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Changes in surgical mortality during COVID-19 pandemic by patients' race, ethnicity and socioeconomic status among US older adults: a quasi-experimental event study model

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ABSTRACT

Objectives To examine changes in the 30-day surgical mortality rate after common surgical procedures during the COVID-19 pandemic and investigate whether its impact varies by urgency of surgery or patient race, ethnicity and socioeconomic status.

Design We used a quasi-experimental event study design to examine the effect of the COVID-19 pandemic on surgical mortality rate, using patients who received the same procedure in the prepandemic years (2016–2019) as the control, adjusting for patient characteristics and hospital fixed effects (effectively comparing patients treated at the same hospital). We conducted stratified analyses by procedure urgency, patient race, ethnicity and socioeconomic status (dual-Medicaid status and median household income).

Setting Acute care hospitals in the USA.

Participants Medicare fee-for-service beneficiaries aged 65–99 years who underwent one of 14 common surgical procedures from 1 January 2016 to 31 December 2020.

Main outcome measures 30-day postoperative mortality rate.

Results Our sample included 3 620 689 patients. Surgical mortality was higher during the pandemic, with peak mortality observed in April 2020 (adjusted risk difference (aRD) +0.95 percentage points (pp); 95% CI +0.76 to +1.26 pp; p<0.001) and mortality remained elevated through 2020. The effect of the pandemic on mortality was larger for non-elective (vs elective) procedures (April 2020: aRD +0.44 pp (+0.16 to +0.72 pp); p=0.002 for elective; aRD +1.65 pp (+1.00, +2.30 pp); p<0.001 for non-elective). We found no evidence that the pandemic mortality varied by patients' race and ethnicity (p for interaction=0.29), or socioeconomic status (p for interaction=0.49).

Conclusions 30-day surgical mortality during the COVID-19 pandemic peaked in April 2020 and remained elevated until the end of the year. The influence of the pandemic on surgical mortality did not vary by patient race and ethnicity or socioeconomic status, indicating that once patients were able to access care and undergo surgery, surgical mortality was similar across groups.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ We used Medicare fee-for-service data for this study—a large nationally representative dataset of US adults.
- ⇒ The quasi-experimental event study design allowed us evaluate differences in surgical mortality before and after the COVID-19 pandemic for each discrete time-period (month) among patients without COVID-19 infection.
- ⇒ We rely on COVID-19 diagnostic codes from administrative data to determine COVID-19 infection status, and our findings may not generalise to non-US non-older adult populations.

INTRODUCTION

The COVID-19 pandemic resulted in a severe and prolonged disruption to healthcare systems. To date, over 1 million people have died due to COVID-19 infection in the USA.[1] Beyond those who succumbed to the virus, COVID-19 also affected healthcare utilisation, access and quality resulting in an estimated 260 000 excess deaths during the pandemic not directly attributable to COVID-19 infection.[2 3] The COVID-19 pandemic also disrupted the provision of surgical care. In March and April 2020, the American College of Surgeons (ACS) and Centers for Medicare and Medicaid Services (CMS) recommended the postponement of non-emergent and elective procedures.[4–6] As a result, from March to June 2020, US hospitals reduced the number of surgeries performed by 48%.[7] Following updated guidance from the ACS and CMS recommending the re-initiation of non-emergent surgical procedures, the number of surgeries gradually increased up to July 2020 when rates once again reached prepandemic levels.[8 9]

While the reduction in surgeries caused by the COVID-19 pandemic is well described, less research has focused on the impact of this disruption on surgical mortality.[7] Furthermore, most studies focus on COVID-19-related mortality after narrow subsets of procedures, study inpatient surgical mortality or evaluate only the first few months of the pandemic.[10–14] For example, a recent study using data from 56 hospitals in the USA and Europe found increased mortality for patients undergoing surgical procedures during the first 3 months of the pandemic in 2020.[15] This was, however, a small study conducted at a limited number of hospitals, and therefore the findings may not be generalisable nationally or beyond the first 3 months of the pandemic. Furthermore, it is unknown if the pandemic's disruption in surgical care may have exacerbated disparities in care, specifically surgical mortality based on race, ethnicity or socioeconomic status (SES).[16–18]

To address this important knowledge gap, we sought to define the impact of the COVID-19 pandemic on mortality following the 14 most common procedures among Medicare fee-for-service beneficiaries without COVID-19 infections from 2016 to 2020 using a quasi-experimental event study design. We also investigated whether the impact of the pandemic varied by procedure urgency, patient race and ethnicity or SES.

