Non-elective Coronary Artery Bypass Graft Outcomes are Adversely Impacted by COVID-19 Infection, but not Altered Processes of Care: An N3C and NSQIP Analysis

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Analysis of Non-elective Coronary Artery Bypass Graft Outcomes during the COVID-19 Pandemic

Retrospective Cohort Study

Pre-COVID Control 2016-2018

Pre-COVID (n=2,254) Unadjusted analysis between all four groups

COVID-19 Pandemic

Negative (n=16,252) Active (n=127*) Convalescent (n=367*) Adjusted analysis between COVID groups

No difference in mortality between Pre-COVID and COVID-Negative.

↑↑↑↑ mortality for COVID-Active (vs. COVID-Negative and COVID-Convalescent)

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

Graphic source: Blaesen Medical Communications, Inc.

*To comply with NSC guidelines these values have been skewed.
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Glossary of Abbreviations

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

Central Picture:
Patient selection criteria from N3C and NSQIP datasets.

Central Message
Altered processes of care during the COVID pandemic did not worsen outcomes for COVID-Negative patients. However, CABG in COVID-Active patients is associated with significantly increased mortality.

Perspective Statement
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.

**Objective**

The effects of COVID-19 infection and altered processes of care on non-elective coronary artery bypass graft (CABG) outcomes remains unknown. We hypothesized that COVID-19 infection would lead to longer lengths of stay and higher mortality when 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 controls were from the National Surgical Quality Improvement Program database. Adjusted analysis of the three COVID groups was performed via generalized linear models.

**Results**

In total, 17,293 patients underwent non-elective CABG (16,252 COVID-Negative, 127 COVID-Active, 367 COVID-Convalescent, and 2,254 Pre-COVID). Compared to Pre-COVID, there was no difference in mortality for COVID-Negative patients, whereas COVID-Active experienced increased mortality. Mortality, and pneumonia were higher in COVID-Active compared to COVID-Negative and COVID-Convalescent groups. Adjusted analysis demonstrated COVID-Active had higher in-hospital mortality, 30- and 90-day mortality, and pneumonia when compared to COVID-Negative patients. COVID-Convalescent patients had shorter length of stay, but higher renal impairment.
Conclusions

Traditional processes of care were altered during the COVID-19 pandemic. This study finds non-elective CABG in patients with active COVID-19 is associated with significantly increased mortality, and pneumonia. Equivalent mortality in COVID-Negative and Pre-COVID patients suggests pandemic-associated changes in processes of care did not impact CABG outcomes. Additional research into optimal timing of CABG after COVID infection is warranted.

Keywords

Non-elective Coronary artery bypass graft
COVID-19
Pandemic
Outcomes
Introduction

The COVID-19 pandemic significantly impacted healthcare delivery and processes of care around the world. Emergency rooms and hospitals were inundated with patients, forcing reallocation of resources away from certain hospital operations, particularly elective surgery.\textsuperscript{1-3} The National Health Service introduced provisional changes that reduced surgical and endoscopic activity and only promoted essential emergency procedures.\textsuperscript{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.\textsuperscript{2, 3, 6} Additionally, surgeons and their teams were relocated to support understaffed areas of the hospital.\textsuperscript{3} As a result, access to surgical care was limited, with likely negative impact to patients and global healthcare systems.\textsuperscript{7}

Resultant changes in surgical volume and outcomes during the pandemic remain mixed. While some studies report minimal changes in complication rates during the pandemic, other studies found despite decreased daily admissions, there was increased 30-day mortality.\textsuperscript{5, 8} Comparing the pandemic timeframe to pre-COVID controls, D’Urbano et al. found a 41.3% reduction in the number of patients who underwent emergency surgery, however, surgical complication rates during this time period increased.\textsuperscript{1} In the realm of cardiac surgery, most literature reports no significant pandemic changes in surgical outcomes.\textsuperscript{9} However, although recent research has evaluated the impact of the COVID-19 pandemic on various surgical procedures, the postoperative outcomes of non-elective 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 COVID-19 infection would lead to longer hospital lengths of stay and higher mortality when 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 de-identified patient-level data for over 19 million total patients and over six-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 01/24/2022); N3C project ID RP-75E880. The N3C Publication committee confirmed this manuscript is in accordance with N3C data use and attribution policies; however, this 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 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 on-going development of this community resource (covid.cd2h.org/acknowledgements). We described this study 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 where the number of patients was less than 20 was blinded, and to prevent back calculation at times counts were skewed by up to five. All analysis was performed with the unskewed counts. Skewed counts are denoted with $^\forall$ in text and tables.

