

An Interactive Web-Based Dashboard for COVID-19 Hospitalizations in the U.S.

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Abstract

Many institutions have tracked the progression of COVID-19 in the U.S. in terms of the growth of the number of confirmed cases and the death count. However, there was no comprehensive source that daily documents the COVID-19 hospitalization status across states and sub-states. This paper aims to present a web-based unified dashboard that tracks the COVID-19 hospitalization trends and compares the situations across states and sub-states. We also introduce the designed information system behind the dashboard that supports the data collection and visualization. Hospitalization data for six metrics are collected from the department of health of each state. State and sub-state level data are presented in numeric and graphic form, and analyses on the hospitalization trends weighted by the number of population and hospital beds are provided for each metric by state. Our work provides researchers, policymakers, and healthcare professionals with information that can enhance their understanding of the COVID-19 hospitalizations situation. Its insights help them proactively plan, mobilize, and allocate hospital resources for the social good during the pandemic.

Keywords: COVID-19, hospitalization, data visualization, health informatics

1. Introduction

Since the first case of COVID-19 in the U.S. was reported in January 2020, the pandemic's progression in the country has been tracked by many institutions. Several dashboards have been created to document, compare, and analyze the daily change in the number of confirmed cases and the death count [1,2]. While these are important metrics to understand the pandemic's spread and fatality rate, they do not precisely reflect the status quo of the pandemic, nor do they provide an adequate lens into its impact on the healthcare infrastructure across different states and sub-states. This is because the case count is an underestimate in the absence of community-wide serologic testing, and the death count is a lagging metric and insufficient for proactive hospital capacity planning [3]. In contrast, hospitalization number is both an objective and dynamic metric useful for hospital capacity planning and resource mobilization. Most importantly, it informs the public of the pandemic's situation from the healthcare perspective.

However, most U.S. states were not reporting COVID-19 hospitalization data in a consistent and reliable manner. A single, unified repository for such data was not available to the public [4]. To fill this void, the Medical Industry Leadership Institute (MILI) [5] and the Management Information Systems Research Center (MISRC) [6] at the Carlson School of Management of the

University of Minnesota started the COVID-19 Hospitalization Tracking project [7] on March 26. In this project, we aim to create an interactive web-based dashboard for visualizing and analyzing the progression trend of COVID-19 hospitalization across states and sub-states in the U.S. using the public hospitalization data from official sources of all the 50 states and the District of Columbia. This paper presents the project and introduces the designed information system that supports its data collection and visualization. Our work disseminates real-time hospitalization information across the country and provides relative stakeholders with analytical insights to improve hospital capacity planning and resources balancing for social good during the pandemic.

We aggregate and display the hospitalization data on the dashboard with current updates and historical trends in numeric and graphic forms. The data is categorized into six metrics: the number of current hospitalizations, the number of cumulative hospitalizations, the number of currently in ICU cases, the number currently on ventilator cases, the number of cumulative in ICU cases, and the number of deaths. We further support these displays with visualizations of some weighted analyses by state, which include historical trends weighted by population size, historical trends weighted by the number of hospital beds, and so on. The web-based interactive dashboard is freely available to the public, researchers, policymakers, and healthcare professionals online (<https://carlsonschool.umn.edu/mili-misrc-covid19-tracking-project>).

2. Materials and Methods

The dashboard was officially launched on April 6. Since then, we have been consistently collecting, tracking, and publicly displaying the available official COVID-19 hospitalization data from all reporting states daily and at both state and sub-state levels. Data is collected and assessed from the Department of Health websites and other official data sources of all states. Each state's website is reviewed daily in three shifts, starting at 1:00 pm central time with 2-hour intervals. Later shift validates earlier entries and fills in new updates.

On the state level, when the dashboard was first launched, only 23 states were reporting any metric of hospitalization data. As of August 31, 49 states report current hospitalizations, 38 states report cumulative hospitalizations, 31 states report currently in ICU cases, 25 states report currently on ventilator cases, 13 states report cumulative in ICU cases, and all states report total deaths. A summary statistics of the state-level data is provided in Table 1. On the sub-state level, the dashboard currently displaces data for counties/regions of 20 states, with different data availability for each metric in each state.

Table 1. Summary statistics of the state-level data (as of 8/31/2020)

Metric	NO. of Reporting States ^a	Total Number	Mean	Std. Dev.	Min	Max
Current Hospitalizations	49	32,568	664.65	952.56	3	4,273
Cumulative Hospitalizations	38	377,038	9,922.05	16,868.78	141	99,924
Currently in ICU Cases	31	5,431	175.19	222.43	4	1,266
Currently on Ventilator Cases	25	1,879	75.16	54.48	1	161
Cumulative in ICU Cases	13	17,488	1,345.23	1,230.38	50	4,489
Total Deaths	51	171,800	3,368.63	4,754.63	37	25,327

^a State-level data include all the 50 states in the U.S. and the District of Columbia.