METHODS

Data source and study participants

Medicare is a US federal health insurance programme for individuals aged over 65 years, or have certain disabilities, and people with end-stage renal disease or amyotrophic lateral sclerosis (ALS). Medicare enrolls about 63 million Americans distributed between traditional fee-for-service Medicare (60% of enrollees in 2020) and Medicare Advantage (health insurance plan offered by private insurance companies, 40% of enrollees).[19] We used data from 100% of Medicare fee-for-service inpatient claims from 1 January 2016 to 31 December 2020. We restricted our analysis to those continuously enrolled in part A (covers inpatient hospital stays, care in skilled nursing facility, hospice care and some home healthcare) and part B (covers certain doctors' services, outpatient care, medical supplies and preventive services) and were aged 65–99 years.[20] Our sample included patients who underwent one of the following 14 most common procedures performed in the Medicare data: abdominal aortic aneurysm repair (AAA repair; open and endovascular), appendectomy (open and laparoscopic), coronary artery bypass grafting (CABG), cholecystectomy (open and laparoscopic), colectomy, cystectomy, hip replacement, hysterectomy, knee replacement, laminectomy, liver resection, lung resection, prostatectomy and thyroidectomy (online supplemental table A). We included elective and non-elective procedures that were performed within 3 days of hospital admission. To focus our analysis on health system influences on mortality rather than COVID-19 infection, we excluded patients who had a diagnosis of COVID-19 infection (n=989) as defined by International Classification of Disease codes B97.29 (From 1 January 2020 to 31 March 2020) or U07.1 (from 1 April 2020 to 1 December 2020). There were minimal missing data (1.8%) thus data were not imputed and analysis was performed for patients with complete variables.

Exposure variable

The exposure of interest was the COVID-19 pandemic. This was defined by creating a categorical month variable, with February designated as the reference followed by pandemic months March–November. The second exposure is a binary variable defining COVID-19 pandemic 'treatment' years (2020=1) and COVID-19 prepandemic 'control' years (2016–2019=0).

Outcome variable

The primary outcome was 30-day mortality, defined as death within 30 days of procedure date. The Medicare Beneficiary Summary File was used for date of death, which is verified using death certificates. Overall, 99% of death days have been validated in the Medicare data, and we excluded patients whose death days have not been validated (<1%).[21]

Adjustment variables

We adjusted for patient characteristics and hospital fixed effects. Patient characteristics included sex, age (65–69, 70–74, 75–79, 80–84, 85–89, 90–94, 95–99 years), race and ethnicity (White non-Hispanic, Black non-Hispanic, Hispanic and other), 27 chronic conditions (defined by the Medicare's Chronic Condition Warehouse in the Master Beneficiary Summary File[22]; online supplemental table B), dual-eligibility for Medicaid (beneficiaries enrolled in Medicare who are also eligible for Medicaid, a US health insurance programme for low-income individuals), median household income (estimated as tertiles from beneficiary's zip code of residency (<US$53 662, US$53 662–US$73 894, >US$73 894) using the 2019 US Census Bureau American Community Survey data),[23] type of procedure (indicator variable for 14 surgical procedures), weekday versus weekend operation and urgency of procedure (elective vs non-elective (urgent, emergent); based on admission type code). Hospital fixed effects were included to control for both measured and unmeasured characteristics (time-invariant characteristics) of hospitals, effectively comparing outcomes of patients treated at the same hospital. We omitted the stratification variable from our regression when we conducted stratified analysis (eg, we excluded race and ethnicity from our regression when we conducted a stratified analysis by patient race and ethnicity).

