Socio-Demographic Drivers of Surgical Services Utilization Under Pandemic Conditions

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Abstract

The COVID-19 epidemic exposed extreme strains in hospital service delivery. An open question is the extent to which surgical service delivery is impacted by racial, economic, and behavioral demographic covariates. These covariates may have a statistically significant impact of service delivery that disproportionately affected medical provider guidance on what surgeries were performed and the patient cohorts being served. We take a data-driven approach to address this issue by examining pre-, peri-, and post-pandemic surgical utilization from a very large medical claims dataset representative of the US healthcare ecosystem. A statistical analysis of surgical volumes by a robust set of socio-demographic data elements highlights various findings.

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Chapter 1

Introduction

1.1 Introduction

A mysterious cluster of pneumonia cases was reported in Wuhan, China at the end of December, 2019 (Worobey, 2021). The acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was eventually discovered as the cause of this outbreak with the condition named as coronavirus (COVID-19) (World Health Organization, 2022). The disease spread quickly from China, developing into an international pandemic, with the world watching in real-time as the first cases were reported in Europe and a large, deadly outbreak occurred in Northern Italy (Spiteri et al., 2020). The first case of COVID-19 in the United States was reported at an urgent care clinic in Snohomish County, Washington on January 19, 2020 (Holshue et al., 2020). By the end of February, the disease had spread to New York City with 13,000 deaths reported by May (Gonzalez-Reiche et al., 2020, p. 1).

The WHO declared the COVID-19 outbreak a global pandemic on March 11, 2020 (Cucinotta & Vanelli, 2020) followed by an emergency declaration for the entire United States (FEMA, 2020). Most non-essential businesses and services were closed across the country during the shutdown. The U.S. healthcare system experienced severe and widespread disruptions as a result of these measures and from the effect of coronavirus caseloads on medical services. Providers faced difficult decisions about conserving critical resources, such as ”hospital and ICU beds, respirators, transfusion capacity as well as protective gear (e.g. PPE)” (American College of Surgeons, 2020a, p. 1). Healthcare workers were also vulnerable to infection, with one study reporting a cumulative 11.33% infection rate amongst its staff (Colaneri et al., 2020). All of these effects compounded to create unprecedented strain on medical systems worldwide as the pandemic progressed.

1.2 Background of the Problem

Surgical services experienced particularly acute and unprecedented disruption. With the exception of urgent or emergent cases, most surgical procedures were postponed or canceled during the shutdown, representing a major loss of revenue for many healthcare providers. One study noted a decrease in procedure counts of 48% overall during the initial shutdown period compared with the corresponding weeks in the prior year (Mattingly et al., 2021). April 2020 represented a nadir when procedure counts were at their lowest compared with the same month in the previous year. Total procedure counts in May were also heavily impacted compared with 2019.

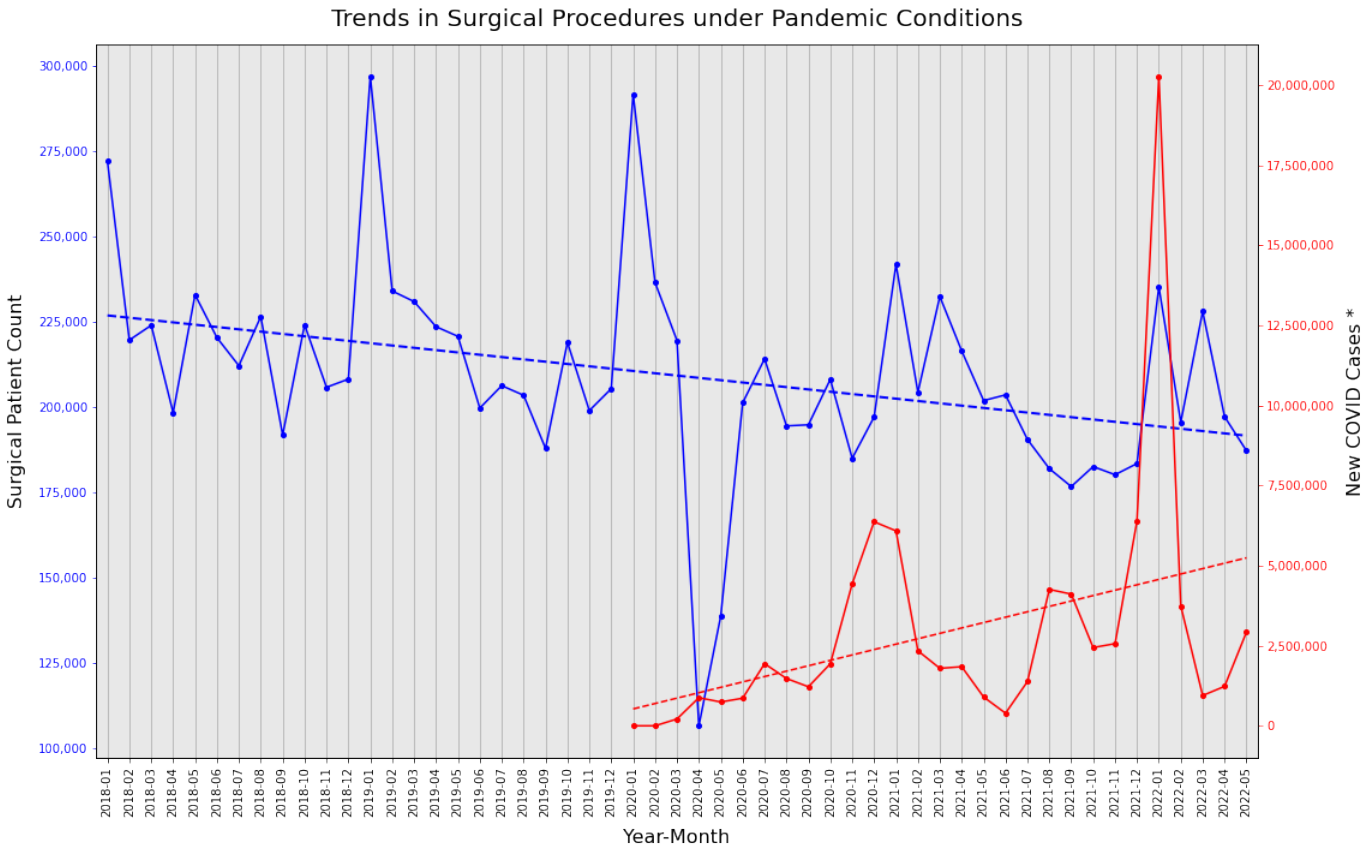

Figure 1.1: Trends in Surgical Procedures under Pandemic Conditions

The overall trends in surgical patient volume are shown in figure 1.1 for claims included in this study. Counts naturally fluctuate significantly from month to month based on seasonal factors. An extreme drop in patient counts during April 2020 was evident, as well as the relatively quick recovery and return to the mean. Also shown in the graph are COVID cases as tallied by the CDC data tracker (CDC, 2022). Pearson's correlation coefficient was calculated on monthly COVID cases and surgery counts during the post-shutdown period, resulting in a negative correlation of -0.43 and p-value $<$ 0.05, implying that higher COVID caseloads were associated with fewer patient counts. This type

of correlative analysis would be inappropriate for the March-May shutdown period because COVID counts were drastically underestimated during this time period (Wu et al., 2020).

Following the nationwide emergency declaration, several professional medical organizations, including the American College of Surgeons (ACS) and the Center for Medicare & Medicaid Services (CMS), issued guidelines for surgical services under pandemic conditions. The ACS issued a joint statement on April 17 outlining recommended procedures and considerations for resumption of elective surgeries (American College of Surgeons, 2020b). The CMS document recommended a tiered framework in which elective procedures were postponed to handle the most pressing and life-threatening conditions. Immediate treatment was recommended only for the highest tier of cases in which ”lack of in-person treatment or service would result in patient harm” (Center for Medicare & Medicaid Services, 2020, p. 2). The FACS provided much more detailed guidance by surgical specialty with similar goals (American College of Surgeons, 2020a). Both notices provided guidance for conserving limited healthcare resources and limiting the exposure of patients and staff to infection. Resumption of elective surgeries began in late May after the government-mandated shutdown, with recovery continuing into June and July, by which time rates had rebounded approximately to 2019 levels for most types of procedures (Mattingly et al., 2021, p. 3).

1.3 Statement of the Problem

Social Determinants of Health (SDH) are important factors affecting health outcomes and include ”socio-economic, cultural, environmental, living and working conditions, social and community networks, and lifestyle choices” that ”contribute to a person’s health and well-being” (Bonner, 2018). Some typical examples might include patient age, race and gender. Disparities based on these factors are common in many areas of medicine. For example, COVID-19 death rates varied significantly amongst different racial and age groups (Boserup, McKenney, & Elkbuli, 2020, p. 1617). An open question is the extent to which surgical service delivery during the pandemic was impacted by these racial, economic, and behavioral population characteristics. These variables may have had a statistically significant impact on service delivery that disproportionately affected medical provider guidance on what surgeries were performed and the patient cohorts being served.

1.4 Purpose of the Study

This study takes a data-driven approach to address the issue by examining surgical utilization before and during the pandemic from a very large medical claims dataset representative of the U.S. healthcare ecosystem. A statistical analysis of surgical volumes by a subset of socio-demographic data elements highlights various findings. The study will attempt to determine if disparities in surgical services were present during the pandemic and quantify the magnitude of these differences.

1.5 Research Questions

The following questions are addressed:

- To what extent were changes in *total surgical service utilization* correlated with patient race, education, or economic level?
- To what extent were changes in *specific surgeries or groups of related procedures* correlated with patient race, education, or economic level?

Sub-questions related to individual factors may include:

- Was educational achievement level associated with higher or lower utilization of surgical services during the pandemic compared with previous periods?
- Did economic stability level affect access to surgical procedures during the pandemic?
- Were there any racial disparities in surgical procedure access based on comparison to prior time periods?

The null hypothesis for each factor is that there were no differences or disparities caused by the pandemic, whereas the alternative is that the pandemic affected access to surgical care of patients within each subcategory differently.

1.6 Significance of the Study

Hospital leadership and individual service providers need to be aware of disparities in access between different demographic and economic groups. Additionally, revenues may be disproportionately associated with one or more of these groups, affecting overall finances for these organizations. Understanding

the effects of surgical triage on different cohorts compared with prior periods can help administrators in planning for future scenarios in which services may be limited due to exigent circumstances such as a pandemic or other systemic disruption.

1.7 Definition of Terms

Social Determinants of Health (SDH) are ”are the conditions in the environments where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks” (U.S. Department of Health and Human Services, 2020). SDH are divided into a number of domains, and this study will focus on just a few.

Current Procedural Terminology Codes (CPT) are a standardized set of codes for doctors and healthcare professionals to specific services and procedures in medical records (American Medical Association, 2020). A limited set of **Category I** codes denoting major surgical procedures was used in the analysis for this study.

An **urgent or emergency surgery** is performed because of an urgent, possibly life-threatening medical condition. An example of a common urgent or emergent surgical procedure is an appendectomy (Johns Hopkins Medicine, 2020).

An **elective surgery** is scheduled in advance and may lead to a better quality of life. Some elective surgeries are performed for serious, life-threatening conditions such as cancer (Johns Hopkins Medicine, 2020) but may not technically be classified as urgent or emergent.

A **pre-** period is a duration of time before the pandemic, used for comparison purposes. A **peri-** period is some time interval during the primary pandemic, such as the month of April, 2020 during the initial shutdown. A **post-** period is a duration of time after the primary pandemic like April, 2021. For the purposes of this study, the **nadir** period is April, 2020 when surgical services dropped to their lowest levels compared with the same month in previous years. This time frame will be used as a basis of comparison to characterize changes in specific population groups and types of surgeries.

1.8 Assumptions, Limitations, and Delimitations

A proprietary database of medical claims records was used for this study. Uninsured patients who underwent surgical procedures during the relevant time periods were thus excluded from the analysis.

