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1. Introduction

Since the first confirmed case of the respiratory illness caused by a newly discovered coronavirus (SARS-CoV-2) virus in the United States (US) on January 20, 2020 [1], Texas has accounted for almost 10% of the more than 30 million total confirmed cases nationwide, and has the second highest number of positive coronavirus cases in the US, and as of April 8, 2021 approximately 49,000 Texans have also died from coronavirus disease 2019 (COVID-19) [2]. Measures to mitigate the risks of COVID-19 have included limiting personal contact and social distancing in several states, together with expanded testing, contact tracing, and wearing face masks [3,4]. Nationally, on March 13, 2020 the US government declared a national emergency and, beginning on March 31, 2020, Texas announced further measures to control the spread of COVID-19 through mandated shelter-in-place orders, and social distancing [5]. These measures were implemented for a period of almost one month, with phased reopening in Texas beginning on April 27, 2020.

Despite the recommendation on March 24 from the US Centers for Disease Control and Prevention (CDC) to issue guidelines for continuing vaccinations for children less than 2 years of age [6], calls for social distancing have produced reductions in the availability and utilization of routine childhood vaccinations in several states [7–9]. State-sponsored shelter-in-place mandates in some states, including Texas, have resulted in reductions in uptake of routine childhood vaccination, in part due to closing of vaccination sites and parental fears of disease risk from pediatrician visits [7,8]. For example, Massachusetts reported a 68% decline in vaccine doses administered in the first two weeks of April in 2020, in comparison with the same period in 2019 [8]. Other states, including Minnesota and Michigan, have also reported a decrease in the uptake of measles vaccination [8,9]. Additionally, New York City reported a 63% decline in the number of vaccine doses...
administered to children during a six-week period in the pandemic lockdown [10].

Nationally, the CDC has noted significant declines in childhood vaccination rates in association with social distancing mandates. This includes more than 50% decline in measles-containing vaccinations (MCV) for young children, as well significant declines in other non-influenza vaccines [6]. Data for routine pediatric vaccines from Vaccines for Children Program (VFC) and Vaccine Safety Datalink (VSD) from January 6–April 19, 2020, found the sharpest decline in measles immunization uptake in the US following the week after the national emergency declaration on March 13, 2020 [6].

Any disruption to immunization services, even for a short duration, can result in an increased number of vaccine-preventable disease infections, contributing to childhood morbidity and mortality due to vaccine-preventable diseases [11]. We examine the impact of the preventive measures implemented to combat the SARS-CoV-2 pandemic on children's vaccination coverage in Texas and provide recommendations to address the challenges.

2. Methods

We analyzed data from the Texas Immunization Registry (ImmTrac2) to assess changes in children's recommended vaccination coverage over a 10-year period, encompassing before and during the SARS-CoV-2 pandemic. ImmTrac2 is an opt-in registry that obtains and stores vaccine records from different sources including health care providers, the Texas Department of State Health Services (DSHS), and Vital Statistics Unit (VSU). Because this was a secondary data analysis, the Texas A&M University Institutional Review Board deemed it exempt from human subject research.

Immunization data were extracted in September 2020 on immunizations administered from May 2010 through May 2020. Data at the county level were provided for May 2019 and May 2020 for comparison by rurality. We assessed the vaccination status of children at four time points: 1, 5, 16 and 24 months old.

Up-to-date status for individual vaccines and combined vaccine series recommended by the Advisory Committee for Immunization Practices (ACIP) were assessed at the point in time (1 May 2020) and compared with 1-month cohorts for points in time May 2010 to May 2019.

- 3 month-old children: The first dose of hepatitis B (HepB) within 3 days of birth.
- 5-month-old children: received all doses in the recommended vaccine series, including 2 HepB, 2 Rotavirus (Rotarota), 2 DTaP, 2 Hib, 2 PCV13, and 2 Polio.
- 16-month-old children: received all doses in the recommended vaccine series, including 3 DTaP, 2 Polio, 1 MMR, 3 or 4 doses of Hib, 2 HepB, 1 Varicella and 4 PCV13.
- 24-month-old children received all doses in the recommended vaccine series, including 4 DTaP, 3 Polio, 1 MMR, 3 or 4 doses of Hib, 3 HepB, 1 Varicella, and 4 PCV13.