Statistical analysis

We examined changes in surgical mortality rates in the year when the healthcare delivery system was disrupted by the COVID-19 pandemic (2020) relative to years unaffected by the pandemic (2016–2019). We estimated this using the quasi-experimental event study design (also referred as the staggered difference-in-differences (DiD) design) that allows us to assess the effect of the COVID-19 pandemic on surgical mortality while adjusting for potential confounders.[24–30] The event study design is an extension of DiD; rather than testing for a difference in *means* before (January) and after (March–November) the intervention between treatment (patients who received a surgical procedure in 2020) vs control groups (patients who received a surgical procedure in 2016–2019), the event study design elucidates between-group differences for each discrete time-period (ie, month). Thus, we compare changes in mortality during months before (January 2020) and after (March–November 2020) the pandemic affected the health systems (using patients who received a surgical procedure in February as the reference group). The use of the event study design enables us to more explicitly assess the assumption of the DiD that the difference in the outcome variables between treatment and control groups is constant over time (parallel trend assumption). In addition, the event study design presumes no functional form for change overtime in the pre-event or post-event periods which allows for the assessment of dynamic effects month-by-month and allows us to increase the granularity with which we can assess changes over the event (allows for the examination of multiple time-period-specific estimates, which enhances the understanding of the temporal dynamics). As the regression coefficients of interaction terms of logistic regression models (interaction of ORs) are difficult to interpret, we used the linear probability model (ie, fitting ordinary least squares regression models with Huber-White heteroscedasticity-robust SEs) for all analyses. To allow for sufficient follow-up time for 30-day mortality rates after surgery and allow for accurate month-by-month differences in our outcomes with event study design, we excluded surgical procedures performed from 1 December to 31 December in each year.

Sensitivity analysis

We conducted several sensitivity analyses. First, to address the possibility that patient comorbidity burden may have influenced the association between the COVID-19 pandemic and surgical mortality, we performed our analysis without controlling for the 27 chronic conditions, but including the remaining covariates as specified above. Second, to assess whether our findings were sensitive to our model selection, we conducted a survival analysis by plotting a 30-day Kaplan-Meier survival curve, defining the treatment group as patients who underwent a surgical procedure in April 2020 (during the pandemic), and the control group as patients who received a surgery in April 2016–2019 (the same months of the year before the pandemic). We also compared these groups using Cox proportional hazard model, controlling for the same patient characteristics as above and hospital fixed effects. Lastly, to address the possibility of differences in baseline data between our comparison, we reanalysed the data using propensity scores with inverse probability weighting to compare the overall mortality rate of the pandemic cohort (operations in April 2020) with the control prepandemic cohort (operations during April 2016–2019).

Stratified analyses

We compared whether the association of the COVID-19 pandemic on mortality varied by procedure urgency by conducting a stratified analysis of non-elective versus elective surgeries, adjusted for the same patient characteristics and hospital fixed effects. To test whether the effect of the COVID-19 pandemic on mortality varied by patient race, ethnicity and SES, we conducted stratified analyses by patient race and ethnicity (White, Black, Hispanic and other) and SES defined as (1) dual Medicaid coverage and (2) median household income estimated from residential zip codes. To formally test the interaction between pandemic month and subgroups of race or SES, we used a Wald test to account for clustering (standard likelihood-based tests are not available with clustered data).

P values were two-sided and results were statistically significant at $p<0.05$. For table 1, p values were calculated using t-tests for means and χ^2 tests for categorical variables. We used SAS software (SAS Institute) for data preparation and Stata V.16.1 (StataCorp) for all analyses.

Patient and public involvement

No patients or members of the public were involved in setting the research question or the outcome measures, nor were they involved in developing plans for the design or implementation of the study or asked to advise on interpretation or writing up of results. Although we support the importance of patient and public involvement, this was a secondary data analysis of existing claims data where the identifiers were not available for patients or members of the public for analysis, and as such it was not practical to involve them as members of this research study.

RESULTS

Our analysis included 3 620 689 Medicare beneficiaries who underwent one of 14 operations during the 4-year study period. A minority of the operations occurred during the 2020 pandemic year: 522 850 (14.4%). The demographic and procedure characteristics are shown in table 1. The mean age was 74.9 years with a slight female majority (56.4%). Overall, 2 766 170 (76.4%) of procedures were elective, and the most common procedure was knee replacement 1 033 769 (28.6%).