The data only included claims from private insurers, so Medicare, Medicaid and VA patients were also not represented. The total number of claims by year was not normalized for the possible addition of new providers. An expert estimated that the total claims volume could increase by around 2-3% per year due to this effect, though it is unknown whether this was the case for 2018 through 2020. A limited set of indicators was selected for the study based on the data available. The limitations of the dataset excluded other potential variables that might have been of interest but were not present.

1.9 Conclusion

The COVID-19 virus quickly spread from its place of origin in China to cause an unprecedented global crisis. The pandemic and the resultant shutdown caused major disruptions in medical services, particularly for surgical procedures. The extent to which these disruptions in surgical services correlated with patient demographic and economic characteristics is an open question. This study will attempt to establish whether variables such as patient race, education level or economic stability level effected access to surgical procedures during this period, based on statistical measurements of usage across a number of different canonical surgery types and groups.

Chapter 2

Review of the Literature

2.1 Introduction

The specific research area of impacts on surgical services during the pandemic by racial, demographic and economic groups is relatively unexplored in the literature and lacks many specific references. But there are several key sources which do discuss impacts to surgical services in the U.S. population during the pandemic. These include some analysis of group cohorts by age, gender, and region. The client for this study provided references to several directly relevant journal articles as a basis for extension by this analysis. These articles are covered in-depth within the review, as they heavily informed the conceptual and theoretical framework for the study.

2.2 Search Description

Two main areas were investigated in the literature search. The first was the general impact of COVID-19 on U.S. society and its medical systems. Several well-known articles on this topic were referenced within the aforementioned primary articles that covered surgical procedures. These important historical articles were used for introductory and background material. Additionally, searches were performed with in the McIntyre Library (UW-Eau Claire, 2022) system using phrases such as ”covid surgical services.” These resulted in articles covering the impact of the pandemic on surgical services, though the SDH aspect was generally unstudied.

2.3 Conceptual or Theoretical Framework

This study is primarily concerned with characterizing surgical services disruptions during the COVID-19 pandemic based on possible socio-demographic and economic covariates. Since this is a relatively novel research area, there are no exact matches for sources. However, two different journal articles were provided by the client as a framework and starting point for analysis. One of these studies addressed surgical services utilization during the pandemic across major and minor CPT code groups and a set of exemplar procedures, in addition to several other related topics (Mattingly et al., 2021). The other study discussed impacts to surgical services within the Veteran's Administration (VA) network (Rose et al., 2021). The client was a co-author on both of these articles. Together, these two articles provided the primary conceptual and theoretical framework for this the analysis. A number of articles detailing impacts on surgical subspecialties such as oncology are also included in the review, as well as one discussing general impacts on the US healthcare system. In addition to these works, a number of well-known articles on the COVID-19 pandemic and its origins were used as background and introductory material.

2.4 Review of Research

2.4.1 COVID-19 Pandemic

The COVID-19 pandemic itself is a well-explored topic in the academic literature with a wealth of additional source material in governmental documents, the mainstream media, and so on. An article in the *New England Journal of Medicine* was used for background on the early origins of the pandemic in the United States (Holshue et al., 2020). A document in *Science* covered the spread of coronavirus to New York City and the subsequent deadly outbreak there (Gonzalez-Reiche et al., 2020). A number of governmental declarations were used as background material for the pandemic timeline, including FEMA's initial emergency declaration (FEMA, 2020). Two main documents issued by well-known professional medical organizations provided guidelines for surgical services triage under pandemic conditions (American College of Surgeons, 2020a) (Center for Medicare & Medicaid Services, 2020) as well as guidance on resuming services as conditions improved (American College of Surgeons, 2020b). This material emphasizes the unprecedented nature of the pandemic, its rapid spread throughout the world, and the shutdown procedures put in place. The surgical guidance documents outline

triage procedures put in place, which were used by medical providers in determining which surgical services should be performed during the shutdown, as opposed to being postponed, canceled, or resolved with (possibly temporary) alternative treatments.

2.4.2 Surgical Service Disruptions

The study "Trends in US Surgical Procedures and Health Care System Response to Policies Curtailing Elective Surgical Operations During the COVID-19 Pandemic" aims to "describe the change in surgical procedure volume in the US after the government suggested shutdown and subsequent peak surge in volume of patients with COVID-19" (Mattingly et al., 2021, p. 1). The Mattingly study analyzed claims data provided to a Standard University research group as part of the COVID-19 Research Database consortium, which is a "a cross-industry collaborative of deidentified data provided pro bono to facilitate COVID-19 research" (Mattingly et al., 2021, p. 3). Twelve months of data from 2019 were used as a baseline to characterize pre-pandemic patient volumes. Participants included all those who had a claim for a surgical procedure during the specified period. Double counting was avoided by including only the first claim in cases where there were multiple ones in the same calendar year from an identical patient. A surgical procedure was defined as one that would typically be expected to be performed in an operating room, so procedures such as injections and biopsies were excluded. The study used 11 major and 25 minor categories defined by sets of medical codes. An additional analysis was performed on 12 high-volume "exemplar procedures" selected as representative of elective, mixed elective and urgent, or always urgent (Mattingly et al., 2021, p. 3-4).

The Mattingly study functions as a direct departure and comparison point for this study's research, as both use a similar set of private insurance claims. That article primarily used Incidence rate ratios (IRRs) as a method of assessing surgical activity volumes during the initial shutdown and subsequent surge. The study used a total of 13.1 million procedures from January 1, 2019 through January 30, 2021 which included 3498 Current Procedural Terminology (CPT) codes. The study notes a decrease of 48% in total procedure counts across all major categories during the initial shutdown compared with the same period in 2019. The study found that otolaryngology (ENT) and cataract procedures decreased the most among the major categories and that organ transplants and cesarean deliveries did not differ significantly from their 2019 levels. Additionally, the study found that surgical procedure volumes rebounded to approximately 2019 levels following the initial shutdown and that there was

a correlation between COVID-19 case volumes and surgical procedure counts, whereas there was no correlation between these variables during the subsequent surge.

The Mattingly study found a -10.2% change in overall surgical procedure volume in 2020 vs 2019 for the entire year which was nearly identical between women and men. Those under the age of 18 saw a -21.3% decrease with those in the age bracket between 18 and 79 seeing roughly the same levels of change, between -8.6% and -9.3%. Those older than 80 saw slightly more decrease at -11.1%. The study also divided the patients by census region, finding that those in the Northeast had the largest decrease in service counts at -18.0%. The West had the smallest decrease at -5.3% with the Midwest and South in between these. (Due to these demographics being well-covered in the article, the current study will not include them in its cohorts.) Exemplar procedure volume was studied during the initial shutdown compared to the same period in 2019, finding that elective procedures such as cataract repair and bariatric surgery decreased the most with IRRs of 0.11 and 0.12 respectively. Arranged by most to least elective, the IRR measurements increased for these procedures with the most urgent ones, such as caesarean deliveries, showing little to no change compared with 2019 values. The study also found a negative correlation between volumes of COVID-19 patients and surgical procedure counts. The majority of US states were found to have had surgical procedure rates equaling or exceeding those from 2019 in the post-shutdown period.

Overall, the Mattingly study found that there was a major decrease in surgical procedures during the shutdown when there was guidance in place recommending restrictions to perform surgeries on only the most urgent cases. The decrease is attributed to ”compliance with directives to curtail elective surgical procedures and perform only urgent or emergent procedures” (Mattingly et al., 2021, p. 9). They also conclude that surgical volumes for emergency surgical procedures such as amputations or organ transplants were almost unaffected, suggesting that providers complied with directions to only treat life-threatening, urgent conditions while postponing most elective care. After these restrictions had been lifted, volumes for most procedures tended to rebound to 2019 levels, approximately. This resulted in only a -10% change in total volumes in 2020 compared with 2019. There was an inverse relationship found between COVID-19 disease burden by state and surgical procedure rates during the shutdown but not during the surge, when volumes were maintained at 2019 levels or above. The study states that the exact causes of the missing operations for the entire year are unknown and may include ”decisions to defer or forgo care for nonurgent conditions” or ”successful nonoperative management of conditions potentially requiring surgical treatment” (Mattingly et al., 2021, p. 9). This area of causation

is highlighted by the study as one worthy of possible future research.

2.4.3 VA Services

A similar study to Mattingly used data from Veterans Affairs hospitals rather than private insurance claims (Rose et al., 2021). (The two articles share a number of the same authors and a similar research methodology.) The Department of Veterans Affairs (VA) performs ”over 600,000 operations annually and is the largest single health system in the US.” The VA followed previously mentioned national guidelines to stop elective surgeries beginning March 15, 2020. The definition of urgent or elective cases was not provided by any specific VA directive, leaving care decisions and triage up to the staff of individual facilities. The VA system has ”a capitated care payment model minimally influenced by market forces” and so may be used to approximate the minimum surgical volumes in the context of a ”national health crisis” such as the COVID-19 pandemic (Rose et al., 2021, p. 1). This research will be referred to as the ”Rose study.”

The Rose study used the VA Corporate Data Warehouse, a comprehensive nation-wide repository of electronic health records at VA facilities, to analyze all surgical procedures from January 1, 2019 to July 1, 2020. This research was performed earlier than Mattingly and did not include the entirety of 2020 in its analysis. Weekly procedure counts by specialty and 17 specific procedures were compared for three periods, defined as Pre-Mandate, Mandate, and Restart (Rose et al., 2021, p. 1). This study also used IRR analysis with Poisson regression on daily surgical procedure counts to characterize changes between comparable periods. The study found that operations in the VA system decreased more than 75% from the Pre-Mandate to Mandate periods, with specialties such as plastic surgery and orthopedic surgery decreasing the most and more typically urgent or emergent areas like cardiac and vascular decreasing the least. This result aligns with the subsequent conclusion that elective procedures saw much greater declines than urgent or emergent ones. As the study states, ”surgical operations with the largest decline were associated with function and quality of life rather than survival.” And ”[D]uring the Restart period, these same quality of life-driven procedures rebounded most dramatically but no procedures have yet to return to prepandemic levels” (Rose et al., 2021, p. 1). An additional study found that even hospitalization levels for emergency conditions within the VA system were heavily affected during many weeks of the pandemic (Baum & Schwartz, 2020). Whether these ”missing” patients went to non-VA facilities or did not receive treatment at all for their conditions is unknown.

2.4.4 General Medical Services

General impacts on medical services during the pandemic were also reviewed (Whaley et al., 2020). The Whaley study examined ”[c]hanges in use of preventive services, nonelective care, elective procedures, prescription drugs, in-person office visits, and telemedicine visits [during] the first 2 months of the COVID-19 pandemic in 2020 relative to existing trends in 2019 and 2018” (Whaley et al., 2020, p. 1). This research attempted to identify possible disparities in health care use based on the patient's race and income, identified by economic and demographic characteristics of the population in their zip code.

Patient populations with similar demographics were studied for the years 2018, 2019, and 2020. Statistics were ”regression-adjusted” and normalized per 10000 persons (Whaley et al., 2020, p. 1). Changes for March and April 2020 were characterized by use rates for a variety of medical procedures, including colonoscopies, mammograms, homoglobin tests, and so on. The study noted smaller reductions for in-person visits in zip codes with lower-income or majority racial or ethnic minority populations along with a lower adoption rate of telemedicine visits. Overall, the study identified a dramatic reduction in preventative and elective care during the first two months of the pandemic compared with analogous periods in 2018 and 2019, which is consistent with the broad conclusions of other sources.