We calculated the percent of children who were “up-to-date” as of 1 May each year and corresponding 95% confidence intervals using exact methods. We additionally estimated the percent change in the number of doses administered for the month of May in 2019 and the month of May in 2020 in rural and urban counties. We used chi-squared tests to determine whether the percent change was significantly different for urban and rural counties ($\alpha = 0.05$).

4. Results

Information on immunizations administered in Texas between 2010 and 2020 was extracted for 325,922 children at birth, 342,906 5-month-old children, 364,611 16-month-old children, and 336,442 24-month-old children. The percent of children who were “up-to-date” at birth, 5 months, 16 months, and 24 months increased from 2010 to 2019 (Fig. 1). However, between 2019 and 2020, we observed a 47–58% decline in immunization coverage for 5- and 16-month-olds (Fig. 1). In 2019, 64.7% (95% CI 64.1, 65.3%) of children 5 months of age were recorded as fully immunized as compared to 34.6% (95% CI 34.0, 35.1%) in 2020; 43.0% (95% CI 42.4, 43.5%) of children 16 months of age were fully immunized in 2019 compared to 18.1% (95% CI 17.7, 18.6%) in 2020. In contrast, we observed a smaller decline (5%) in the percent of 24-month-old children who were fully immunized and a 2% increase in the percent of infants who received a birth dose of Hepatitis B.

When we considered administration of specific recommended vaccines, among children 5 months of age, we observed a 44–
47% reduction in receipt of each of the major recommended vaccines between 2019 and 2020, with exception to Hepatitis B (Fig. 2). Hepatitis B vaccination among 5-month-olds declined by 23%. Among children 16 months of age, we observed a 27–56% reduction in administration of individual scheduled vaccines between 2019 and 2020 (Fig. 3). Hepatitis B, DTaP and polio vaccination rates among 16-month-olds declined by 2–7%. Among children 24 months of age, we observed less than a 7% reduction in scheduled vaccines between 2019 and 2020 (Fig. 4) although Hepatitis A coverage declined 27%. In urban counties during May 2019, 10,049 vaccination doses were administered to children 5 months of age, 7,210 doses were administered to children 16 months of age, and 4,050 doses were administered to children 24 months of age.
administered to children 16-months of age, and 6,146 doses were administered to children 24-months of age. In comparison, during the same period in 2020, 143 fewer doses were administered among 5-month-olds, 1,312 fewer doses among 16-month-olds, and 2,688 fewer doses among 24-month-olds. In rural counties in May 2019, 901 doses were administered to 5-month-olds, 332 doses were administered to 16-month-olds, and 334 doses were administered to 24-month-olds. During the same time period in May 2020, 258 fewer doses of childhood vaccines were administered among 5-month-olds, 40 fewer doses were administered to 16-month-olds, and 130 fewer doses were administered to 24-month-olds. The percent of decline in doses administered to children 5 months of age comparing May 2019 to May 2020 was 27.2% (95% CI 24.3, 30.2%) greater in rural counties (-28.6%; 95% CI 31.7, -25.7%) than urban counties (-1.4%; 95% CI -1.7, -1.2%). The percent decline in doses administered to children 16 months of age was slightly greater (6.2%; 95% CI 1.8, 10.0%) in urban counties (-18.2%; 95% CI -19.1, -17.3%) compared to rural counties (-12.1%; 95% CI -15.5, -8.5%). There was no difference in the decline in doses administered to children 24 months of age in rural compared to urban areas (4.8%; 95% CI -0.7, 10.0%).

5. Discussion

Our findings indicate that the emergence of SARS-CoV-2 in Texas coincided with significant declines in childhood immunizations, similar to what has been noted nationally and in multiple other states [8–10]. The declines were greatest for routine immunizations among the 5-month and 16-month aged groups, and were lowest for vaccines administered at birth. Analysis of data by county shows that 5-month-old children in rural areas may experience more disruption to immunization services than 5-month-old children in urban areas.

These declines in childhood immunization rates appear to overlay existing issues in maintaining uptake of certain vaccines. Although uptake of most vaccines appeared to increase prior to the pandemic between May 2010 and May 2019, MMR coverage appears to have declined in Texas since 2015, reaching 77% among 16-month-olds and 82% among 24-month-olds by 2019. During the pandemic, MMR coverage appears to have declined further. Whether the declining trend in MMR acceptance would have continued without the pandemic is unknown. Regardless, high coverage of MMR is required to avoid the occurrence of outbreaks, indicating the already low level of measles vaccination coverage, exacerbated by the pandemic could have substantial public health consequences.