The overall unadjusted mean 30-day mortality rate was 1.88%. After adjusting for potential confounders, we found that the 30-day mortality rate increased significantly during the COVID-19 pandemic. We observed an association of the COVID-19 pandemic with mortality, starting in March (figure 1; adjusted risk difference

Table 1 Sample characteristics for Medicare patients undergoing 14 common surgical conditions, 2016–2019 vs 2020

Characteristic	Total	Prepandemic (2016–2019)	Pandemic (2020)	P value
Patients, no. (%)	3 620 689	3 097 839 (85.6)	522 850 (14.4)	NA
Patient characteristics				
Patient age, years, mean (SD)	74.9 (6.7)	74.9 (6.7)	75.3 (6.9)	<0.0001
Patient sex				
Male	1 580 059 (43.6)	1 345 662 (43.4)	234 397 (44.8)	<0.0001
Female	2 040 630 (56.4)	1 752 177 (56.6)	288 453 (55.2)	
Patient race/ethnicity				
White	3 164 072 (87.4)	2 707 019 (87.4)	457 053 (87.4)	<0.0001
Black	180 129 (5.0)	155 876 (5.0)	24 253 (4.6)	
Hispanic	126 489 (3.5)	108 776 (3.5)	17 713 (3.4)	
Other	149 999 (4.1)	126 168 (4.1)	23 831 (4.6)	
Dual Medicare Medicaid, no. (%)	338 707 (9.4)	291 053 (9.4)	47 654 (9.1)	<0.0001
Median household income*, US$, mean (SD)	69 380.8 (27 857.0)	69 276.8 (27 833.4)	69 997.3 (27 988.7)	<0.0001
Coexisting conditions, no. (%)				
CHF	868 819 (24.0)	733 477 (23.7)	135 342 (25.9)	<0.0001
COPD	936 662 (25.9)	794 834 (25.7)	141 828 (27.1)	<0.0001
Diabetes	1 313 144 (36.3)	1 120 226 (36.2)	192 918 (36.9)	<0.0001
Chronic kidney disease	1 258 956 (34.8)	1 048 081 (33.8)	210 875 (40.3)	<0.0001
Neurological disorders	711 059 (19.6)	597 808 (19.3)	113 251 (21.7)	<0.0001
Cancer	790 589 (21.8)	670 710 (21.7)	119 879 (22.9)	<0.0001
Procedure characteristics				
Procedure urgency, no. (%)				
Elective	2 766 170 (76.4)	2 395 188 (77.3)	370 982 (71.0)	<0.0001
Non-elective	854 519 (23.6)	702 651 (22.7)	151 868 (29.1)	

*Median household income is estimated from the beneficiary's zip code of residency. Coexisting conditions presented represent a smaller selection of the 27 conditions included in the Chronic Condition Warehouse.
CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; NA, not available.

(aRD) +0.24 percentage points (pp), 95% CI +0.05 to +0.44 pp; p=0.01). The mortality peaked in April 2020 (aRD +0.95 (+0.64 to +1.26 pp); p<0.001). We observed a higher mortality rate in most subsequent months of the pandemic, where the aRD rose from +0.21 to 0.95 pp (figure 1, online supplemental table C). Results were broadly similar when examining the association between the COVID-19 pandemic and surgical mortality, without controlling for patient comorbidity burden (online supplemental figure A and online supplemental table D). Findings from the Kaplan-Meier survival analysis and Cox proportional hazard model were consistent with our findings using event study design (online supplemental figure B and online supplemental table E), and findings from our model using propensity score matching was also qualitatively unaffected in a sensitivity analysis (aRD +0.53 pp for April 2020; 95% CI +0.32 to +0.74 pp; p<0.001; online supplemental table F).

Among beneficiaries undergoing elective surgery, the magnitude of the increased mortality was smaller than for non-elective surgery in April 2020 (aRD +0.44 (95% CI +0.16 to +0.72 pp); p=0.002 for elective; aRD +1.65 (+1.00 to +2.30 pp); p<0.001 for non-elective; figure 2, online supplemental table G). Mortality after elective surgery between May and September returned to levels similar to prepandemic years (control). In contrast, mortality after non-elective surgery remained significantly elevated in each subsequent month of the 2020 pandemic year.

The impact of the COVID-19 pandemic on surgical mortality did not vary by patient race and ethnicity (p for interaction=0.29) or Medicaid dual eligibility (p for interaction=0.05; figure 3, online supplemental tables H,I). We also assessed surgical mortality by median household income and found no difference in postoperative mortality between low-income, middle-income and high-income patients during the pandemic (p for interaction=0.49; figure 3; online supplemental table J).

