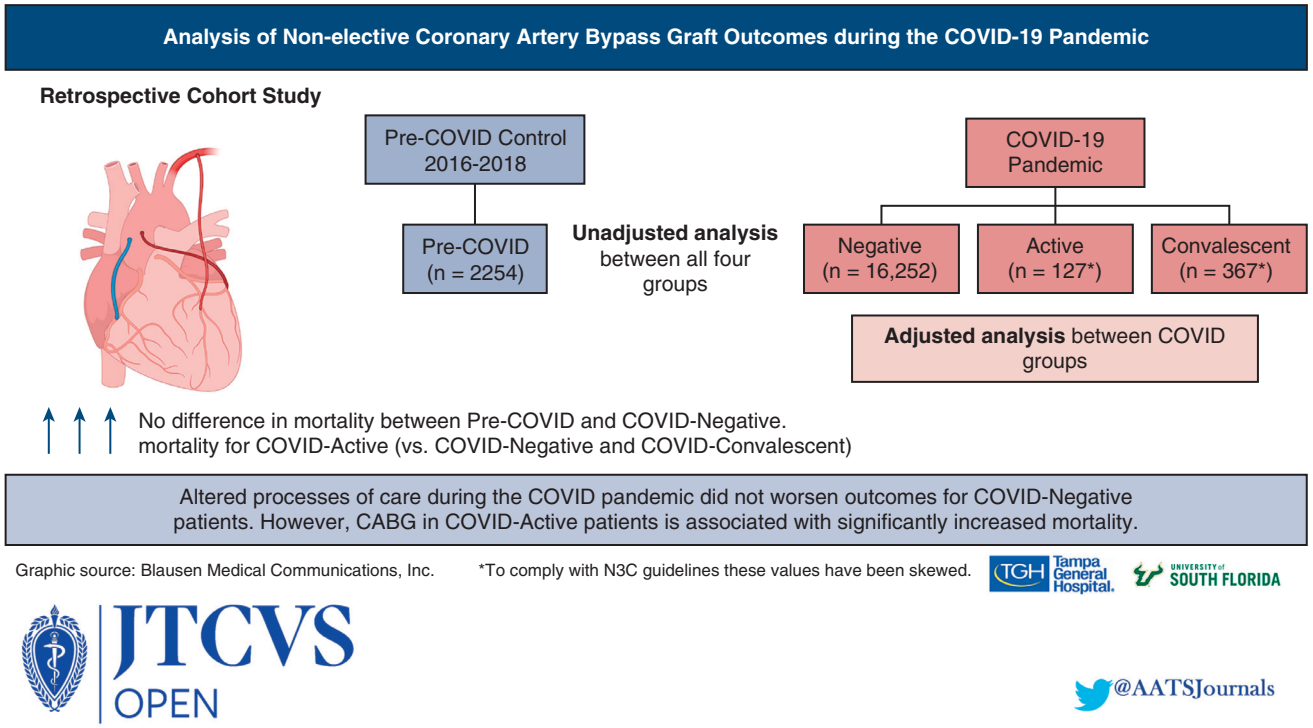


FIGURE 2. Analysis of nonelective coronary artery bypass grafting outcomes during the Coronavirus disease 2019 pandemic. *CABG*, Coronary artery bypass grafting.

and repurpose existing floors into intensive care units. Delay of elective surgical cases often resulted in postponement of operations for cancer resection and nonoperative management of pathology that otherwise would have been treated surgically.[3-5] In this study, the lack of difference in mortality for COVID-negative patients during the pandemic suggests that these significant changes in care processes experienced during the pandemic did not result in overtly worse mortality for patients undergoing nonelective CABG. This is in concordance with similar surgical literature regarding pandemic outcomes across elective surgical cases.[23-25] A review of CABG outcomes during the pandemic by Parcha and colleagues[26] suggested there was no increased risk of mortality during the pandemic for these patients compared with prepandemic controls, although the authors did not discern whether cases were performed on an emergent or an elective basis. These findings suggest that hospital systems and surgeons were able to maintain prepandemic standards of care during the pandemic despite significant institutional and process challenges to an extent so as to not result in increased mortality.

