SPECIFIC AIMS

In March of 2020, the COVID-19 pandemic upended the U.S. health care system, as providers rapidly shifted focus and resources towards managing the surge in COVID-19 patients who were hospitalized. The COVID-19 pandemic has led to well-documented reductions in many health care services. Many individuals have delayed care due to concerns of COVID-19 infection and recommendations from the Centers for Diseases Control and Prevention (CDC). Recently developed COVID-19 vaccines provide highly effective against the coronavirus.[34] Beyond the primary benefit of reducing COVID-19 infection and transmission risk, an unexplored additional benefit of the availability of COVID-19 vaccines are the creation of a way for patients who have delayed care needs to safely get care. There are several possible mechanisms for this effect. While many primary care providers were left out of vaccine distribution, some patients may receive the vaccine from their primary care provider who will encourage them to receive delayed care.[35] Second, after being fully vaccinated the individual may seek care that they had previously deferred due to the CDC's guidelines and avoiding receiving in person care. Through these pathways, COVID-19 vaccines may have an important secondary benefit on health outcomes that last beyond the immediate COVID-19 pandemic. In addition, these secondary health benefits can lead to long-term differences in health outcomes between vaccinated and non-vaccinated populations. Beyond the risks of COVID-19 infection, vaccinated populations may be more likely to receive preventive care than non-vaccinated populations, which can indirectly impact health outcomes.

Importantly, these secondary benefits of COVID-19 vaccines may not be equal across patient populations. The impacts of the COVID-19 pandemic have not been experienced equally, with racial and ethnic minorities experiencing higher COVID-19 infection and death rates, and higher rates of economic uncertainty.[1-3] Non-adoption of COVID-19 vaccines and vaccine hesitancy may be exacerbated among gender, education, racial, urbanicity, and income strata.[36] Patients who have not been vaccinated or who live in areas with low COVID-19 vaccination rates may not have the same ability to benefit from returns to care. Disparities in vaccine adoption can lead to long-lasting effects on patient health, and could disproportionately impact vulnerable patient populations. To inform policies that ensure access to health services in the years following the COVID-19 pandemic and for planning for future public health emergencies, it is vital to understand how vaccine use changed health care delivery, and whether vaccine access barriers disproportionately impact healthcare utilization for vulnerable patient populations. We propose the following aims:

Aim 1: Use national data from the CDC and smartphone-based mobility tracking data that is geo-linked to health care provider's locations to assess if increased community-level COVID-19 vaccination rates are associated with increased mobility to health care providers (e.g., physician offices, hospitals, ambulatory surgical centers, rehabilitation facilities, and nursing homes).

Aim 2: Use data from the Indiana Network for Patient Care electronic health exchange to estimate the association between individual-level COVID-19 vaccination and use of preventive and elective medical services, and whether rebounds in care differ based on patient social and economic vulnerability status.

Aim 3: Compare long-run health outcomes between vaccinated and non-vaccinated patients, and if disparities in vaccination rates exacerbate health disparities among vulnerable and NIA-priority patient populations.

RESEARCH STRATEGY

Preliminary research by the study team using SafeGraph state-level mobility data demonstrates increased mobility to many health care providers following increases in community-level COVID-19 vaccination rates during the early phases of the COVID-19 vaccination campaign. We hypothesize that even larger variation exists at the county- and individual-level. Vaccination rates in a state were associated with large and statistically significant increases in physical mobility across a range of establishment types. For example, a one-dose increase in a state's COVID-19 rate per 100 adults is associated with a statistically-significant increase of 1.7% in visits to nursing homes, which have been an epicenter of COVID-19 deaths and a focus of early vaccination campaign. This preliminary finding supports our hypothesis that individuals may be returning to their health care providers to receive deferred care. Whether patients similarly respond to COVID-19 vaccination by receiving in-person care, for both primary care services and care that was delayed during the COVID-19 pandemic, remains unclear. This study proposes to examine if increased access to COVID-19 vaccines is associated with increased use of delayed health care services.