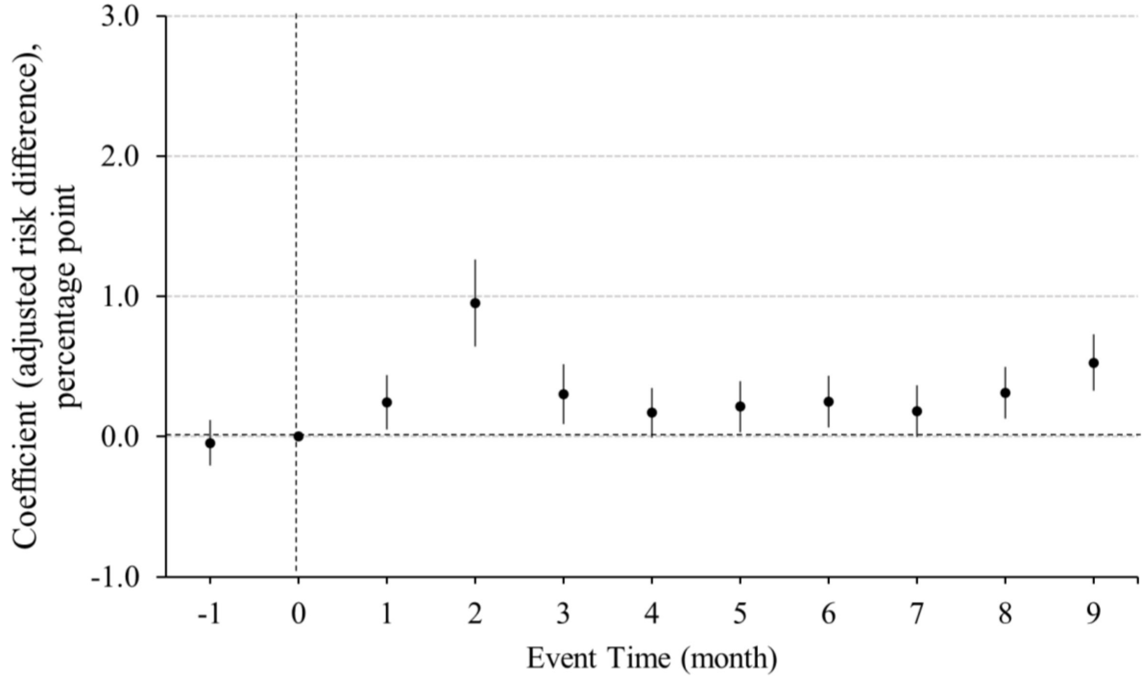

Figure 1 Effect of the COVID-19 pandemic on 30-day postoperative mortality among Medicare patients. Authors' calculation using Medicare data from 2016 to 2020. Event time corresponds to months before and after the February baseline month (0=February). Error bars represent 95% CIs. Coefficients estimated using event study design and represent change in mortality for pandemic year (2020) relative to the pandemic control years (2016–2019), additionally adjusting for patient age, sex, race and ethnicity, Medicaid dual coverage, median household income estimated from beneficiary's residential zip code, comorbidities, weekend versus weekday operation, procedure type, procedure urgency and hospital fixed effects. Coefficient estimate indicates the difference-in-differences estimate of (pandemic year month X–prepandemic year month X)–(pandemic year month February–prepandemic year month February).

DISCUSSION

Using nationally representative data of Medicare beneficiaries who underwent common surgical procedures in the USA, we found a significant increase in surgical mortality associated with the COVID-19 pandemic. The increase in surgical mortality was most pronounced in April 2020, and remained elevated through the end of 2020. The effect of the pandemic on patient mortality was larger for non-elective than for elective procedures. We found no evidence that the effect of the pandemic varied by patient race and ethnicity or SES. Taken together, these findings indicate that within this