**Effects of COVID-19 Infection**

Adult patients (≥18 years of age) who underwent coronary artery bypass surgery under a non-elective scenario (Supplemental Table 1 for included OMOP-CDM concepts) were queried from the N3C enclave using level 3 data from 2020-2022. Patients defined as ‘non-elective’ included those admitted through the emergency room or 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, COVID-Active if they had a positive test ≤2 weeks before their CABG, and COVID-Convalescent (COVID-Conv) if they had a positive test >2 weeks before their CABG. 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 post-operative 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. A subsequent sensitivity analysis was undertaken to compare results of models with and without imputed data. Univariable analysis was performed with t-test or Chi-square with pairwise comparison or ANOVA with Tukey post-hoc test, as applicable; p values <0.05 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, where the new significance level is obtained by dividing 0.05 by the number of tests performed.

Adjusted analysis via generalized linear models with binomial distribution family (logistic regression) for dichotomous outcomes was performed for COVID-Negative (referent group), COVID-Active, and COVID-Conv cohorts. As an outcome variable, length of stay was categorized to 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. Specifically, each outcome was adjusted for age, sex, race, and Quan-Charlson Comorbidity score, based on supporting literature. Results are reported as odds ratio (OR) with 95% confidence intervals (CI). Data gathering and cleaning was performed in the N3C Enclave and all analyses performed using R.

Effects of COVID-19 Pandemic

Pre-COVID controls were compared with the established N3C COVID-Negative patients to determine the effect of the altered processes of care that were seen during the COVID-19 pandemic.
pandemic. The American College of Surgeons National Surgical Quality Improvement Project (NSQIP) database from 2016-2018 was queried for adult patients who also underwent non-elective CABG (Supplemental Table 1 for CPT codes) to create a Pre-COVID control group. Non-elective 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 marked as “outpatient.” 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. There were no missing data values from NSQIP. Univariable analysis was performed with t-test or Chi-square with pairwise comparison or ANOVA with Tukey post-hoc test, as applicable; p values <0.05 were considered statistically significant.

Primary outcomes were LOS, in-hospital, and 30-day mortality. Ninety-day mortality was unable to be obtained for Pre-COVID due to database limitations. Additionally, individual complication rates could not be compared between Pre-COVID and COVID groups due to database differences between N3C and NSQIP.

Results

A total of 15,186,903 overall patients were available for review in 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 one of the three defined COVID-19 groups (n = 7,040), or were less than 18 years of age (n = 9) were excluded. A total of 17,293 patients were identified as having undergone urgent or emergent CABG and were included for analysis. The N3C cohort included 16,747 patients: 16,252 COVID-Negative, 127® COVID-Active, and 367® COVID-Conv. A total of 2,254 patients were included from the NSQIP Pre-COVID control group (Figure 1). Baseline
patient characteristics are reported in Table 1. There were no differences with respect to age or sex between groups. There were more white patients in the Pre-COVID group, and more black patients in the COVID groups (p<0.01). Each COVID group had a significantly different distribution of Q-scores (all p≤0.01).

**Effect of COVID-19 Infection**

There was no difference in LOS between COVID-Active (11.60 ± 12.10 days) and other COVID groups. Active COVID patients had higher in-hospital and 30-day mortality than all other groups (p<0.01 for all comparisons).

Between COVID groups, COVID-Active patients experienced higher in-hospital, 30- and 90-day mortality than COVID-Negative and COVID-Conv cohorts (p<0.01). COVID-Active patients had higher rates of 30- and 90-day post-operative pneumonia compared to COVID-Negative (p<0.01), while COVID-Conv patients experienced higher rates of 30- and 90-day post-operative renal impairment when compared to COVID-Negative and COVID-Active patients (p<0.05). There were no differences between COVID groups for incidences of 30- and 90-day post-operative wound infection nor cerebrovascular accidents (Table 1).

Adjusted analysis between COVID groups using COVID-Negative as comparison demonstrated COVID-Active patients had higher in-hospital, 30-day and 90-day pneumonia rates, but no differences in LOS, renal impairment or cardiovascular events. When compared with COVID-Negative, 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 significantly differ.