2.1. State data

The dashboard tracks and visualizes six metrics of COVID-19 hospitalization data on the state level, including the number of current hospitalizations, the number of cumulative hospitalizations, the number of currently in ICU cases, the number currently on ventilator cases, the number of cumulative in ICU cases, and the number of deaths. The data for each metric is displayed in separate dashboard views with color-layered map (the darker the color, the larger the number) and sorted table by state, and supported by graphs of trend lines across time for each state. The list of data availability of each metric and the primary source for each state is provided in Table 2.

Table 2. Summary of state data availability and the primary source for COVID-19 hospitalizations (as of 8/31/2020)

State	Hospitalizations to Date	ICU to Date	Current Hospitalizations	Currently in ICU	Currently on Ventilator	Total Deaths	Primary Source
AK*			X		X	X	Alaska Dept. of Health & Social Services
AL	X	X	X			X	Alabama's COVID-19 Data & Surveillance Dashboard
AR	X		X		X	X	Arkansas Department of Health Services
AZ*	X		X	X	X	X	Arizona Department of Health Services
CA*	X	X	X	X		X	California COVID-19 Data & Tools
CO	X		X			X	CO Dept of Public Health & Environment Case Data
CT*	X		X			X	Connecticut Dept. of Public Health
DC			X	X	X	X	Government of District of Columbia
DE			X	X		X	Delaware Division of Public Health
FL*	X					X	Florida's COVID-19 Data & Surveillance Dashboard
GA*	X	X	X		X	X	Georgia Dept. of Public Health
HI*	X					X	Hawai'i Dept. of Health
IA*	X		X	X	X	X	COVID-19 in Iowa
ID	X	X	X	X		X	Idaho Division of Public Health
IL			X	X	X	X	Illinois Dept. of Public Health
IN*	X	X		X	X	X	Indiana's Novel Coronavirus Response
KS	X	X				X	Kansas Dept. of Health & Environment
KY	X	X	X	X		X	Team Kentucky
LA			X		X	X	Louisiana Dept. of Health
MA	X		X	X	X	X	MA Dept of Public Health COVID-19 Dashboard
MD	X		X	X		X	Maryland Dept. of Health
ME*	X		X	X	X	X	Maine Division of Disease Surveillance
MI*			X	X	X	X	Michigan Coronavirus
MN	X	X	X	X		X	Minnesota Dept. of Health
MS	X		X	X	X	X	Mississippi State Department of Health
MO*			X			X	Missouri Dept. of Health & Senior Services
MT	X		X			X	Montana State Library
NC			X			X	North Carolina Dept. of Health & Human Services
NE	X		X			X	Nebraska Dept. of Health & Human Services
ND	X		X			X	North Dakota Dept. of Health
NH	X	X	X			X	New Hampshire Dept. of Health & Human Services
NJ*	X		X	X	X	X	New Jersey Dept. of Health COVID-19 Hub
NM	X		X			X	New Mexico Dept of Public Health Dashboard
NV			X	X	X	X	Nevada Dept. of Health & Human Services
NY*	X		X	X	X	X	Syracuse.com
OH*	X	X	X	X	X	X	Ohio Dept. of Health
OK	X		X	X		X	Oklahoma State Dept. of Health
OR	X		X	X	X	X	Oregon Health Authority
PA			X		X	X	Pennsylvania COVID-19 Dashboard
RI	X		X	X	X	X	Rhode Island Dept. of Health
SC	X		X			X	South Carolina Testing Data & Projections
SD	X		X			X	South Dakota Dept. of Health
TN	X		X			X	Tennessee Dept. of Health COVID-19
TX*			X			X	Texas COVID-19 County Dashboard
UT*	X	X	X	X		X	Utah Dept. of Health
VA*	X		X	X	X	X	Virginia Dept. of Health
VT	X	X	X			X	Vermont Public Health Response
WA*	X		X		X	X	Washington COVID-19 Status
WI*	X	X	X	X		X	Wisconsin Dept of Health Outbreaks
WV			X	X	X	X	West Virginia Dept. of Health & Human Resources
WY	X		X			X	Wyoming Infectious Disease Epidemiology Unit

X Data is available.

* State is reporting county/region level data.