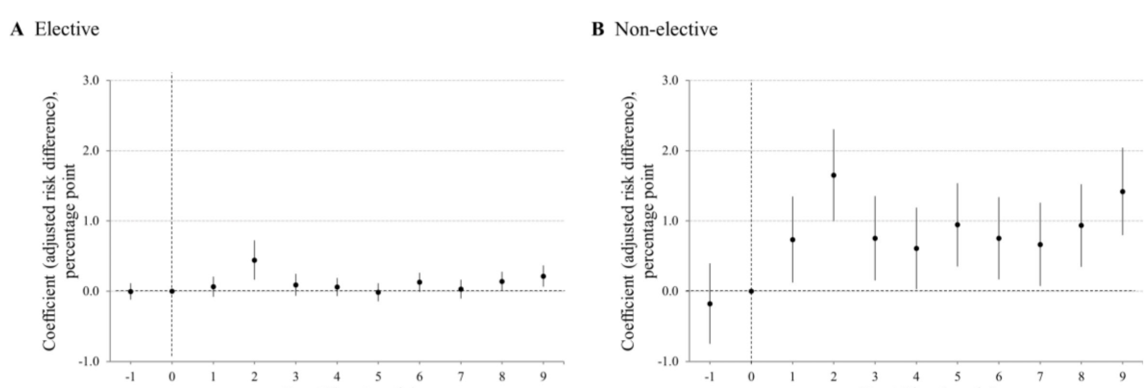

Figure 2 The effect of the COVID-19 pandemic on 30-day postoperative mortality among Medicare patients, by urgency of surgery. Authors' calculation using Medicare data from 2016 to 2020. Event time corresponds to months before and after the February baseline month (0=February). Error bars represent 95% CIs. The effect of the COVID-19 pandemic varied between elective versus non-elective procedures (p for interaction=<0.0001). Coefficients estimated using event study design and represent change in mortality for pandemic year (2020) relative to the pandemic control years (2016–2019), stratified by urgency of surgery, additionally adjusting for patient age, sex, race and ethnicity, Medicaid dual coverage, median household income estimated from beneficiary's residential zip code, comorbidities, weekend versus weekday operation, procedure type and hospital fixed effects. Coefficient estimate indicates the difference-in-differences estimate of (pandemic year month X–prepandemic year month X)–(pandemic year month February–prepandemic year month February).