2.4.5 Surgical Specialties

Several more studies provided insight into how specific surgical specialties were affected during the pandemic. Chang and Liu found significant decreases in oncological patient counts across all subspecialties for December 2019 to May 2020 compared with December 2018 to May 2019 (Chang & Liu, 2020). They used one-way analysis of variance and pairwise comparisons to identify statistically significant differences in mean counts, finding that all types of surgery in the study were affected by the pandemic. Hewage and Harky studied cardiac surgical services and noted a ”shortage of ventilators, intensive care beds, personal protective equipment, and staff in the workforce of the healthcare system” (Mohamed Abdel Shafi, Hewage, & Harky, 2020). They found that services became more centralized and were restructured to maintain care, with active triage measures put in place to determine which patients were in need of immediate, potentially life-saving care. An article on gastrointestinal surgeries in India described a range of precautionary procedures undertaken to minimize infection risk, includ-

ing COVID-19 tests for incoming patients, minimization of traffic within the operating theatre, various adjustments to surgical techniques, and so on (Kapoor, Perwaiz, Singh, & Chaudhary, 2021). Patients were also selected based on urgency with benign cases postponed. The study claimed that no patients in the study contracted COVID-19 while in hospital, and they attribute this success to the thoroughness of these measures. Finally, a review article on thoracic surgical services noted similar wide-ranging procedures to minimize infection risk including restriction of visitor attendance, tele-medicine appointments in place of in-person checkups, and reduction of the length of stays for patients. These various studies show that while the pandemic had a severely disruptive effect on surgical services delivery, providers were pro-active in implementing measures to maintain care even during the most adversely affected time period.

Chapter 3

Research Methodology

3.1 Introduction

The year of 2020 saw a significant overall drop in surgical patient counts of approximately 10% compared with 2019 and a decrease of 48% during the initial shutdown period (Mattingly et al., 2021, p. 9). The extent to which the level of these changes differed based on patient racial, economic and demographic factors is an open question. The Mattingly study states that ”we did not include data on diagnostics, race, or other social determinants of health in this analysis and cannot make claims about the association of underlying conditions with surgical treatment decisions or potential disparities in operative access.” The purpose of this study is including several of these factors in a statistical analysis to determine if there appeared to be correlations with levels of service disruption.

3.2 Research Design

The analysis is primarily descriptive and based on comparing counts between time periods. The year of 2019 is a baseline for normal conditions whereas 2020 was heavily affected by the pandemic. In particular, the month of April was the nadir period when surgical procedure counts were at their lowest, so it is used to characterize the most extreme effects of the pandemic on the relevant medical services and patient cohorts. In addition to counts, proportions were computed and analyzed for yearly and monthly periods, to determine if these differed between periods.

Specific techniques included in the study included:

- Exploratory data analysis using *barcharts*
- *Percent change of yearly patient counts* for 2020 over 2019
- *Percent change during the nadir period* compared with the equivalent month in 2019
- *Times series* charts showing percent change in patient counts for 2020 over the corresponding months in 2019
- *Chi-square test of proportions* for the nadir period versus the same month in 2019
- Detailed *contingency tables* with chi-square test results (p-value) comparing the nadir period with the same month in 2019

Percent change is used to provide a measurement of how much a given subcategory was effected between periods. Differences between the percent change values within social determinant categories may infer an effect stemming from these factors.

3.3 Research Questions and Hypotheses

Section 1.5 outlined the high-level research questions to be addressed using available demographic and economic factors. Several assumptions underlie expectations of possible differences between disruptions based on these factors. Economic factors are likely to have the greatest correlations to decreases in patient counts. Research suggests that trends in adverse health outcomes may correlate with lower income and educational levels in the United States (Venkataramani, O'Brien, Whitehorn, & Tsai, 2020). The less economically stable are likely to have lower quality insurance with higher deductibles and limits compared to those who are more economically well off. This situation may lead to surgeries being deferred or forgone entirely based on financial considerations. One study noted significant differences in knee replacement surgery rates between racial groups, for instance (Skinner, Zhou, & Weinstein, 2006). Disparities in care that are present in normal conditions are likely to have persisted during the pandemic. A large proportion of surgeries under normal conditions are elective rather than urgent or emergent, and it is expected that wealthier groups have better access to this type of care, so they may have been disproportionately effected during the pandemic, with a greater level of disruption present.

The shutdown from March 16 to May 3 in 2020 saw a cessation of nearly all elective surgeries at most private healthcare facilities. Given this level of disruption, the impact on total patient counts during this period should likely be somewhat higher amongst wealthier economic groups, assuming that access to elective surgeries is economically disproportionate to some extent, a priori. Following the shutdown, deferred surgical procedures should be expected to drive an increase in overall patient counts with possible differences in the recovery period between groups. Tracking which surgeries were deferred until a later date or forgone entirely because of the shutdown or other pandemic-related factors was essentially impossible to determine analytically, but month-by-month trends may show notable variation within a category, suggesting that certain types of patients may have returned after the shutdown to receive care that was necessary for personal or occupational reasons.

3.4 Population and Sample

There were 3501 CPT codes included in the analysis, corresponding to major surgeries requiring the usage of an operating room. These were selected by Dr. Sherry Wren of Stanford University to cover 10 major and 25 minor surgical groups. The definitions of the groups and the number of codes in each are described in appendix A.1. Patient health insurance claims matching these codes were selected for the study from the total claims data for the relevant years. In order to avoid double-counting, these records were de-duplicated by selecting only the first claim per year as a contribution to patient count. (It was a common occurrence in the dataset to have multiple claims for a single surgery performed on the same patient.) After filtering, approximately 7.6 million claims were included across the full range of 2018 through 2020. The years 2019 and 2019 were used as comparatively normal periods and 2020 functioned as a measure of pandemic conditions.

3.5 Instrumentation and Data Collection

Patient data was collected from an enterprise data warehouse containing a large proportion of the total claims data for the United States. The healthcare organization maintaining this data store processes approximately 40% of the private insurance claims nationwide and retains this information for data analytics. Within the data warehouse, records had already been deidentified according to industry standards following federal privacy regulations such as HIPAA. Patients in the database were assigned

a unique hash code identifier and their names and addresses were not retained for analysis. These and other standard procedures ensured that patient consent for inclusion in the study was not legally or ethically necessary, as the risk of re-identification for an individual patient was deemed to be negligible.

The data warehouse also contains a separate table of demographic and economic data with 25 main dimensions, originally purchased from an external data broker. Patients were assigned to specific records in this table according to a proprietary, probabilistic matching algorithm with less than a 1% non-match rate. For the study, a subset of the best-measured and most interesting factors were selected. A three way table join of the surgical codes, patient claims, and social determinant data was saved to a custom table within a user database schema within the data warehouse. These records were then de-duplicated and saved to another table that was used for the final analysis. SQL queries were used to read from the final table into a cloud computing environment where analysis was performed.

3.6 Data Analysis

Exploratory data analysis was done with bar charts to investigate which of the factors seemed appropriate for further analysis. Some were found to contain too many ”unknown” (unmeasured or unmatched) values and were subsequently dropped. A subset of the factors available were chosen for further analysis. The primary ones included patient race, education level, and economic stability. Each factor was represented as a categorical variable with a number of sub-categories. For instance, **Race** was a category with ”African American,” ”Hispanic,” etc. as subcategories. Percent change measurements on each of these sub-categories was used to measure the effect of pandemic conditions.

Percent change is a simple metric to measure differences in counts between time periods, calculated using the following formula:

$$PCT\_CHANGE = (NEW - OLD)/OLD$$

These values were determined for each subcategory across all surgical procedures to show the percent change in 2020 as a percentage of those in 2019. The percent change metrics within a given category were compared by subcategory to determine if any significant differences were apparent. The same metric was used to measure differences between the nadir period and the corresponding period in the prior year.

Contingency tables were constructed for each category by major surgical group. This procedure postulated the time period as the effect with the subcategory count as the dependent variable. As part of

this analysis, proportions were calculated from the contingency tables in order to compare them from year to year. These tables were used in a chi-square test to determine if the time period seemed to be associated with a difference in proportions. Tests were performed using 2019 and 2020 as a measure of pandemic conditions and 2018 and 2019 as a point of comparison. The combination of percent change metrics by year and month and the chi-square test of proportions were used to evaluate if significant differences were present between the subcategories, either in proportions or percent change.

3.7 Conclusion

The extent to which surgical service delivery was correlated with racial, demographic and economic factors during the coronavirus pandemic is an open question within the field of medical research. Significant total drops in yearly and monthly surgical patient counts were noted in the literature. Patient data was gathered from a major claims database, filtered and aggregated by surgical code, and joined to a table of patient social determinant factors. Several categories were selected after preliminary analysis and the percent change during these periods was compared with normal, baseline periods. Additionally, contingency tables were constructed on which a chi-square test of proportions was performed to assess if the time period seemed to be associated to a statistically significant difference in proportions.

Chapter 4

Results

4.1 Introduction

4.1.1 Data Exploration and Selection

Each social determinant used in the analysis was stored as a categorical variable in the database. A patient's identity was connected to a categorical measurement for every field aside from those without matches. The available data columns which were considered for initial inclusion are described in appendix A.2. The data dictionary does not provide information on all the factors which were available in the social determinants table, only those that were considered initial candidates for inclusion before the data selection process. Their values range from binary (yes/no) measurements to three or more subcategories per variable. Those fields in which the raw data had many values on a scale, such as the economic stability rating, were generally reduced into a practical number of categories based on ranges. The social determinants database had a large number of factors available, so a selection process was implemented to find those which would be most useful and interesting for analysis.

4.1.2 Available Social Determinant Factors

The list of factors initially considered for inclusion in the analysis were the following:

- **Big Tall or Plus Size** is a Y/N measurement denoting a purchase of women's Plus Size or Men's Big and Tall clothing within the last 24 months. It could presumably be used as a proxy for patient obesity.
- **Economic Stability** is an economic stability rating derived from a proprietary set of criteria. The numeric scale was reduced to a smaller set of possible values by range.
- **Education 2nd Individual** and **Education 2nd Individual** denote the highest level of educational achievement by the first and second person in the household, respectively. It is unknown which of these correspond to the patient in the insurance claim.
- **Estimated Income** denotes the income bracket of the household.
- **Home Market Value** is an estimation of the value of the household's residence if they are homeowners.
- **Marital Status** denotes if anyone in the household is married.
- **Number of children** is the highest known number of children in the household.
- **Occupation 1st Individual** and Occupation 2nd Individual is an encoding of the occupation of the 1st and 2nd individuals in the household, respectively. These were transformed into to a reduced number of possible values based on the raw data (e.g. white collar professions were grouped into one sub-category).
- **Race** indicates the race demographic of the household.
- **Homeowner or renter** is a Y/N value indicating whether the household is owner or renter occupied.
- **Senior Adult in Household** indicates if there is a person over age 55 and a person over age 25 with a least an 18 year difference between them in the household.

The null hypothesis for each of these is that the proportions within a given category (e.g. race) did not vary significantly by sub-category (e.g. white, hispanic, etc.) between a "normal" (pre-pandemic)

time period compared with an analogous one during the pandemic. The three primary variables selected were **Race**, **Economic Stability** and **Education 1st Person** with others included depending on the specific analysis.

4.1.3 Feature Selection

Bar charts of counts showing categories and the number of unknown values were used as the primary tool for data exploration and feature selection. Some fields that initially appeared promising were eliminated due to a low match rate, with values appearing as ”NaN” or ”Unknown.” For other fields, the quality of the data itself was suspect due to an inherently low match rate or suspicions that it was inaccurately measured. Variables with a large difference in counts between sub-categories were considered for elimination. Some of the lower quality variables are shown in figure 4.1.