2.2. Sub-state data

Sub-state data are available either at the county level or the regional level (e.g., the healthcare emergency readiness coalition regions (HERC) of Wisconsin, which consists of several contiguous counties). We present the sub-state hospitalization data in a different dashboard view for five of the six metrics mentioned earlier, excluding the number of cumulative in ICU cases as no state reports this metric of sub-state data. The dashboard allows users to select specific metrics and states (to which the sub-state data belongs) for interactive visualization and shows the data with a linked color-layered map and sorted table. The link between the map and table enables the two types of displays to change simultaneously based on users' selection. The list of sub-state data availability of each metric and the primary source is provided in Table 3.

Table 3. Summary of sub-state data availability and primary sources for COVID-19 hospitalizations (as of 8/31/2020)

State	County or Region ^a	Hospitalizations to Date	Current Hospitalizations	Currently in ICU	Currently on Ventilator	Total Deaths	Primary Source
AK	County	X				X	Alaska Dept. of Health & Social Services
AZ	County	X				X	Arizona Department of Health Services
CA	County		X	X			California COVID-19 Data & Tools
CT	County		X			X	Connecticut Dept. of Public Health
FL	County	X				X	Florida's COVID-19 Data Dashboard
GA	County	X				X	Georgia Dept. of Public Health
HI	County	X				X	Hawai'i Dept. of Health
IA	Region		X	X	X		COVID-19 in Iowa
IN	Region	X		X		X	Indiana Health Information Exchange
ME	County	X				X	Maine Division of Disease Surveillance
MI	Region		X	X	X		Michigan Coronavirus
MO	Region		X		X		Missouri Hospital Association
NJ ^b	Both	County	Region				New Jersey Dept. of Health COVID-19 Hub
NY	Region		X	X			New York Forward
NYC ^c	Borough	X				X	NYC Health
OH	County	X				X	Ohio Dept. of Health
TX	Trauma area		X				Texas COVID-19 County Dashboard
UT	County	X				X	Utah Dept. of Health
VA	Locality	X				X	Virginia Dept. of Health
WA	County	X				X	Washington COVID-19 Status
WI	Region		X	X			Wisconsin Dept of Health Outbreaks

X Data is available.

^a Sub-state administrative division is on different levels or named differently across states.

^b NJ reports both county and region level sub-state data. It reports county-level data for Hospitalization to Date and region level data for Current Hospitalizations.

^c New York City's report is independent from the state of New York.

2.3. Workflow

Figure 1 presents the workflow of the dashboard. Our research team members first manually collect data from each state (and its counties/regions) daily and input it into a dynamic "live" database that instantly stores the updated data. Each state's website is checked three times each day in the afternoon for verification and quality assurance. We then create an "extract" database that duplicates the "live" database at 8 pm central time every day once most states have released their daily report. The reason for doing this duplication is that all states do not release their data simultaneously. Hence, the "extract" database that only updates once a day helps us obtain a daily snapshot that shows all states' updates until 8 pm and is more suitable for daily analysis and dashboard queries. We also provide some temporal trend analysis for the six metrics on the state level, such as the current and cumulative hospitalization in each state per 100K adults, the percentage of hospital beds occupied by COVID-19 hospitalizations for current hospitalization,

etc. Each state's population and hospital bed capacity data used in these calculations are obtained from the American Community Survey [8] and the American Hospital Association Survey [9], respectively. We finally update the public-facing dashboard at midnight every day. The dashboard queries the information from the "extract" database and shows the results of our analyses.