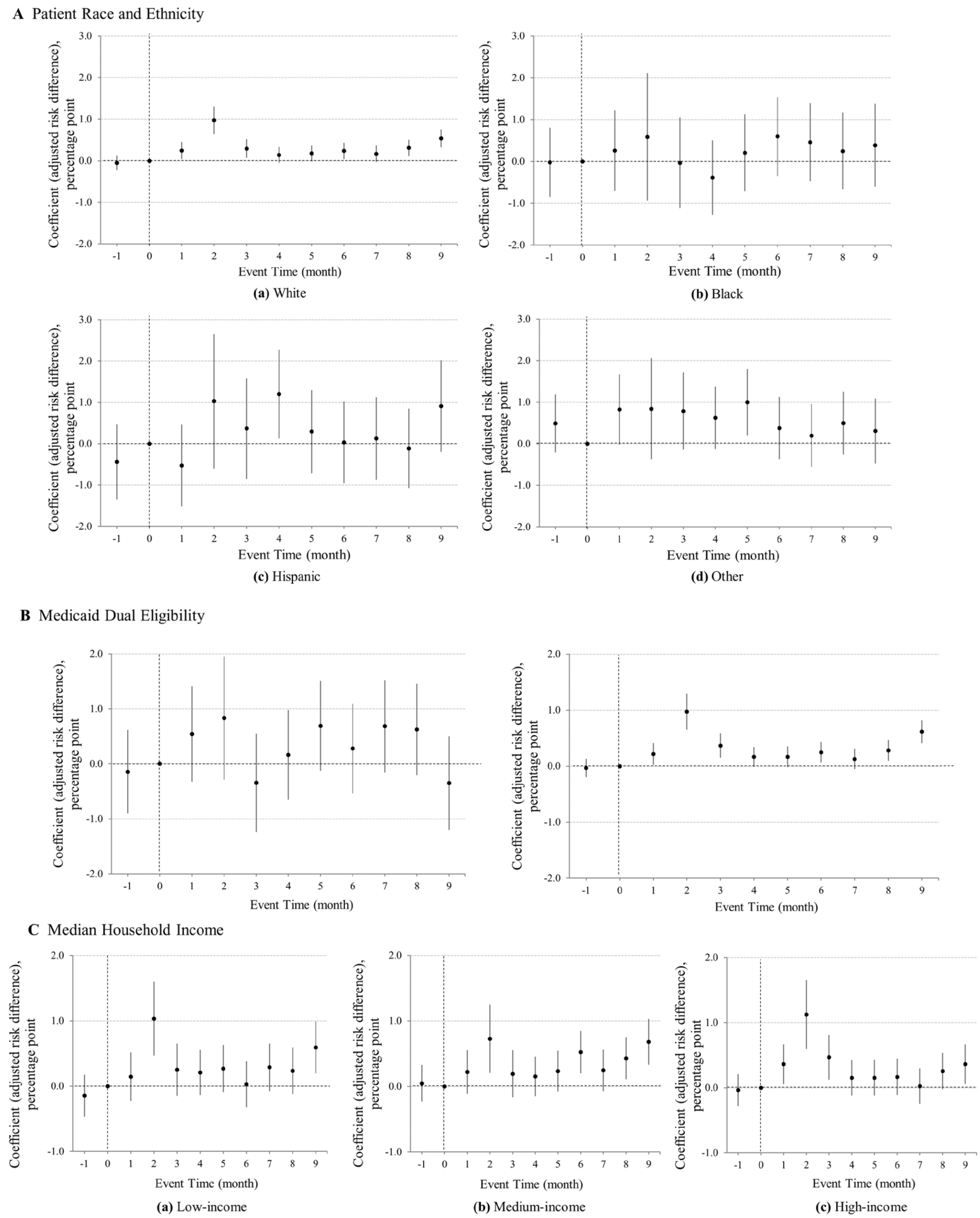

Figure 3 The effect of the COVID-19 pandemic on 30-day postoperative mortality among Medicare patients, by patient race, ethnicity and SES. Authors' calculation using Medicare data from 2016 to 2020. Event time corresponds to months before and after the February baseline month (0=February). Error bars represent 95% CIs. The effect of the COVID-19 pandemic did not vary between patient race and ethnicity (p for interaction=0.29) or Medicaid dual eligibility (p for interaction=0.05). Coefficients estimated using event study design and represent change in mortality for pandemic year (2020) relative to the pandemic control years (2016–2019), stratified by patient race and ethnicity (A), Medicaid dual eligibility (B) and median household income (C) additionally adjusting for patient age, sex, Medicaid dual coverage (except B), race and ethnicity (except A), median household income estimated from beneficiary's residential zip code (except C), comorbidities, weekend versus weekday operation, procedure type, procedure urgency and hospital fixed effects. Coefficient estimate indicates the difference-in-differences estimate of (pandemic year month X–prepandemic year month X)–(pandemic year month February–prepandemic year).

national sample of Medicare patients without COVID-19 infection, disruptions in surgical care during the COVID-19 pandemic were associated with a meaningful and prolonged increase in the mortality of patients undergoing surgical procedures regardless of race and ethnicity, or SES.

The spike in surgical mortality seen in the first few months of the pandemic, particularly among urgent surgeries, may be explained by changes in patient selection. The pandemic resulted in dramatic shifts in hospital-based medical care which had significant impacts on surgical care, including restricted scope and capacity.[5 6] In response to CMS and professional society guidance, hospitals dramatically reduced elective procedures and prioritised time-sensitive indications for surgery, including emergency surgery.[7] Our sample mirrors these trends, with the pandemic era procedures containing a higher proportion of urgent and emergent procedures. Additionally, the impact of caring for COVID-19 patients resulted in resource strain including inadequate staffing, supplies and ICU beds, which all have been associated with excess deaths.[31] These changes reflect a diminished ability for healthcare systems to care for higher acuity patients presenting with indications for non-elective surgery. This system strain may explain our findings that months with higher burdens of COVID-19 cases in the US population (ie, July and October–November) are also the months with the elevated surgical mortality. As for the sustained increase in mortality seen throughout 2020, in addition to the factors described above, we propose that delays in presentation may have also contributed. The COVID-19 pandemic was associated with an overall reduction in healthcare utilisation in 2020. However, despite reduced utilisation, the patients that did present often had more advanced disease states for a number of conditions including cancer, myocardial infarction and appendicitis.[32–38] This delay in presentation may have driven some of the increase in mortality we observed as more advanced disease states are associated with increased surgical mortality for both elective and non-elective surgeries.[39–41]