While COVID-19 vaccines promise highly effective immunizations against the coronavirus, recent surveys highlight potential barriers to adoption. Non-adoption of COVID-19 vaccines may be exacerbated among gender, education, racial, urbanicity, and income strata. To assess potential disparities in rates of utilization, we will examine differential effects among medically and socially vulnerable patient populations. We will

identify medically vulnerable patients as those with multiple chronic conditions and patients with cognitive barriers (e.g., Alzheimer's and dementia). Socially vulnerable populations will be defined using both patient-level data (dual-eligibility status for Medicare and Medicaid, and both self-reported and imputed race/ethnicity)[5] and geography-level (county and zip code) measures (education status, median household income, broadband internet access, and both urban/rural continuum status and rural-urban commuting area codes[6]) using data from the American Community Survey. We hypothesize that counties with a higher share of non-white individuals or a higher share of more individuals below the Federal Poverty Level will have a lower rebound in unmet health care utilization. We base this hypothesis on existing work by members of the research team that has found larger declines in health care utilization in areas of the country with a higher share of non-white residents or a higher share of individuals below the Federal Poverty Level.

This study will combine several innovative sources of data:

SafeGraph mobility data: We will use data from SafeGraph as a second way to measure healthcare utilization in conjunction with the electronic medical records data. These data have been previously used to measure foot traffic during the COVID-19 pandemic to various locations.[57,58] SafeGraph aggregates GPS pings from about 45 million mobile devices and numerous applications, approximately 10% of those within the United States from January 2019 onwards. The data include measurements of traffic patterns, both to a large collection of points-of-interest (POIs), and to/from residences of the users. Following ongoing work, we will try to probabilistically link providers from the National Plan and Provider Enumeration System (NPPES) to SafeGraph's "Weekly Patterns" database using machine learning algorithms.[42] For each POI, SafeGraph reports its geographic location, industry via the National American Industry Classification System code, and the total number of visitors in their mobile device panel that have visited each day. We have used machine learning algorithms to link this data to the NPPES provider registry datasets.[59]

Indiana Network for Patient Care Health Information Exchange data: We will use linked patient-level data from the Indiana Network for Patient Care (INPC). The INPC is the nation's largest inter-organizational clinical data repository and the primary platform that enables the Indiana Health Information Exchange. The Indiana Health Information exchange connects more than 100 hospitals, 14,000 practices and nearly 40,000 providers who contribute healthcare data on approximately 18 million patients and across 10 billion clinical observations. Most of the data come from electronic health records (EHR) databases generated during from routine clinical care across multiple healthcare systems. The INPC covers 66.7% of Indiana's population, and its data mirror the "integrated patient record" available to clinicians in integrated delivery networks, attenuating the common problem of data fragmentation plaguing retrospective databased studies. It includes inpatient, outpatient, and office-based medical records, from all payers, including populations not commonly captured in medical claims data, such as the uninsured and patients enrolled in Medicaid. Importantly, the INPC data links individual-level data on clinical encounters with COVID-19 vaccination status, which will allow us to test the effects of COVID-19 vaccination on use of health services.

Table 1: Potentially Unmet Care During COVID-19 Pandemic

Service Type	Population
Breast cancer screening	Women ages 45-64*
Colorectal cancer screening	Men and women ages 45-64*
Influenza vaccines	All populations
Infant immunizations	Households with children ages 0-2
Primary care visits	High-risk populations

**Limited to individuals without prior screening in recommended periods, depending on screening type, patient risk, and patient disease history*

In these data, we will identify individual-level COVID-19 vaccination rates using the following procedure codes: **91300, 91301, 0001A, 0002A**,**0011A**, **0012A**. For unmet care needs, we will use the procedures in Table 1.

We will use a regression-based approach to measure the association between vaccination rates and use of preventive and elective care. Our regression models will include fixed effect controls for geographic region, which account for underlying differences that exist across states even prior to vaccinations, and fixed effect controls for week, which account flexibly for nationwide trends during our study period. Thus, our multivariate regression models will measure the association between changes in the intensity of the vaccination campaign and changes in the use of unmet care needs, after adjusting for systematic differences across states and allowing for flexible nationwide time trends. For each study aim, we will examine differences across the medical and socially vulnerable patient populations described above.