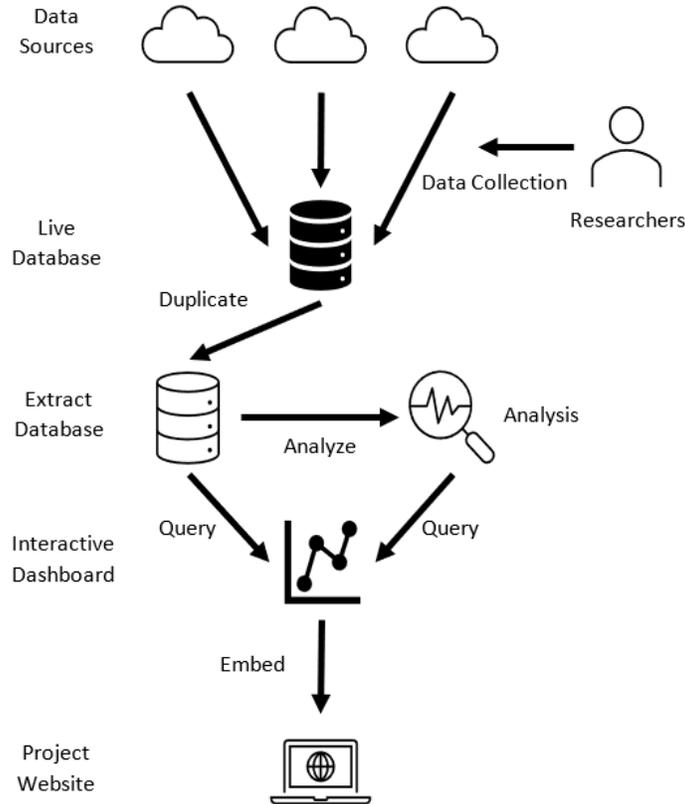


Figure 1. The Workflow of the Dashboard

3. Design of the dashboard

We aim to present a publicly accessible interactive web-based dashboard for visualizing and analyzing the progression trend of COVID-19 hospitalization in the U.S. across states and sub-states. The dashboard is designed to aggregate hospitalization data from different state sources into a unified repository for easy horizontal (across states and sub-states) and vertical (across time) comparisons. The dashboard is developed using Tableau [10], and we use its inbuilt widgets to generate the data visualizations with proper parameter/variable creations and computations. Data visualizations (e.g., color-layered map, table, and trend graph) are implemented to convert the data into easily understandable information for readers at all levels. Interactive tools (e.g., selecting different states or metrics, zoom, and pop-up windows along with mouse movement) are introduced to enhance user experience. The dashboard is embedded in the COVID-19 Hospitalization Tracking Project website hosted by University of Minnesota Carlson School of Management for free access. The data shown in the dashboard is the actual data reported by the states and their counties/regions. We do not use any estimation or smoothing technique to impute missing data or make projections.

4. Results

A screenshot of the dashboard's home page is shown in Figure 2. We present the dashboard both in numeric and graphic forms. We provide a sorted (Figure 2 (1)) table of raw data for each metric by state on the left side of each dashboard view. On the top of the table, we provide the total number (Figure 2(2)) of the focal metric across states and the number of reporting states (Figure 2(3)). We also embed the United States geographic map [10] (Figure 2(4)) in each dashboard view with color-coding to indicate the magnitude difference of a metric across states (the darker the color, the larger the number). When users move their mouse over a particular state, bubble pop-ups (Figure 2(5)) will appear to display the state's data. Users can click on each dashboard view (Figure 2(6)) to access data of different metrics.

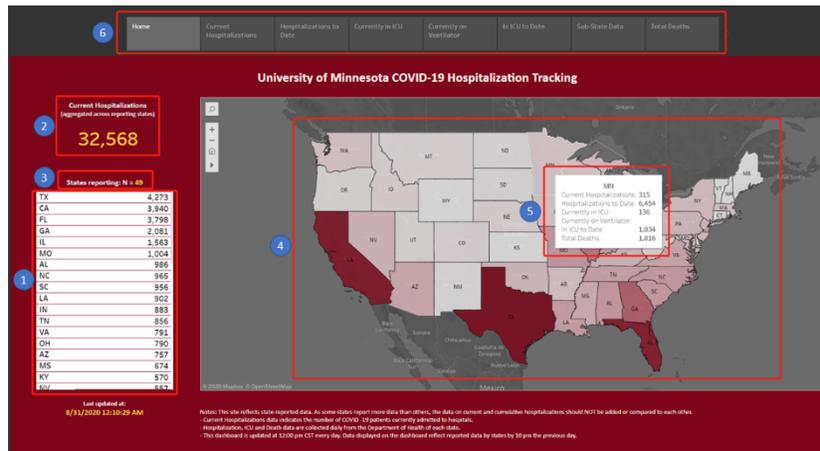


Figure 2. Homepage of the Interactive Web-Based Dashboard

Further, on the state level, we show some detailed analyses for each metric. For example, a screenshot of the current hospitalizations metric is shown in Figure 3 that presents the current hospitalizations trend across time (Figure 3 (1)). We further weight the current hospitalizations by 100K adults (Figure 3 (2)), compute the percentage of hospital beds occupied by current COVID-19 hospitalizations (Figure 3 (3)), and display these calculations on the dashboard. A drop-down menu (Figure 3 (4)) for selecting the data display by state is located at the top right corner of each trend plot. This option allows users to either view the trend for each state individually or compare the trend across different states.