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

Effect of COVID-19 Pandemic:

Pre-COVID patients experienced significantly longer hospital LOS than COVID-Negative
(p<0.01) and COVID-Conv (p<0.01) patients. Additionally, there was no difference in in-hospital
or 30-day mortality between COVID-Negative and Pre-COVID cohorts (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 coronary artery bypass grafting procedures 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
non-elective CABG patients, which suggests that changes in processes of care during the pandemic
did not negatively affect patient outcomes when CABG cases were performed non-electively.
However, there were higher mortality and complication rates amongst COVID-Active CABG
patients, indicating active COVID-19 infection contributes significantly to morbidity for patients
who require non-elective CABG. Additionally, post-operative renal impairment was significantly
higher in the COVID-Conv group compared with COVID-Negative, suggesting 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 ‘processes of care’ were initially necessary to appropriately triage and care for those affected by COVID-19, ensure adequate staffing and supply levels, and repurpose existing floors into intensive care units. Delay of elective surgical cases often resulted in postponement of operations for cancer resection and non-operative management of pathology which would have otherwise been treated surgically.\textsuperscript{3-5} In this study, the lack of difference in mortality for COVID-Negative patients during the pandemic suggests that these significant changes in processes of care experienced during the pandemic did not result in overtly worse mortality for patients undergoing non-elective CABG. This is in concordance with other similar surgical literature regarding pandemic outcomes across elective surgical cases.\textsuperscript{23-25} Parcha et al.’s review of CABG outcomes during the pandemic suggested there was no increased risk of mortality during the pandemic for these patients compared with pre-pandemic controls, though the authors did not discern if cases were performed on an emergent or elective basis.\textsuperscript{26} These findings suggest hospital systems and surgeons were able to maintain the pre-pandemic standards of care during the pandemic, despite significant institutional and process challenges, to such an extent it did not result in increased mortality.

Patients with active COVID-19 infection undergoing non-elective CABG appear to have higher rates of mortality when 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 attributable to confounders resulting from non-elective CABG procedures (i.e., acute renal failure requiring dialysis in setting of active COVID-19 infection). While there are no large analyses of outcomes for active COVID-19 patients undergoing CABG, several small case series of patients with active COVID also reported higher rates of morbidity and mortality.\textsuperscript{9, 10, 27-30} Together and in agreement with this analysis, active COVID-19 infection among patients
undergoing urgent or emergent surgical procedures does appear to confer increased risk of perioperative morbidity and mortality. Indeed, Knisely and colleagues’ recent examination of COVID-19 patients demonstrated those undergoing urgent and emergent surgical procedures were at increased risk of severe complications regardless of pre-operative ASA 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. Non-elective 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 the confounder of a significant active respiratory illness. This study highlights the increased risks associated with non-elective 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.

While this study found no difference in rate of post-operative renal impairment for COVID-Active when compared to COVID-Negative patients, COVID-Conv patients experienced higher rates of renal impairment at 30- and 90-days post-procedure. The COVID-Conv cohort 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’ review of patients that recovered from COVID-19 who underwent CABG, which did not find increased rates of post-operative renal impairment. Notably however, we were unable to control specifically for patients
with pre-existing renal disease. As there is a growing research interest in ‘Long COVID’ and its lasting effects, further investigation of this finding is indicated.

Despite increased rates of renal impairment for COVID-Conv patients, mortality rates were not significantly different than COVID-Negative patients, indicating mortality risk returns to baseline if the COVID infection was more than two weeks prior to surgery. Bhattacharya et al.’s case series examining urgent CABG for recent COVID-recovered patients had a mortality rate of 9% (1/11 patients), however this sample is likely too small to extrapolate to the larger population.

In this nationally representative sample, we report COVID-Conv mortality rates ranging from 2.7% in-hospital to 3.8% at 90-days post-operatively. Further research on COVID-recovered CABG outcomes is lacking at this time and further work to elucidate these trends are needed.

The COVID-19 pandemic presented unique and unprecedented challenges to cardiac surgeons and hospital systems. Patients with active COVID-19 infection inherently have higher risks of morbidity and mortality, which can be further exacerbated by peri-operative stress and the need for mechanical ventilation. Additionally, these patients often present in a pro-inflammatory state, coagulopathic, and in respiratory distress, further complicating their peri-operative course. What’s more, the use of cardiopulmonary bypass during coronary bypass can worsen this inflammatory process, which could ultimately lead to multiorgan dysfunction syndrome. The Society of Thoracic Surgeons supported guidance providing recommendations for the management of patients with active COVID-19 undergoing cardiac surgery, which includes the use of personal protective equipment, careful preoperative optimization when able, and consideration for alternative surgical approaches. The treatment of active COVID-19 patients requiring urgent/emergent CABG is likely best suited for a multidisciplinary approach, with input from infectious disease physicians, cardiac anesthesiologists, and cardiac critical care physicians.
to optimize patient outcome while minimizing risks 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, post-operative surgical wound infection rates were very low in our COVID cohorts, which is likely due to the nature of database research – sometimes the anticipated data is not available. This can occur if the requisite diagnosis codes are not well-utilized in the EMR.