Hepatitis B immunizations are administered in the hospital after birth. Since we did not observe declines in administration of Hepatitis B birth dose, this may indicate that immunizations requiring a clinic or in-office visit are solely impacted by the COVID-19 pandemic [9]. The larger declines in doses administered we observed in rural counties of Texas may indicate that disruptions to childhood immunization are further exacerbated by barriers to immunization experienced prior to the COVID-19 pandemic in rural communities, including affordability and more limited geographic access to immunization services [12].

These results suggest that strategies to mitigate transmission of SARS-CoV-2 may have had unintended consequences in terms of reductions in vaccination among children in Texas. Our findings, in conjunction with those of previous studies, suggest that

![Fig. 4. Percent of 24-month-old children up-to-date with recommended childhood vaccines at 1 May between 2010 and 2020, by vaccine – Texas, ImmTrac2, May 2010 to May 2020. Abbreviations: DTaP, ditheria-tetanus-acellular pertussis vaccine; MMR, measles-mumps-rubella vaccine; Hib, Haemophilus influenzae B; PCV13, pneumococcal conjugate-13 vaccine.](image-url)
immunization and other preventive health services requiring in-
person visits have been adversely impacted by the COVID-19 pan-
demic [5–9]. Declines in vaccination coverage below 90–95% put
herd immunity at risk for children in Texas, potentially resulting
in the increase of vaccine preventable diseases. The situation
may be aggravated when coupled with the effects of COVID-19,
thereby significantly taxing the already stressed healthcare system
[13]. The CDC recommends continued administration of routine
immunization during the pandemic to prevent transmission of
other preventable infectious diseases [14]. According to the Amer-
ican Academy of Pediatrics (AAP), while telehealth visits are rec-
ommended, in-person visits, especially for vaccination, should
not be discontinued unless community circumstances require the
limitation of in-person visits, in which case curbside or drive-
through vaccination can be implemented by clinics to limit
patient-provider contact [14]. Healthcare providers, especially in
communities with low immunization rates, will have to provide
catch-up immunizations and have effective recall programs in
place that provide timely reminders to parents when vaccinations
are scheduled.

The use of an opt-in registry for our study presents several
strengths and limitations. As ImmTrac2 is an opt-in registry, data
may not necessarily reflect general population estimates. ImmTrac2
data used in the study might not reflect the true vacci-
nation coverage at the population level and result in the underes-
timation of routine immunizations administered in Texas. How-
ever, the registry has several strengths. ImmTrac2 collects
data from multiple sources, including healthcare providers, phar-
macies, public health clinics, Medicaid claims administrators,
Texas Department of State Health Services (DSHS), Vital Statistics
Unit (VSU) and other organizations, which increases the accuracy
of the reported data. Furthermore, the data are useful for evaluat-
ing trends in immunization over time, which was the primary aim
of this study. Although our analysis provides a rapid evaluation of
trends in childhood vaccination during the COVID-19 pandemic,
future evaluation of trends in childhood immunization coverage
using population-based estimates from representative surveys
such as National Immunization Survey would be useful for con-
firming our findings.

Considering the ongoing SARS-CoV-2 transmission in the Uni-
ited States, it is paramount that healthcare providers continue to
adhere to established preventative COVID-19 care protocols in order
to avoid two successive years of low immunization coverage. There
is an urgent need to address gaps in accessing immunization ser-
dices, including possible increases in vaccine hesitancy resulting
during the pandemic [15]. Survey data have indicated significant
levels of COVID-19 vaccine hesitancy, especially among underrep-
resented minority populations [16]. It is therefore critical to build
vaccine confidence and to reduce barriers to immunization where
possible by disseminating clear health messages, improving acces-
sibility, implementing culturally responsive strategies (e.g., mes-
ages in local languages), and developing empathy to effectively
combat vaccine hesitancy and ultimately increase children's
immunization and COVID-19 vaccination coverage rates.

Declaration of Competing Interest

The authors declare that they have no known competing finan-
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