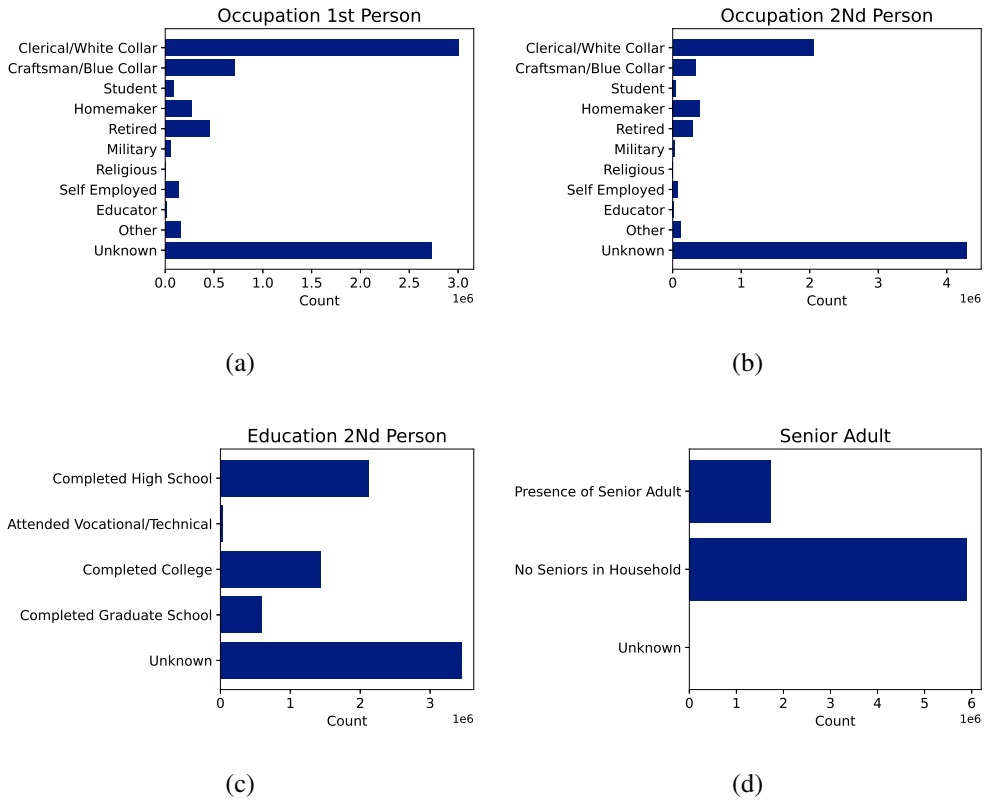

Figure 4.1: Low Quality Social Determinants

The Occupation 1st Person and Occupation 2nd Person fields have very imbalanced categories. Education 2nd Person and Senior Adult have low match rates. (The specific match rates of each factor are not included in this study for reasons of data propriety.)

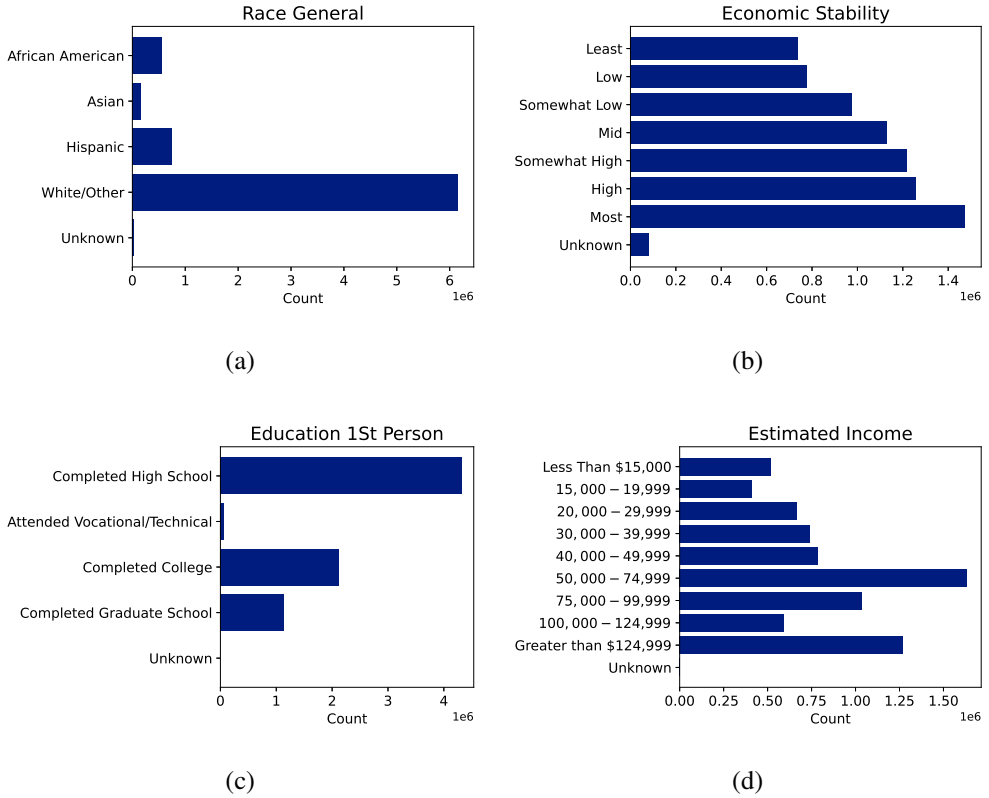

Figure 4.2: High Quality Social Determinants

Figure 4.2 shows categories that were determined to be of higher quality and thus greater interest. The race category had a high match rate and roughly reflected the expected demographic proportions within the general population. Potential differences in service levels between different racial demographics was also determined to be of high interest in terms of societal importance, and the nature of the data meant that there few other explicitly demographic measurements available. **Economic Stability** was evenly distributed between sub-categories and had relatively few ”Unknown” values. Similarly, the educational achievement measure had virtually no unfilled values with a reasonable distribution between sub-categories. **Estimated Income** appeared to be balanced between sub-categories as well and provided an additional economic covariate. **Home Market Value** is not plotted here but will be used as an additional economic factor. Overall, patient race, economic stability, and education level were determined to be of high interest in assessing the impact of the pandemic.

4.2 Findings

4.2.1 Analysis of Proportions

Chi-squared tests were used to determine whether the proportion of patients within each major surgical group and category were effected by pandemic conditions. A separate contingency table was constructed for each combination of category and major surgical group. This was used in a chi-square test of proportions to measure the difference between two time periods, the nadir of April 2020 and the same month in the prior year (April 2019). Differences in proportions of patients across subcategories would provide evidence that the pandemic had an effect. The same analysis was performed using data from April 2018 and April 2019 to provide a point of comparison during a normal period. An example contingency table for only musculoskeletal (MSK) surgeries and race is show in figure 4.3 with the the full set of surgical groups in figure 4.4 that includes p-values as a measure of significance. The full table includes the proportion that subcategory represents in parentheses.

race_general yearmo	African American	Asian	Hispanic	White/Other
201904	4549	1339	5959	58142
202004	1798	465	2282	21904

Figure 4.3: Example Contingency Table

Group	P-value	Year	African American	Asian	Hispanic	White/Other
Cardiovascular	0.47736	2019	1661 (0.105)	318 (0.02)	1647 (0.104)	12241 (0.771)
		2020	1006 (0.101)	216 (0.022)	1069 (0.108)	7625 (0.769)
ENT	0.092898	2019	70 (0.075)	31 (0.033)	73 (0.079)	754 (0.812)
		2020	34 (0.048)	18 (0.025)	53 (0.075)	603 (0.852)
General	0.22795	2019	4937 (0.078)	1475 (0.023)	7687 (0.122)	49141 (0.777)
		2020	2271 (0.076)	748 (0.025)	3561 (0.12)	23198 (0.779)
MSK	0.1382	2019	4549 (0.065)	1339 (0.019)	5959 (0.085)	58142 (0.831)
		2020	1798 (0.068)	465 (0.018)	2282 (0.086)	21904 (0.828)
Nervous System	0.046229	2019	1434 (0.063)	351 (0.015)	1714 (0.075)	19340 (0.847)
		2020	657 (0.068)	162 (0.017)	780 (0.081)	8053 (0.834)
OBGYN	0.0015987	2019	1329 (0.127)	351 (0.034)	1865 (0.178)	6919 (0.661)
		2020	976 (0.13)	250 (0.033)	1496 (0.2)	4767 (0.637)
Skin	0.047991	2019	1989 (0.056)	552 (0.016)	2745 (0.078)	29949 (0.85)
		2020	1164 (0.062)	319 (0.017)	1437 (0.076)	15931 (0.845)
Thoracic	0.34117	2019	163 (0.092)	40 (0.023)	164 (0.093)	1401 (0.792)
		2020	107 (0.082)	38 (0.029)	106 (0.082)	1047 (0.807)
Transplant	0.99584	2019	20 (0.09)	9 (0.04)	41 (0.184)	153 (0.686)
		2020	15 (0.084)	7 (0.039)	34 (0.19)	123 (0.687)
Urology	0.94472	2019	165 (0.082)	57 (0.028)	204 (0.101)	1596 (0.789)
		2020	132 (0.081)	41 (0.025)	160 (0.099)	1291 (0.795)

Figure 4.4: Full Contingency Table for Race

Each chi-square test generated a p-value measuring the association between time period and subcategory proportions within a single surgical group. These test values were arranged into a grid and plotted using a color map in figures 4.6 and 4.5. (Appendix B.1 provides the corresponding test statistic values.) The lighter shade indicates a lower p-value and hence stronger effect. The comparison of 2019 versus 2020 generally shows greater levels of significance than 2018 and 2019, indicating that the patient proportions within each subcategory were different from each other at a statistically significant

level. The test between April 2018 and 2019 shows weaker association based on p-value, indicating that most of the proportions did not differ significantly. Of particular note in the 2019 and 2020 comparisons are the differences in the MSK surgical category. The proportions for every factor were identified as varying significantly. Speculatively, this may indicate that the set of surgeries within this group which did occur during the shutdown period contained a higher proportion of more urgent or emergent procedures than in normal times, and the patient population may have differed correspondingly.

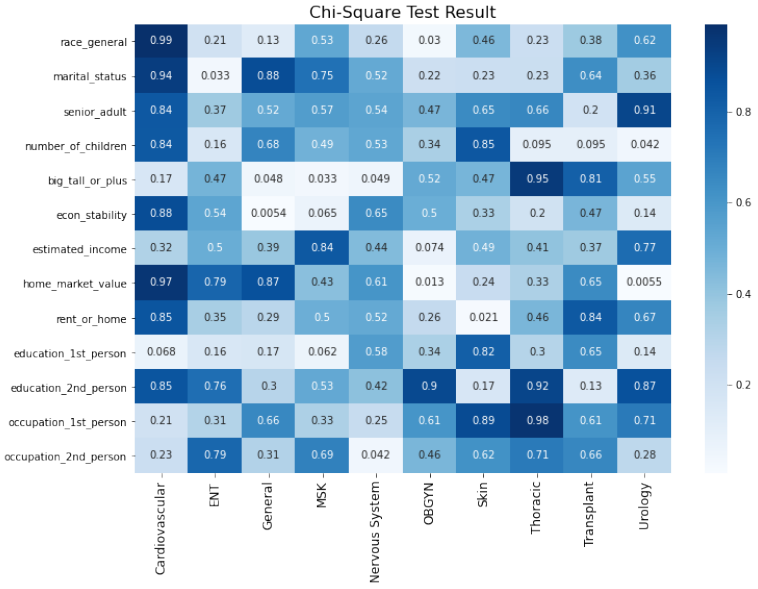

Figure 4.5: Chi-square Test Results for April 2018 and 2019

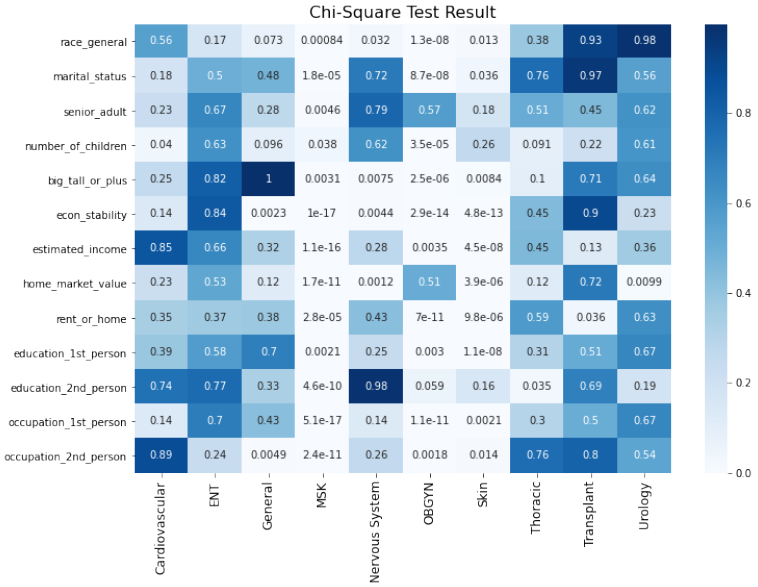

Figure 4.6: Chi-square Test Results for April 2019 and 2020

4.2.2 Time Series

Time series graphs were created showing the month-over-month percent change between 2019 and 2020 for each category. These show that patient levels tended to be roughly analogous between 2019 and 2020 from January to March, or at least varied about the mean in an expected fashion. In April 2020, patient volumes dropped precipitously for all groups, due to cessation of non-urgent or emergent surgical procedures during the shutdown. Patient volumes had largely recovered by the end of the year but for some subcategories remained 5-10% below their 2019 levels to close out the year in December.