We found that the effects of the pandemic on surgical mortality did not vary by patient race and ethnicity or SES. This finding was unexpected given that prior studies reported that racially and ethnically minoritised groups and individuals with low SES experience higher pandemic burdens and worse clinical outcomes in non-surgical studies.[42–45] Several potential mechanisms may explain our findings. First, it is possible that once patients require surgery, the impact of the health system changes associated with the pandemic were experienced similarly across groups in this Medicare sample. Thus, the Medicare insurance coverage may have functioned as an 'equaliser' mitigating the differential impact of pandemic on surgical mortality across race, ethnicity and SES, despite well-documented disparities across these groups prepandemic.[46–48] If this is the case, well-documented disparities in the effects of the pandemic may be driven largely by the lack of healthcare access confronted by minoritised and low-SES populations, rather than healthcare providers treating patients differently based on patients' race, ethnicity and SES. Second, our research focused on the surgical mortality among non-COVID-19-infected patients. Given that racially and ethnically minoritised and low-SES populations had higher rates of COVID-19 infection, by excluding this group to study non-COVID-19-infected individuals, we may be capturing a healthier population who were able to avoid COVID-19 and undergo a needed surgical procedure. Lastly, emerging evidence on access to surgical care report that racial and ethnic minority patients experienced a similar decline in surgical volume compared with white patients.[49 50] Thus, the lack of difference we see between racial and ethnic groups may represent a persistence of pre-existing disparities rather than worsening of disparities that we hypothesised.

Our study builds on prior research examining the association of the COVID-19 pandemic on surgical mortality. Thus far, there have been several studies that have identified increased surgical mortality associated with both elective and non-elective surgeries. However, the most comprehensive of these studies were limited to selected vascular, colorectal or orthopaedic operations, lacked adequate control groups and two studies took place in the UK, where healthcare is nationalised.[11 13] An additional study found an increased inpatient mortality for patients undergoing several common surgeries at hospitals with a high burden of COVID-19-infected patients, similar to our findings, and the mortality was not higher in their Medicare versus commercial subgroup.[14] Since this study analysed data that include US academic medical centres (using the Vizient Clinical Database), our analysis that includes all fee-for-service Medicare inpatient claims across hospital types may be more generalisable in a useful addition to the literature. We provide evidence describing the effect of the COVID-19 pandemic on surgical mortality using a nationally representative sample of older Americans who received surgical procedures during the pandemic.

Our study has limitations. First, while this study uses a quasi-experimental event study design, ultimately our findings are observational in nature and do not demonstrate causality.[36] There may be residual confounding, such as under-recognition of deaths due to COVID-19, which could bias towards increased mortality from infection rather than health system effects. Second, the mortality rate may reflect the lower overall operative volume during the early pandemic. Third, we identified patients with a COVID-19 diagnosis using ICD-10 codes and excluded them from our analytic sample; however, there might be underuse of COVID-19 diagnostic codes, particularly early in the pandemic. Fourth, our study was unable to identify mechanisms linking the COVID-19 pandemic with an increased surgical mortality. Finally, we used the data on Medicare beneficiaries aged 65–99 years who underwent commonly performed surgical procedures, and therefore, our findings may not be generalisable to younger non-Medicare populations or to patients who received less common procedures.

In summary, using a nationally representative sample of Medicare beneficiaries, we found that 30-day surgical mortality was higher for individuals undergoing surgery following the onset of the COVID-19 pandemic. This increase in mortality peaked in April 2020, although mortality remained elevated through the end of 2020. We found no variation in surgical mortality across racial and ethnic groups or SES. Our findings inform the need for improved real-time monitoring of surgical outcomes such that healthcare systems can more quickly identify shortcomings in quality of care and thus better adapt to crises like the COVID-19 pandemic. Future studies should examine the association of the COVID-19 pandemic on surgical outcomes for non-Medicare eligible adults to better assess how the pandemic may have impacted vulnerable uninsured and underinsured populations. Further research is warranted to understand how healthcare and societal factors coalesced to cause the increase in mortality shown in this study.

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Contributors Each author contributed important intellectual content and was provided authorship in accordance with the International Committee of Medical Journal Editors. Research idea and design: MBB, YT; data collection: YT; data analysis and interpretation: MBB, YT, NJJ and RL; drafting of the manuscript: MBB, JMR; critically revising the manuscript for important intellectual content: JMR, NJJ, MM-G, RL, MMR, TAR, CdV and YT. YT serves as the author guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The study was approved by University of California Los Angeles Institutional Review Board.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. We have received the data from the Center for Medicare and Medicaid Services (CMS), and the data use agreement prevents us from sharing it. Anyone interested in using the Medicare claims data should contact the CMS directly.

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