Patients with active COVID-19 infection undergoing nonelective CABG appear to have higher rates of mortality compared to COVID-negative CABG patients. This outcome is likely multifactorial and a combination of not only active COVID-19 infection and its sequela, but also confounders resulting from nonelective CABG procedures (eg, acute renal failure requiring dialysis in setting of active COVID-19 infection). Although there have been no large analyses of outcomes for active COVID-19 patients undergoing CABG, several small case series of patients with active COVID have reported higher rates of morbidity and mortality.[9,10,27-30] In agreement with this analysis, active COVID-19 infection in patients undergoing urgent or emergent surgical procedures appears to confer an increased risk of perioperative morbidity and mortality.[31-34] Indeed, Knisely and colleagues'[33] recent examination of COVID-19 patients demonstrated that those undergoing urgent and emergent surgical procedures were at increased risk of severe complications regardless of preoperative *American* Society of Anesthesiologists category, with a reported risk ratio for death in active COVID-19 patients of 55.00 for those undergoing urgent surgical procedures. These findings have been echoed by other large cohort analyses.[31,32,34] Nonelective coronary bypass in the setting of COVID-19 infection poses a unique challenge to cardiac surgeons not only for the inherent risks of an urgent or emergent procedure, but also for the confounder of a significant active respiratory illness. This study highlights the increased risks associated with nonelective CABG in COVID-19 active patients and suggests careful consideration should be given to the management of these patients to optimize outcomes. Crucially, it is imperative to follow recommended institutional safety protocols and guidelines to minimize the risk

of viral transmission to healthcare workers and other patients, particularly those recovering in the cardiac intensive care unit, while also providing timely care to those in need of urgent revascularization.

Although this study found no difference in the rate of postoperative renal impairment for COVID-active patients compared to COVID-negative patients, COVID-conv patients had higher rates of renal impairment at 30 days and 90 days postprocedure. The COVID-conv group was considered to represent those who had recently recovered from COVID. This interesting finding highlights the concern for lasting post–COVID infection sequelae. However, this finding is in contrast to other analyses, including Bhattacharya and colleagues'[35] review of patients who recovered from COVID-19 and underwent CABG, which did not find an increased rate of postoperative renal impairment. Notably, however, we were unable to control specifically for patients with preexisting renal disease. Given the a growing research interest in "long COVID" and its lasting effects, further investigation of this finding is indicated.

Despite the higher rate of renal impairment in COVID-conv patients, the mortality rate was not significantly different than that in COVID-negative patients, indicating that mortality risk returns to baseline if the COVID infection occurs >2 weeks before surgery. The case series of Bhattacharya and colleagues[35] examining urgent CABG for recent COVID-recovered patients had a mortality rate of 9% (1 of 11 patients); however, this sample likely is too small to allow extrapolation to the larger population. In this nationally representative sample, the COVID-conv mortality rate ranged from 2.7% in-hospital to 3.8% at 90 days postprocedure. Further research on COVID-recovered CABG outcomes is lacking at this time, and future work is needed to elucidate these trends.

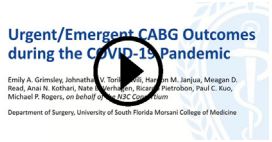
The COVID-19 pandemic has presented unique and unprecedented challenges to cardiac surgeons and hospital systems. Patients with active COVID-19 infection inherently have an elevated risk of morbidity and mortality, which can be further exacerbated by perioperative stress and the need for mechanical ventilation. Additionally, these patients often present in a proinflammatory state, with coagulopathy, and in respiratory distress, further complicating their perioperative course.[2] Moreover, the use of cardiopulmonary bypass during CABG can worsen this inflammatory process[36] and possibly ultimately lead to multiorgan dysfunction syndrome. The Society of Thoracic Surgeons supports guidance providing recommendations for the management of patients with active COVID-19 undergoing cardiac surgery that includes the use of personal protective equipment, careful preoperative optimization when able, and consideration for alternative surgical approaches.[10] The treatment of active COVID-19 patients requiring urgent/emergent CABG likely is best provided through a multidisciplinary approach, with input from infectious disease physicians, cardiac anesthesiologists, and cardiac critical care physicians to optimize patient outcomes while minimizing the risk of viral transmission to other patients and healthcare workers.

Several limitations of this study should be considered, including its retrospective nature and the inherent limitations of large-scale database work. There exists a lack of granularity with regard to variables available for selection, which can inherently lead to confounding. For example, postoperative surgical wound infection rates were very low in our COVID cohorts, likely due to the nature of database research; sometimes the anticipated data are not available. This can occur if the requisite diagnosis codes are not well utilized in the electronic medical record. Additionally, although N3C allows for determination of COVID status, it does not provide patient symptomatology at the time of diagnosis. Moreover, as the institutions contributing to the NSQIP and N3C databases vary, populations included in these databases may differ demographically, socially, and economically. Accordingly, adjusted analysis was used in an attempt to control for various factors, including age and comorbidity composite score, to ameliorate these differences. Additionally, comparison of certain outcomes between the pre-COVID and COVID groups was not possible owing to limitations of the NSQIP database and inherent differences in variable definitions between databases. During the pandemic, physicians and surgeons may have preferentially pursued percutaneous coronary intervention in favor of invasive CABG even in emergent scenarios because of constraints on their practice or hospitals. Alternatively, it is possible that more patients were categorized as nonelective to bypass elective surgery limitations during the pandemic, which may have influenced the larger number of nonelective CABG cases during the pandemic era. Accordingly, the criteria used in the decision to pursue CABG in the urgent/emergent setting might not have been uniform across all hospitals. The findings of this study further emphasize the need for prospective data collection with an increased level of detail for more precise results.