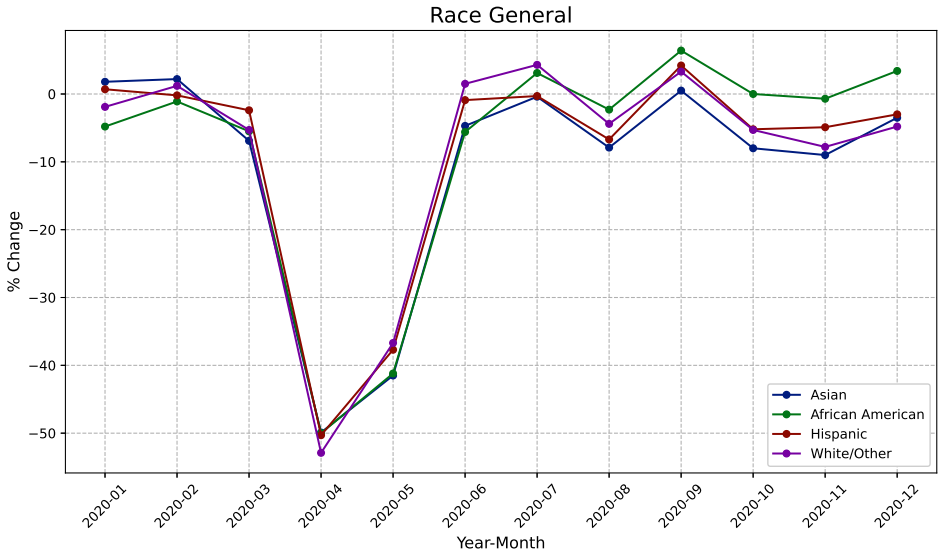

Figure 4.7: Time Series by Race

Figure 4.7 shows the monthly percent change by race. During April of 2020, the ”White/Other” subcategory saw a slightly greater drop in counts than the other groups by about 5% but had surpassed 2019 levels by June. Levels in this group were depressed by approximately 5% by the end of year compared with the prior period. The counts in the ”African American” group did not drop quite as much in June, surpassed their 2019 levels by July, and ended the year higher than in 2019. The causes of these differentials between racial groups is not known. A likely hypothesis is that the complex and varying dynamics of cancellation, rescheduling and deferment varied amongst medical providers and communities during and after the shutdown. Individuals within different demographics may also have had somewhat varying levels of concern regarding the coronavirus itself, which made them more or less likely to utilize medical services, where it was perceived that the risk of infection was relatively high.

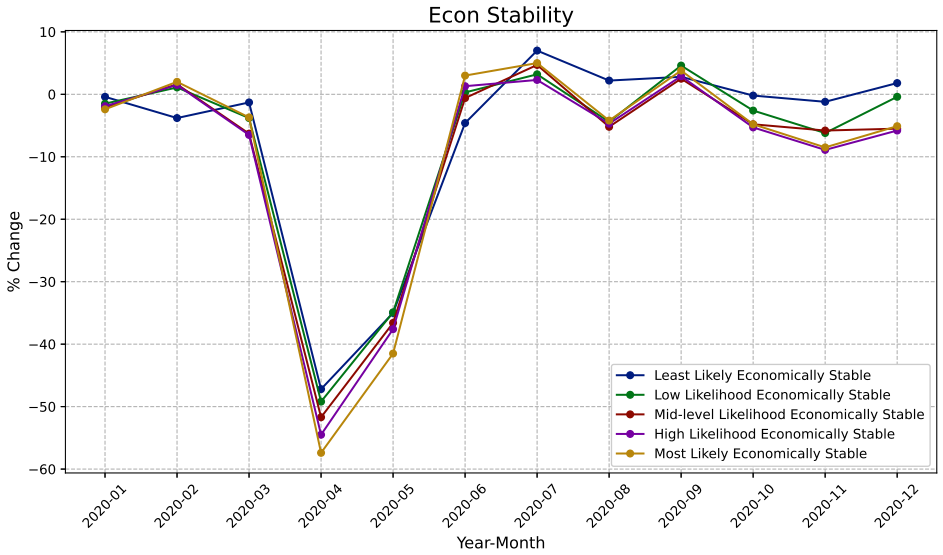

Figure 4.8: Time Series by Economic Stability

The time series for economic stability is displayed in figure 4.8. The April 2020 levels show a pattern indicating a greater drop within the wealthier economic groups. Only the ”Least Likely Economically Stable” group closed out the year surpassing its 2019 levels. Similar to the other series, a rebound appears during June to August, likely because some procedures that were not performed during the shutdown because of triage were deferred to this period. Levels then tended to tail off, with most groups having less volume than 2019 by the end of the year. The ”Most Likely Economically Stable” group matches these effects, with June to September levels above those of 2019 and October below. Once the surgical backlog was addressed, it could be that a proportion of patients were hesitant to go to hospital given the perceived risk of coronavirus transmission.

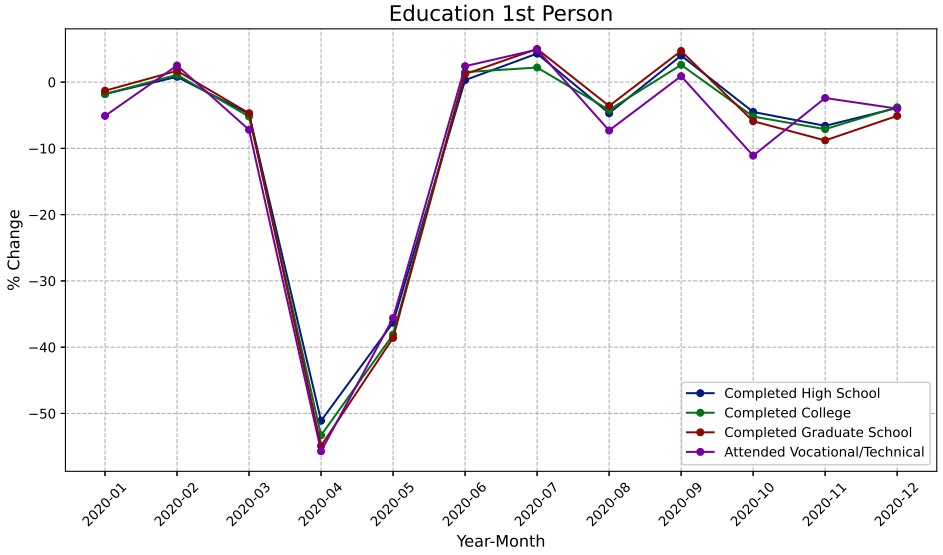

Figure 4.9: Time Series by Education

The time series for Education 1st Person is shown in figure 4.9. (The Vocational/Technical group is much smaller than the other three and may show some spurious variation compared with the others.) The lack of much variation between these groups is somewhat surprising, given that education is a well-known correlate to income level, and the **Economic Stability** series showed notable differences. This could stem from several different effects. Since only those with private insurance are included, the correlation of education to income may be weakened compared with the general population. Education level may also not be accurately assessed within the social determinant data itself.

4.2.3 Percent Change

4.2.4 Yearly Percent Change

Percent change was calculated for the year of 2020 over 2019 within the major social determinant categories. Total numbers of patients in 2019 and 2020 were tallied and the proportion this represented of the total was computed. This metric provides a measure of how much the pandemic affected patient counts on a yearly basis compared with the prior year.

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Asian	55008 (2.1)	49221 (2.1)	-10.5
White/Other	2112803 (80.5)	1917671 (80.3)	-9.2
Hispanic	257296 (9.8)	234128 (9.8)	-9.0
African American	189816 (7.2)	173285 (7.3)	-8.7
Unknown	10893 (0.4)	12820 (0.5)	17.7

Figure 4.10: Percent Change by Race

The percent changes by racial group shown in figure 4.10 show less than a two percent difference across all categories for the entire year. The African American group saw the least change and Asians the most. The White/Other and Hispanic categories were nearly identical. Patient proportions were almost identical between the two years. This figure suggests that race was a weak driver on the level of yearly measurements. The time series chart shows differences on a monthly level within this category that seemed to even out somewhat over the course of the entire year, suggesting that disparities in care may have eventually been addressed, if present.

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Least Likely Economically Stable	43824 (1.7)	40720 (1.7)	-7.1
Very Low Likelihood Economically Stable	207614 (7.9)	192303 (8.1)	-7.4
Low Likelihood Economically Stable	266594 (10.2)	245213 (10.3)	-8.0
Somewhat Low Likelihood Economically Stable	335157 (12.8)	305185 (12.8)	-8.9
Mid-level Likelihood Economically Stable	387368 (14.8)	351440 (14.7)	-9.3
Somewhat High Likelihood Economically Stable	418596 (15.9)	377712 (15.8)	-9.8
High Likelihood Economically Stable	432516 (16.5)	389811 (16.3)	-9.9
Very High Likelihood Economically Stable	420804 (16.0)	377127 (15.8)	-10.4
Most Likely Economically Stable	86231 (3.3)	77771 (3.3)	-9.8
Unknown	27112 (1.0)	29843 (1.3)	10.1

Figure 4.11: Percent Change by Economic Stability

Figure 4.11 shows statistics for the **Economic Stability** category. There is a 3% difference between the lowest and highest values of percent change for the year across all subcategories, which appears significant in the context of the overall level of decrease for all groups (approximately 10%). The time series also showed even larger differences within this category for the nadir period. There is an evident but relatively weak correlation between the level of economic stability and the percent change, with the most economically stable groups showing the most decrease. Individuals in more economically stable households might have had proportionally more elective surgeries compared with the less stable groups during normal periods. The difference in levels of change within the shutdown period between these economic groups may be a result of this disparity, with subsequent monthly levels in the post-shutdown period reflecting resolution of deferred or canceled procedures.

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Completed High School	1481841 (56.4)	1350833 (56.6)	-8.8
Completed College	729991 (27.8)	661201 (27.7)	-9.4
Completed Graduate School	393888 (15.0)	357010 (15.0)	-9.4
Attended Vocational/Technical	19985 (0.8)	17974 (0.8)	-10.1
Unknown	111 (0.0)	107 (0.0)	-3.6

Figure 4.12: Percent Change by Education

The statistics for Education 1st Person show in figure 4.12 show the least change of the three categories. This was largely reflected in the time series presentation which showed similarly small differentials between sub-categories. The reasons for this possibly unexpected effect are unknown.

A complete set of percent change tables is provided in appendix B.3. These largely show that differences between subcategories were within approximately 1% of each other for the entire year. This suggests that while there may have been disparities in care during the shutdown, or at least certain groups experiencing greater or less disruption measured by percent change, these were then largely resolved by the end of the year. One noteworthy exception to this supposition is the retired group in the yearly percent change for **Occupation 1st Person** and **Occupation 2nd Person** show in figures B.13 and B.14. Levels dropped 5% in the ”Retired” group compared to the majority. Assuming that most of those in the ”Retired” category were users of the Medicare program, with some supplementation using private insurance, this may have represented elective (scheduled) procedures being postponed. Fears of infection in hospital may have also played some part, given that coronavirus infection tends to be more severe in older adults (CDC, 2021).