Additionally, while 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 attempt to control for various factors including age and comorbidity composite score to ameliorate these differences. Additionally, comparison of certain outcomes between Pre-COVID and COVID groups was not possible due 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 coronary bypass even in emergent scenarios due to constraints on their practice or hospitals. Alternatively, it is possible that more patients were categorized as non-elective in order to bypass elective surgery limitations during the pandemic, which may have influenced the larger number of non-elective CABG cases during the pandemic era. Accordingly, the decision to pursue CABG in the urgent/emergent setting may not have been uniform across all hospitals. The findings in this
study further emphasizes the need for prospective data collection with increased level of detail for more precise results.

In conclusion, altered processes of care during the COVID-19 pandemic did not appear to worsen clinical outcomes for COVID-Negative patients undergoing non-elective coronary bypass grafting (Figure 2). Active COVID-19 infection, however, was associated with and likely contributed to increased morbidity and mortality. While this analysis solely focused 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.

References


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Center for Clinical Investigation
Table 1. Baseline cohort demographics and patient characteristics

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<th>COVID-Conv (n=367\textsuperscript{a})</th>
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</tr>
<tr>
<td>Race [1,700]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>White</td>
<td>1,893 (84.0%)</td>
<td>12,330 (84.5%)</td>
<td>80 (80.0%)</td>
<td>292 (84.1%)</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>160 (7.1%)</td>
<td>1,507 (10.3%)</td>
<td>&lt;20</td>
<td>40 (11.5%)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>84 (3.7%)</td>
<td>526 (3.6%)</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>117 (5.2%)</td>
<td>237 (1.6%)</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td></td>
</tr>
<tr>
<td>Ethnicity [1,879]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Hispanic</td>
<td>316 (14.0%)</td>
<td>1,020 (7.1%)</td>
<td>&lt;20</td>
<td>24 (7.1%)</td>
<td></td>
</tr>
<tr>
<td>Not Hispanic</td>
<td>1,938 (86.0%)</td>
<td>13,398 (92.9%)</td>
<td>102 (91.1%)</td>
<td>314 (92.9%)</td>
<td></td>
</tr>
<tr>
<td>Quan CCI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>0</td>
<td>NA</td>
<td>8,081 (49.7%)</td>
<td>79 (63.2%)</td>
<td>128 (34.6%)</td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>NA</td>
<td>4,488 (27.6%)</td>
<td>27 (21.6%)</td>
<td>121 (32.7%)</td>
<td></td>
</tr>
<tr>
<td>3-15</td>
<td>NA</td>
<td>3,6834 (22.7%)</td>
<td>&lt;20</td>
<td>121 (32.7%)</td>
<td></td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>NA</td>
<td>3,514 (21.6%)</td>
<td>22 (17.6%)</td>
<td>121 (32.7%)\textsuperscript{x}</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>NA</td>
<td>3,844 (23.7%)</td>
<td>20 (16.0%)</td>
<td>124 (33.5%)\textsuperscript{x}</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>PVD</td>
<td>NA</td>
<td>3,622 (22.3%)</td>
<td>21 (16.8%)</td>
<td>97 (26.2%)</td>
<td>0.07</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>NA</td>
<td>3,476 (21.4%)</td>
<td>21 (16.8%)</td>
<td>97 (26.2%)</td>
<td>0.05</td>
</tr>
<tr>
<td>Dementia</td>
<td>NA</td>
<td>119 (0.7%)</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>0.09</td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td>NA</td>
<td>2,597 (16.0%)</td>
<td>&lt;20</td>
<td>84 (22.7%)\textsuperscript{x}</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Rheumatic disease</td>
<td>NA</td>
<td>650 (4.0%)</td>
<td>&lt;20</td>
<td>23 (6.2%)</td>
<td>0.07</td>
</tr>
<tr>
<td>Peptic ulcer disease</td>
<td>NA</td>
<td>267 (1.6%)</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>0.06</td>
</tr>
<tr>
<td>Mild liver disease</td>
<td>NA</td>
<td>923 (5.7%)</td>
<td>&lt;20</td>
<td>33 (8.9%)\textsuperscript{b}</td>
<td>0.03</td>
</tr>
<tr>
<td>Severe liver disease</td>
<td>NA</td>
<td>147 (0.9%)</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>0.93</td>
</tr>
<tr>
<td>Uncomplicated diabetes</td>
<td>NA</td>
<td>5,797 (35.7%)</td>
<td>43 (34.4%)</td>
<td>196 (53.0%)\textsuperscript{x}</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Complicated diabetes</td>
<td>NA</td>
<td>3,016 (18.6%)</td>
<td>&lt;20</td>
<td>103 (27.8%)\textsuperscript{x}</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Hemi-/paraplegia</td>
<td>NA</td>
<td>154 (1.0%)</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>0.54</td>
</tr>
<tr>
<td>Renal disease</td>
<td>NA</td>
<td>2,700 (16.6%)</td>
<td>&lt;20</td>
<td>92 (24.9%)\textsuperscript{b}</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>COVID-Active</td>
<td>p</td>
<td>COVID-Conv</td>
<td>p</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------</td>
<td>-------</td>
<td>------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Length of stay</td>
<td>1.38 (0.97, 1.97)</td>
<td>0.08</td>
<td>0.73 (0.59, 0.90)</td>
<td>&lt;0.01</td>
<td></td>
</tr>
<tr>
<td>Death (in hospital)</td>
<td>4.27 (2.26, 7.40)</td>
<td>&lt;0.01</td>
<td>0.84 (0.41, 1.50)</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>Death (30 days)</td>
<td>4.46 (2.51, 7.43)</td>
<td>&lt;0.01</td>
<td>0.82 (0.43, 1.40)</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Death (90 days)</td>
<td>4.44 (2.57, 7.23)</td>
<td>&lt;0.01</td>
<td>0.82 (0.45, 1.35)</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>Renal impairment (30 days)</td>
<td>1.48 (0.91, 2.32)</td>
<td>0.10</td>
<td>1.39 (1.03, 1.83)</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Renal impairment (90 days)</td>
<td>1.25 (0.78, 1.92)</td>
<td>0.33</td>
<td>1.20 (0.91, 1.56)</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>CVA (30 days)</td>
<td>0 (0, inf)</td>
<td>0.99</td>
<td>0 (0, inf)</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>CVA (90 days)</td>
<td>0 (0, inf)</td>
<td>0.99</td>
<td>0.93 (0.05, 4.28)</td>
<td>0.94</td>
<td></td>
</tr>
<tr>
<td>Pneumonia (30 days)</td>
<td>4.88 (2.27, 9.21)</td>
<td>&lt;0.01</td>
<td>1.54 (0.76, 2.78)</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Pneumonia (90 days)</td>
<td>4.07 (2.11, 7.15)</td>
<td>&lt;0.01</td>
<td>1.28 (0.71, 2.13)</td>
<td>0.37</td>
<td></td>
</tr>
</tbody>
</table>