In conclusion, altered care processes during the COVID-19 pandemic did not appear to worsen clinical outcomes for COVID-negative patients undergoing nonelective CABG (Figure 2). However, active COVID-19 infection was associated with and likely contributed to increased morbidity and mortality. Although this analysis focused solely on urgent and emergent procedures, the finding of increased renal complications in patients recovering from COVID-19 further complicates the question of optimal surgical timing for COVID patients.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/emergency-cabg-outcomes-are-adversely-impacted-by-covid-infection-but-not-altered-processes-of-care-an-n3-c-and-nsqip-analysis.



Conflict of Interest Statement

The authors reported no conflicts of interest.

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Key Words: nonelective coronary artery bypass grafting, COVID-19, pandemic, outcomes

TABLE E1. Codes used to define the CABG procedure and COVID testing

Code	Description
CPT CABG	
33510	Coronary artery bypass, vein only; single coronary venous graft
33511	Coronary artery bypass, vein only; 2 coronary venous grafts
33512	Coronary artery bypass, vein only; 3 coronary venous grafts
33513	Coronary artery bypass, vein only; 4 coronary venous grafts
33514	Coronary artery bypass, vein only; 5 coronary venous grafts
33516	Coronary artery bypass, vein only; 6 or more coronary venous grafts
33533	Coronary artery bypass, using arterial graft(s); single arterial graft
33534	Coronary artery bypass, using arterial graft(s); 2 coronary arterial grafts
33535	Coronary artery bypass, using arterial graft(s); 3 coronary arterial grafts
33536	Coronary artery bypass, using arterial graft(s); 4 or more coronary arterial grafts
OMOP-CDM CABG	
4336464*	Coronary artery bypass graft
OMOP-CDM COVID test	
586526	SARS-CoV-2 (COVID-19) RNA [presence] in nasopharynx by NAA with probe detection
706156	SARS-CoV-2 (COVID-19) N gene [presence] in specimen by nucleic acid amplification using CDC primer-probe set N1
706158	SARS-CoV-2 (COVID-19) RNA panel: respiratory specimen by NAA with probe detection
706160	SARS-CoV-2 (COVID-19) RdRp gene [presence] in respiratory specimen by NAA with probe detection
706161	SARS-CoV-2 (COVID-19) N gene [presence] in respiratory specimen by NAA with probe detection
706163	SARS-CoV-2 (COVID-19) RNA [presence] in respiratory specimen by NAA with probe detection
706165	SARS-related coronavirus RNA [presence] in respiratory specimen by NAA with probe detection
706169	SARS-CoV-2 (COVID-19) RNA panel: specimen by NAA with probe detection
706170	SARS-CoV-2 (COVID-19) RNA [presence] in specimen by NAA with probe detection
706175	SARS-CoV-2 (COVID-19) N gene [presence] in specimen by NAA with probe detection
715272	SARS-CoV-2 (COVID-19) N gene [presence] in nasopharynx by NAA with probe detection
723476	SARS-CoV-2 (COVID-19) RNA [presence] in nasopharynx by NAA with non-probe detection
723477	SARS-CoV-2 (COVID-19) Ag [presence] in respiratory specimen by rapid immunoassay
723478	SARS-CoV-2 (COVID-19) ORF1ab region [presence] in respiratory specimen by NAA with probe detection
757685	SARS-CoV+SARS-CoV-2 (COVID-19) Ag [presence] in respiratory specimen by rapid immunoassay
586526	SARS-CoV-2 (COVID-19) RNA [presence] in nasopharynx by NAA with probe detection

CPT applies to NSQIP; OMOP-CDM applies to N3C. *CPT*, Current Procedural Terminology; *CABG*, coronary artery bypass grafting; *COVID*, Coronavirus disease 2019; *OMOP-CDM*, observational medical outcomes partnership common data mode; *SARS-CoV-2*, severe acute respiratory syndrome coronavirus 2; *NAA*, neutron activation analysis; *RNA*, ribonucleic acid; *RdRp*, RNA-dependent RNA polymerase. *Includes all descendent concepts except for 37111313 and 2617584.