4.2.5 Monthly Percent Change

Percent change within social determinant categories was shown to not vary much on a yearly basis. Surgical procedures that did not occur due to the shutdown may have been rescheduled for later in the year, largely resolving any differences in care during that period based on these factors. Percent change metrics for the month of April may provide a clearer picture of possible proportional disparities related to the pandemic and shutdown. The percent change metrics for April 2020 over April 2019 were calculated for important social determinants and are shown in figure 4.13. (These all uniformly

represent negative rather than positive percent change, but are displayed as positive numbers here.) Additional percent change graphs are included in appendix B.4.

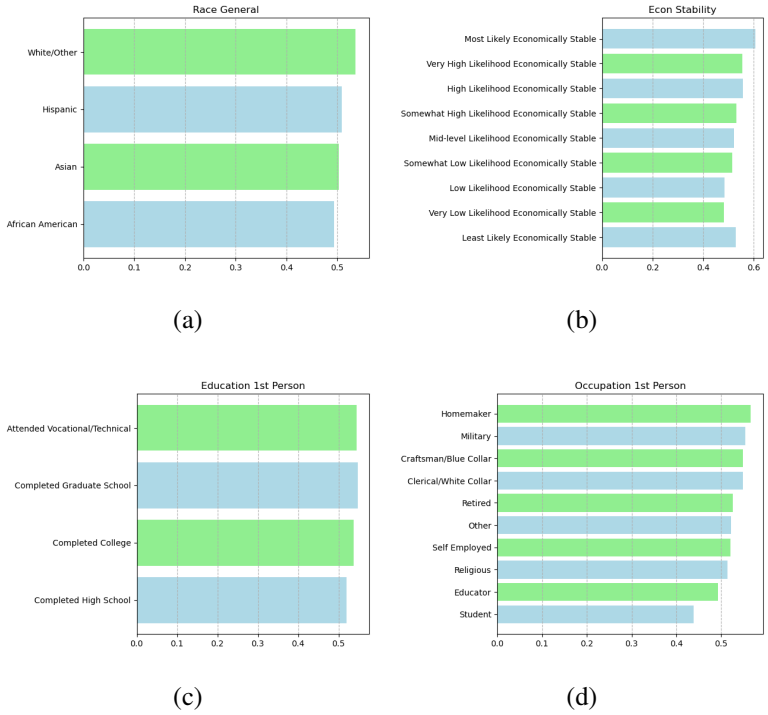

Figure 4.13: Percent Change for April 2019 and April 2020

The ”White/Other” majority group within **Race** shows the greatest change with other groups at somewhat lower but similar levels. The **African American** subgroup saw the least amount of change but only by a small amount. **Economic Stability** shows greater variation with a 60% drop in the ”Most Likely Economically Stable” cohort and 48% for ”Very Low Likelihood Economically Stable.” Economic stability score seems to evince a correlation with percent change during this period, with the higher scores being associated to greater levels of disruption in surgical services. The ”Least Likely Economically Stable” group breaks this trend somewhat, as it shows significantly more change than the closest other group (”Very Low Likelihood Economically Stable”). The **Education 1st Person** subcategories show little variation aside from slightly less comparative change for those who completed high school with no higher education. Finally, **Occupation 1st Person** has a fairly wide range between the highest and lowest levels (though group sizes are highly unequal for this category). The two largest groups, ”Craftsman/Blue Collar” and ”Clerical/White Collar,” have nearly identical measurements with ”Student” as the lowest. The accuracy of these occupational categorizations are unknown and might be low, though the subcategories show some interesting variation between them.

4.3 Conclusion

A number of different social determinant categories were studied in this analysis to determine if the pandemic appeared to effect their level of surgical services disruption disproportionately. These included race, education level, economic stability and a number of other factors. Separate correlation matrices were constructed to compare proportions for the month of April in 2018 and 2019 versus 2019 and 2020. The first provided a baseline measurement of a ”normal” period, whereas the second was used as a proxy for the effect of the pandemic. A chi-square test of proportions showed that the pandemic period evinced greater changes in proportions compared with the baseline, suggesting that there were statistically significant differences in the proportions of subcategories in April 2019 versus 2020. However, close examination of these proportional measurements revealed that they were typically within 1% of each other. This suggests that while proportional changes were detectable and present, the actual differences were small and likely not significant in terms of clinical medical populations.

Percent change metrics were calculated for a number of different periods: the entire year of 2019 versus 2020 and then every month in 2020 over the same one in 2019. The nadir period of April 2020 represented the period of greatest disruption and fell entirely within the shutdown. The month-by-month measurements showed interesting variations within some subcategories, implying that the dynamics surrounding surgical procedure deferment, cancellation and resumption may have differed somewhat amongst certain groups. The yearly metrics were nearly all within 1% of each other for the subcategories, suggesting that any major discrepancies in service based on these factors had largely been resolved by the end of the year, since each subcategory tended to show percent change at the level of -9 to 10%, which matched the total change across all procedures for the entire year. Finally, examination of percent change in the nadir period only (April 2020 vs April 2019) showed the greatest variation between subcategories of all. In particular, **Economic Stability** seemed to be correlated with the level of change, with the more economically stable groups showing greater drops, though the least stable group saw more change than might be expected by this trend.

Chapter 5

Summary, Implications, and Outcomes

5.1 Introduction

The COVID-19 pandemic disrupted medical systems throughout the United States and in particular, surgical services. Guidance from professional organizations to curtail elective surgeries and triage less urgent operations lead to a sharp drop in patient counts during the shutdown period of March 16 to May 3, 2020. Patient levels were more than 50% below 2019 for the month of April, with services in March and May also experiencing significant disruption. The review of research in chapter 2 supports the hypothesis that elective procedures were much more heavily disrupted than urgent or emergent ones. Some categories saw virtually no change from their 2019 levels even in the nadir period, whereas others had only a small fraction of those levels. The extent to which these disruptions were correlated with patient demographic or economic characteristics was cited as an open area of research in the Mattingly study. The results presented here provide some insight on this area.

5.2 Summary of Findings

The chi-square test showed that the time period had an effect on proportions within social determinant categories in comparing April 2020 versus the same month in 2019. A similar test between the two non-pandemic years of 2018 and 2019 displayed far less correlation. This provides evidence that the pandemic time period effected the distribution between categories with particular social determinant categories. However, the actual variations in proportions between April 2019 and 2020 were found to be small upon examination, typically less than 1%. This suggests that though the pandemic had a

measurable effect, it tended to be small and probably not clinically significant.

Percent change metrics for the whole year of 2020 over 2019 indicated that there were similarly only minor differences between categories, suggesting that any disparities in care during the initial shutdown period were resolved on a yearly basis. A notable exception to this were the levels of disruption to those in the "Retired" category within the occupational category. This group experienced a decrease of around 5% more than the majority group in the category, suggesting a greater level of disruption. A plausible hypothesis is that these individuals either deferred elective surgical care past the end of the year or were more reticent about going to medical facilities, possibly perceiving an enhanced risk of COVID-19 infection.

Some notable differences seemed evident in the month-by-month comparisons. In particular, household wealth, income, and other economic factors correlated with steeper declines in patient counts for the most severely effected time period. This was found to be the case for multiple economic covariates, including **Economic Stability**, **Household Income** and **Home Value**, based on time series analysis. Similarly, the **Race** category showed some differences between subcategories in the month-by-month statistics. The "White/Other" group saw around a 5% greater drop than other racial groups initially but had a greater rebound in June to July. Only patients in African American households surpassed 2019 levels in December of 2020, with other groups at 3-5% below. These results suggest that patients in different racial demographics experienced somewhat varying levels of service disruption compared with each on a month-by-month basis as the pandemic unfolded. Factors influencing these differences amongst groups may relate to how soon deferred procedures were rescheduled, willingness to visit medical facilities under pandemic conditions, perceived or actual urgency that a procedure be performed, access to alternatives such as tele-medicine, and so on.

5.3 Conclusions

The study finds that pandemic conditions did lead to some proportional differences within social determinant categories at the yearly and monthly levels. The level of these effects varied by social determinant factors and surgical categories. Urgent or emergent procedures did not appear to have been effected as much as surgical groups that contain a high proportion of elective procedures. Across all surgical groups, including both urgent or emergent and elective procedures, economic factors appeared to have the greatest effect during the nadir period, with a spread of approximately 12% in percent

change between the highest and lowest levels of **Economic Stability** during the nadir. This effect was corroborated by other economic variables such as **Household Income** and **Home Value**. In the period immediately following the shutdown, patient levels in the **Most Likely Economically Stable** group exceeded those from the prior year for June, July and September but remained below 2019 in August, as well as from October through the end of the year. The exact causes of these month-to-month differences are unknown and largely unstudied. Presumably, hospitals rescheduled many operations for the months immediately following the shutdown, perhaps partially to reestablish lost revenue streams. It is plausible that following the resolution of these backlog, some patients were reluctant to visit medical facilities due to fears related to COVID-19, thus depressing patient levels somewhat for certain months following the shutdown.

5.4 Discussion

This study was subject to a number of limitations regarding the nature of the claims data. The absolute number of records included in the study represented a significant proportion of all surgical service claims in the United States for the years studied. However, public insurance systems such as Medicaid, Medicare and VA were not present. The distribution of social determinants within those patients covered by public systems would likely differ compared with patients with private insurance. For instance, those insured by Medicaid would almost certainly skew towards being less economically stable, lower income, etc. The Medicare population would by nature be older and perhaps more likely to undergo surgery in a given year. Certain factors such as **Education 1st Person** may have had less effect than expected due to the nature of the patient population.

5.5 Suggestions for Future Research

The analysis in this study was largely inferential and descriptive. Some attempts at modeling were performed but not included in the main analysis. Appendix B.2 contains some example output from these procedures. The Rose and Mattingly studies covered in the literature review used incidence rate ratio (IRR) modeling to achieve their results. Examining the social determinant factors of surgical services during the pandemic using this type of analysis is an area of possible future research. Additionally, the causative factors of differentials between groups, especially during the nadir period, are largely

unexplored and could constitute a fruitful area of research.

5.6 Conclusion

The extent to which surgical services were disrupted during the pandemic in the United States has been covered in several different contexts, within both the VA and private insurance systems. This study extends these findings by providing some measurements of how much these disruptions varied across the patient population by several social determinants such as race, education level and economic stability. While some differences were found compared to pre-pandemic periods, these were largely found to be clinically, if not statistically, insignificant. Some notable differences were found in month-to-month comparisons of percent change levels between sub-categories, while yearly figures for all studied groups tended to match the overall 9-10% declines noted in the literature, with the notable exception of retirees. This suggests that overall patterns of care leading to some differences amongst surgical services access may have been largely been resolved by the end of the year to result in similar overall declines across most categories. Mattingly noted that medical systems in the United States seemed to show ”adaptability” and ”resiliency” in reestablishing surgical procedure volume following the shutdown (Mattingly et al., 2021). Similarly, proportional differences appeared to be minor compared with baseline periods, suggesting that social determinants were largely weak or drivers of activity during this period compared with the effects of the pandemic and the nature of the surgical procedures themselves.

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Appendix A

Data Dictionary

A.1 Surgical Codes

Major Category	Minor Category	Number of CPT Codes
Cardiovascular	Cardiac	152
	Vascular	321
Cataract	Cataract	3
ENT	Ear, Face, Nose, Mouth, Pharynx	281
General	Breast, Endocrine	45
	Hernia	56
	Hollow Viscus, Peritoneal Cavity	306
	Solid Organ: HPB, Spleen	72
MSK	Amputation	52
	Arthroplasty, Arthroscopy	111
	Fracture	200
	Non Fracture MSK	598
Nervous System	Skull, Brain, Meninges, Nerves	202
	Spine	173
OBGYN	Abortion	8
	C-section	3
	Gynecology	175
Skin	Excision of Skin and Soft Tissue	155
	Grafts, Flaps, and Other Reconstruction	89

A.2 Social Determinants

Social Determinants See next page for SDH field definitions (this page intentionally left blank).