COVID-Negative is referent group. CVA – cerebrovascular accident. Adjusted via generalized linear models based on age, sex, race, and Q-score.
Legends

Figure 1: Patient selection criteria from N3C and NSQIP datasets.

Figure 2: Analysis of Non-elective CABG Outcomes during the COVID-19 Pandemic
Total Patients in N3C (n=15,186,903)

Underwent CABG (n=38,393)

Non-elective CABG (NSQIP) (n=2,254)

Underwent Non-elective CABG (n=16,747)

COVID-Negative (n=16,252)

COVID-Active (n=127*)

COVID-Convalescent (n=367*)

*Values skewed per N3C guidelines
Analysis of Non-elective Coronary Artery Bypass Graft Outcomes during the COVID-19 Pandemic

Retrospective Cohort Study

Pre-COVID Control 2016-2018

Pre-COVID (n=2,254)

Unadjusted analysis between all four groups

COVID-19 Pandemic

Negative (n=16,252)  
Active (n=127*)

Convalescent (n=367*)

Adjusted analysis between COVID groups

No difference in mortality between Pre-COVID and COVID-Negative.

↑↑↑ mortality for COVID-Active (vs. COVID-Negative and COVID-Convalescent)

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

Graphic source: Blasen Medical Communications, Inc.

*To comply with IRB guidelines these values have been skewed.

@AATSJournals
Urgent/Emergent CABG Outcomes during the COVID-19 Pandemic

Emily A. Grimsley, Johnathan V. Torikashvili, Haroon M. Janjua, Meagan D. Read, Anai N. Kothari, Nate B. Verhagen, Ricardo Pietrobon, Paul C. Kuo, Michael P. Rogers, on behalf of the N3C Consortium

Department of Surgery, University of South Florida Morsani College of Medicine