Name	Values	Description
Ask Doc Ad Rx	Least Low Some Higher Most	Likely to ask doctor about medications from advertisements
Men Big Tall Purchase	Y N	Purchase of men's Big Tall clothing in last 24 months
Women Plus Size Purchase	Y N	Purchase of women's Plus Size clothing in last 24 months
Econ Stability	Least Low Somewhat Low Mid Somewhat High High Most	Economic stability score using a proprietary combination of data
Estimated Income	Less Than $15,000 $15,000 - $19,999 $20,000 - $29,999 $30,000 - $39,999 $40,000 - $49,999 $50,000 - $74,999 $75,000 - $99,999 $100,000 - $124,999 Greater than $124,999	Estimated income of the household
Education 1st Person	Completed High School Attended Vocational/Technical Completed College Completed Graduate School	Highest educational achievement of 1st individual in household
Education 2nd Person	Completed High School Attended Vocational/Technical Completed College Completed Graduate School	Highest education achievement of 2nd individual in household
Home Market Value	Less than $100,000 $100,000 - $199,999 $200,000 - $299,999 $300,000 - $399,999 $400,000 - $499,999 $500,000 - $599,999 $600,000 - $699,999 $700,000 - $799,999 $800,000 - $999,999 $1,000,000 - $1,999,999 Greater than $1,999,999	Estimated value of home
Marital Status	Married Single	Marital status of household

Name	Values	Description
Med Info On Web	Least Low Some Higher Most	Likely to ask doctor about medication information from the web
Number Of Vehicles	1 Car 2 Cars 3 or More Cars	Number of vehicles in the household
Number Of Children	None 1 2 3 or more	Number of children in the household
Occupation 1st Person	Clerical/White Collar Craftsman/Blue Collar Student Homemaker Retired Military Religious Self Employed Educator Other	Occupation of 1st person in household
Occupation 2nd Person	Clerical/White Collar Craftsman/Blue Collar Student Homemaker Retired Military Religious Self Employed Educator Other	Occupation of 2nd person in household
Race General	African American Asian Hispanic White/Other	Race of household
Rent Or Home	Renter Homeowner	Indicates if household is owner or renter occupied
Senior Adult	Presence of Senior Adult No Seniors in Household	Presence of senior adult in household
Spanish Speaker	Does Not Speak Spanish Bilingual Spanish and English Prefers Spanish	Indicates if household is Spanish speaking
Veteran Status	Y N	Indicates if there is a veteran in the household

Appendix B

Additional Analysis

B.1 Chi-square Test Statistic

These figures show the chi-square test statistic values for test of proportions on social determinant categories by surgery groups, corresponding to figures 4.5 and 4.6 in the text.

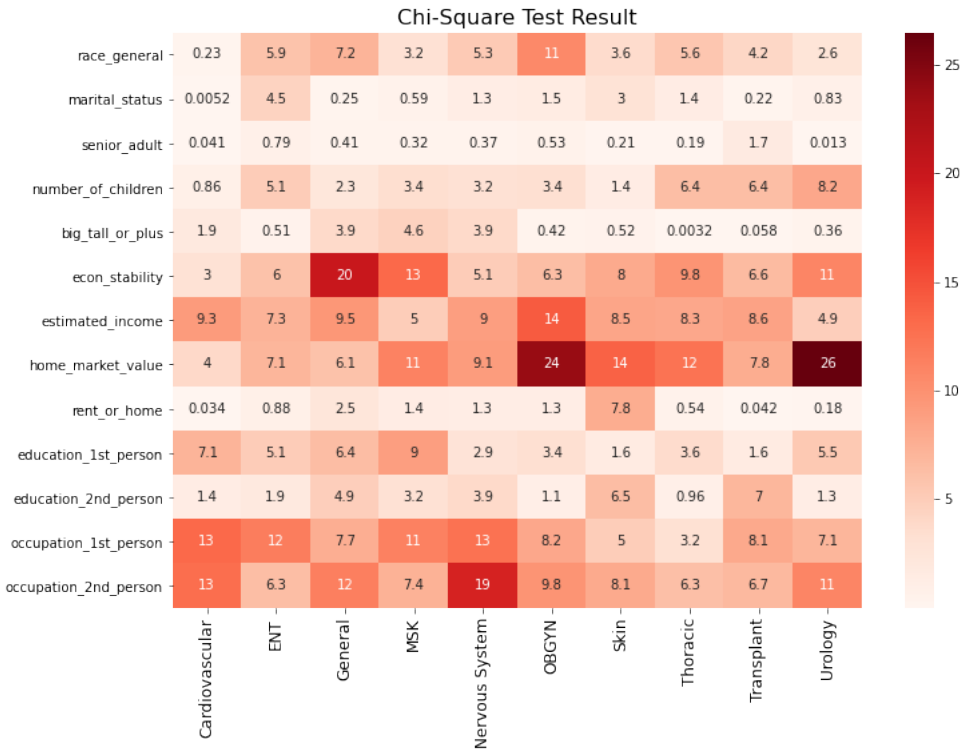


Figure B.1: Chi-square Test Statistic for 2018 to 2019

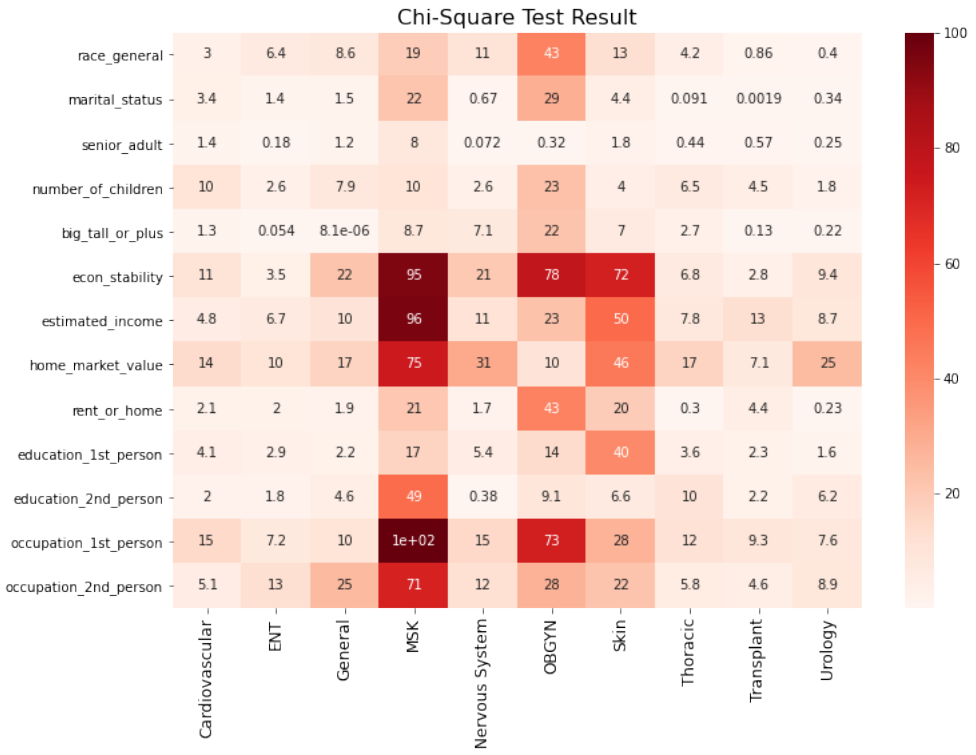


Figure B.2: Chi-square Test Statistics for 2019 to 2020

B.2 Modeling

Some modeling was performed using the Java H2O Machine Learning platform (H2O.ai, 2022). This processing was performed on an older, non-finalized version of the dataset, and thus not included as part of the results. Example output from the modeling analysis is shown below. These results show a correlation with race which appeared to weaken when the full set of records was eventually included in the analysis.

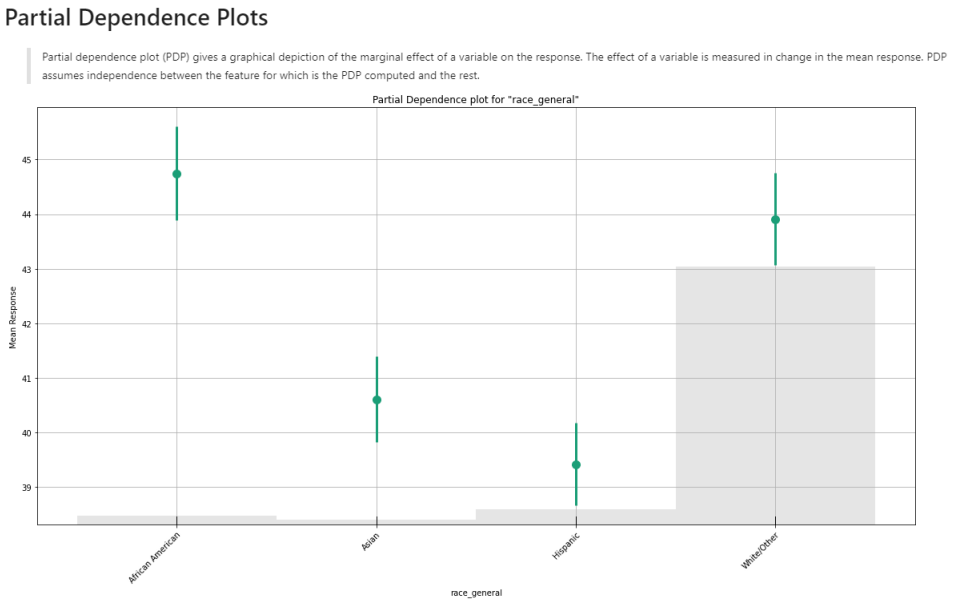


Figure B.3: Partial Dependence Plots

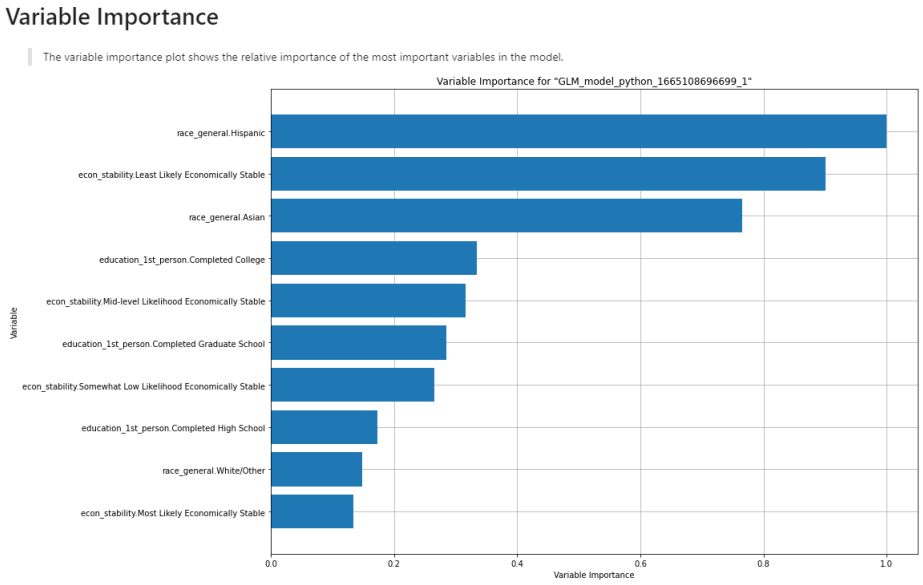


Figure B.4: Variable Importance Chart

Variable Importances:

variable	relative_importance	scaled_importance	percentage
race_general.Hispanic	0.12678	1	0.219618
econ_stability.Least Likely Economically Stable	0.114236	0.901054	0.197888
race_general.Asian	0.0970092	0.765175	0.168046
education_1st_person.Completed College	0.0423233	0.333831	0.0733154
econ_stability.Mid-level Likelihood Economically Stable	0.0400111	0.315594	0.06931
education_1st_person.Completed Graduate School	0.0361308	0.284987	0.0625883
econ_stability.Somewhat Low Likelihood Economically Stable	0.033668	0.265562	0.0583221
education_1st_person.Completed High School	0.0218885	0.172649	0.0379168
race_general.White/Other	0.0188261	0.148494	0.0326119
econ_stability.Most Likely Economically Stable	0.0168996	0.133298	0.0292746
econ_stability.Somewhat High Likelihood Economically Stable	0.0138643	0.109357	0.0240168
econ_stability.Very Low Likelihood Economically Stable	0.0113898	0.0898385	0.0197301
econ_stability.Very High Likelihood Economically Stable	0.00338935	0.026734	0.00587126
econ_stability.Low Likelihood Economically Stable	0.000860918	0.00679062	0.00149134

Figure B.5: Variable Importances

B.3 Yearly Percent Change Tables

This is a complete set of all percent change tables that were constructed for the analysis. These measure the difference between *yearly* patient counts for 2020 compared with 2019.

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Least Likely Economically Stable	43824 (1.7)	40720 (1.7)	-7.1
Very Low Likelihood Economically Stable	207614 (7.9)	192303 (8.1)	-7.4
Low Likelihood Economically Stable	266594 (10.2)	245213 (10.3)	-8.0
Somewhat Low Likelihood Economically Stable	335157 (12.8)	305185 (12.8)	-8.9
Mid-level Likelihood Economically Stable	387368 (14.8)	351440 (14.7)	-9.3
Somewhat High Likelihood Economically Stable	418596 (15.9)	377712 (15.8)	-9.8
High Likelihood Economically Stable	432516 (16.5)	389811 (16.3)	-9.9
Very High Likelihood Economically Stable	420804 (16.0)	377127 (15.8)	-10.4
Most Likely Economically Stable	86231 (3.3)	77771 (3.3)	-9.8
Unknown	27112 (1.0)	29843 (1.3)	10.1

Figure B.6: Percent Change: Economic Stability

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Completed High School	1481841 (56.4)	1350833 (56.6)	-8.8
Completed College	729991 (27.8)	661201 (27.7)	-9.4
Completed Graduate School	393888 (15.0)	357010 (15.0)	-9.4
Attended Vocational/Technical	19985 (0.8)	17974 (0.8)	-10.1
Unknown	111 (0.0)	107 (0.0)	-3.6

Figure B.7: Percent Change: Education 1st Person

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Completed High School	730201 (27.8)	659899 (27.6)	-9.6
Completed College	496308 (18.9)	449037 (18.8)	-9.5
Completed Graduate School	202891 (7.7)	183782 (7.7)	-9.4
Attended Vocational/Technical	12459 (0.5)	11183 (0.5)	-10.2
Unknown	1183957 (45.1)	1083224 (45.4)	-8.5

Figure B.8: Percent Change: Education 2nd Person

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Less Than $15,000	177110 (6.7)	160549 (6.7)	-9.4
$15,000 - $19,999	140915 (5.4)	127677 (5.3)	-9.4
$20,000 - $29,999	229548 (8.7)	208295 (8.7)	-9.3
$30,000 - $39,999	254095 (9.7)	229957 (9.6)	-9.5
$40,000 - $49,999	269701 (10.3)	243493 (10.2)	-9.7
$50,000 - $74,999	561030 (21.4)	509955 (21.4)	-9.1
$75,000 - $99,999	355813 (13.6)	323973 (13.6)	-8.9
$100,000 - $124,999	203162 (7.7)	184756 (7.7)	-9.1
Greater than $124,999	434331 (16.5)	398363 (16.7)	-8.3
Unknown	111 (0.0)	107 (0.0)	-3.6

Figure B.9: Percent Change: Estimated Income

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Unknown	635 (0.0)	550 (0.0)	-13.4
M	1143268 (43.5)	1031668 (43.2)	-9.8
F	1481913 (56.4)	1354907 (56.8)	-8.6

Figure B.10: Percent Change: Gender

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Less than $100,000	253851 (9.7)	229037 (9.6)	-9.8
$100,000 - $199,999	546984 (20.8)	494755 (20.7)	-9.5
$200,000 - $299,999	443213 (16.9)	403154 (16.9)	-9.0
$300,000 - $399,999	280301 (10.7)	257374 (10.8)	-8.2
$400,000 - $499,999	163893 (6.2)	149660 (6.3)	-8.7
$500,000 - $599,999	93688 (3.6)	85249 (3.6)	-9.0
$600,000 - $699,999	59701 (2.3)	54525 (2.3)	-8.7
$700,000 - $799,999	37735 (1.4)	34314 (1.4)	-9.1
$800,000 - $999,999	38529 (1.5)	34672 (1.5)	-10.0
$1,000,000 - $1,999,999	44971 (1.7)	40736 (1.7)	-9.4
Greater than $1,999,999	9560 (0.4)	8444 (0.4)	-11.7
Unknown	653390 (24.9)	595205 (24.9)	-8.9

Figure B.11: Percent Change: Home Market Value

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Married	1670533 (63.6)	1511497 (63.3)	-9.5
Single	955172 (36.4)	875521 (36.7)	-8.3
Unknown	111 (0.0)	107 (0.0)	-3.6

Figure B.12: Percent Change: Marital Status

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Retired	158055 (6.0)	135957 (5.7)	-14.0
Craftsman/Blue Collar	244404 (9.3)	220047 (9.2)	-10.0
Educator	5523 (0.2)	4986 (0.2)	-9.7
Homemaker	93546 (3.6)	84690 (3.5)	-9.5
Self Employed	48498 (1.8)	44038 (1.8)	-9.2
Clerical/White Collar	1034242 (39.4)	940496 (39.4)	-9.1
Military	18853 (0.7)	17172 (0.7)	-8.9
Student	28835 (1.1)	26320 (1.1)	-8.7
Other	54581 (2.1)	49845 (2.1)	-8.7
Unknown	936441 (35.7)	860962 (36.1)	-8.1
Religious	2838 (0.1)	2612 (0.1)	-8.0

Figure B.13: Percent Change: Occupation 1st Person

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Retired	101908 (3.9)	87967 (3.7)	-13.7
Religious	462 (0.0)	407 (0.0)	-11.9
Self Employed	25389 (1.0)	22753 (1.0)	-10.4
Homemaker	138381 (5.3)	124068 (5.2)	-10.3
Other	39282 (1.5)	35524 (1.5)	-9.6
Craftsman/Blue Collar	113616 (4.3)	102770 (4.3)	-9.5
Clerical/White Collar	705555 (26.9)	639564 (26.8)	-9.4
Student	16534 (0.6)	15040 (0.6)	-9.0
Educator	5097 (0.2)	4651 (0.2)	-8.8
Unknown	1470071 (56.0)	1345587 (56.4)	-8.5
Military	9521 (0.4)	8794 (0.4)	-7.6

Figure B.14: Percent Change: Occupation 2nd Person

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Asian	55008 (2.1)	49221 (2.1)	-10.5
White/Other	2112803 (80.5)	1917671 (80.3)	-9.2
Hispanic	257296 (9.8)	234128 (9.8)	-9.0
African American	189816 (7.2)	173285 (7.3)	-8.7
Unknown	10893 (0.4)	12820 (0.5)	17.7

Figure B.15: Percent Change: Race General

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Homeowner	2203190 (83.9)	1994047 (83.5)	-9.5
Renter	422517 (16.1)	392973 (16.5)	-7.0
Unknown	109 (0.0)	105 (0.0)	-3.7

Figure B.16: Percent Change: Rent or Home

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Presence of Senior Adult	598832 (22.8)	540692 (22.7)	-9.7
No Seniors in Household	2026984 (77.2)	1846433 (77.3)	-8.9

Figure B.17: Percent Change: Senior Adult in Household

Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Prefers Spanish	69682 (2.7)	62540 (2.6)	-10.2
Does Not Speak Spanish	2431054 (92.6)	2207867 (92.5)	-9.2
Bilingual Spanish and English	114187 (4.3)	103898 (4.4)	-9.0
Unknown	10893 (0.4)	12820 (0.5)	17.7

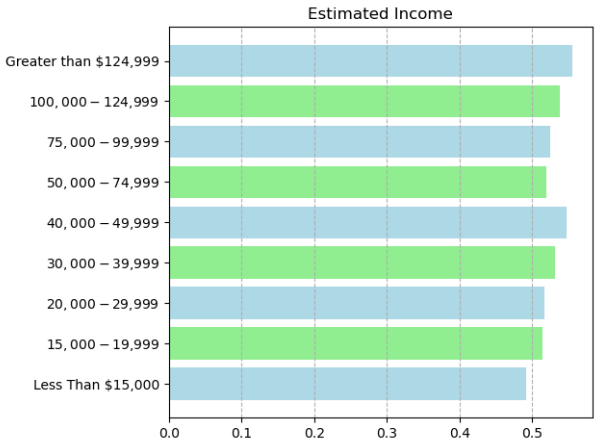
Figure B.18: Percent Change: Spanish Speaking Households

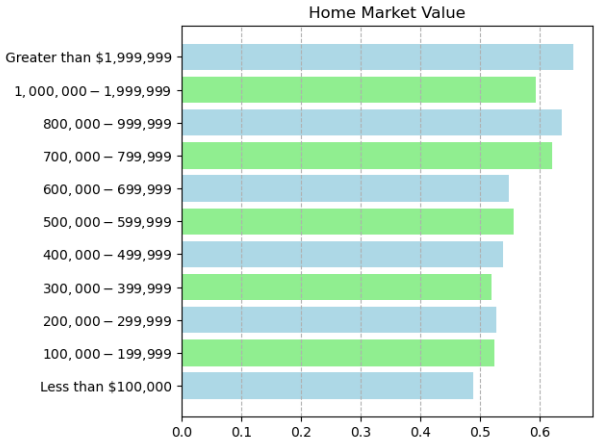
Characteristic	Patients 2019 (%)	Patients 2020 (%)	% Change
Y	674855 (25.7)	606303 (25.4)	-10.2
N	1950961 (74.3)	1780822 (74.6)	-8.7

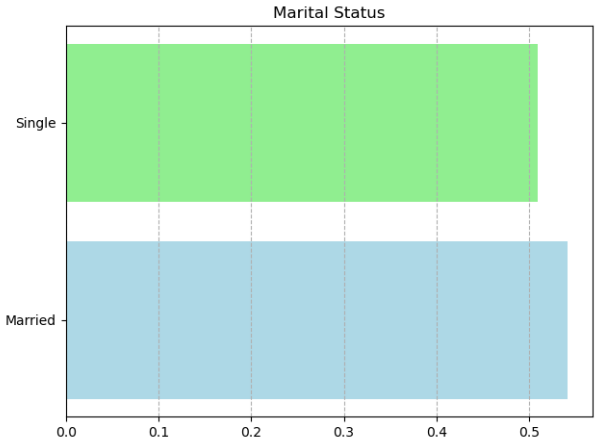
Figure B.19: Percent Change: Veteran Status

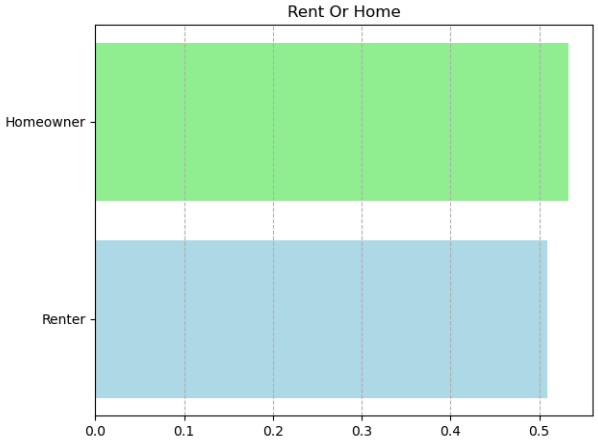
B.4 Percent Change for the Nadir Period

Below are additional percent change graphs for the nadir period, comparing April 2019 with April 2020.






Marital Status
Single
Married
0.0
0.1
0.2
0.3
0.4
0.5


Rent Or Home
Homeowner
Renter
0.0
0.1
0.2
0.3
0.4
0.5