In Figure 3, the left-hand table shows that on August 31, the total current hospitalizations across the nation is 32,568, with the selected populous state Texas reporting the largest number of 4,273 followed by California (3,940), Illinois (1,563), and New York (429, covered). Each state's trend lines demonstrate the changes in hospitalizations over time, with New York in gray, Illinois in red, California in blue, and Texas in pink. We observe that the number of current hospitalizations in the state of New York, which used to be the center of the pandemic in the country, experienced a peak point around April 12, two months after the outbreak of the pandemic. Illinois's peak was observed later in April. In contrast, California and Texas saw their peak points around July 20, three months after New York reached its peak and became the new hotspot states. We observe that after early June, the number of current hospitalizations in these two states started to pick up again, as the states announced reopening [12] for some of the businesses, and there was an epicenter switch due to the policy changes.

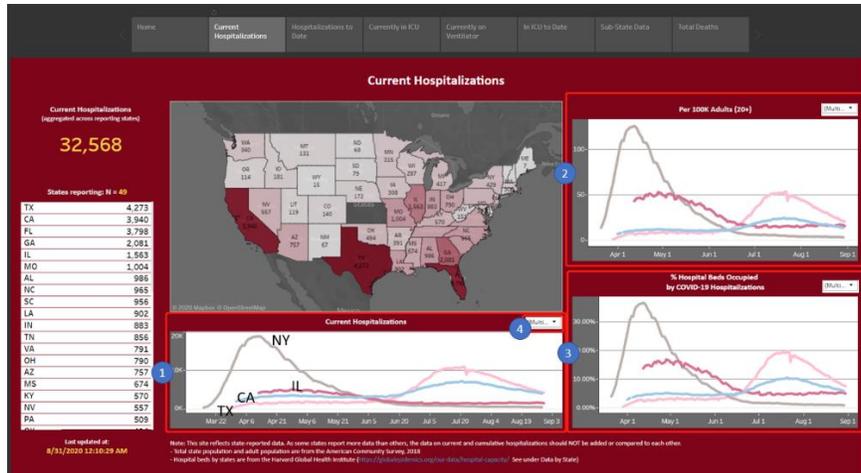


Figure 3. Screenshot of Dashboard for the Current Hospitalizations Across Time by State

Figure 4 compares the percentage of hospital beds occupied by COVID-19 hospitalizations in different regions of the country. We select four representative states in each region to demonstrate regional variations. We observe that the west coast region generally has the lowest percentage except for Arizona, which witnessed a rapidly increasing trend after the state's stay-at-home order expired on May 15 [13]. Similarly, some southern states such as Louisiana, Texas, and Mississippi also saw the percentage rebound after their reopenings around mid-June [12]. States in the northeast region reached peaks at around mid to late April, and since then have not seen a trend reversal. Likewise, Illinois in the mid-west region reached a peak around late April, and the rest of the states generally have flat trends. Tracking such percentage change can help healthcare practitioners understand the hospital capacity across time to efficiently prepare for necessary resource allocations, such as adding or reducing the number of general hospital beds and ICU beds in local hospitals.

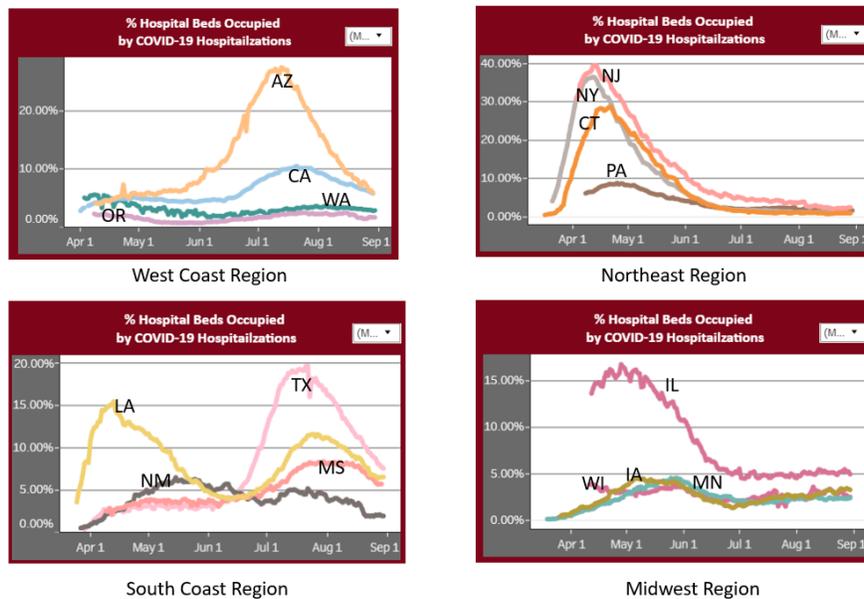


Figure 4. Comparison of the Percentage of Hospital Beds Occupied by COVID-19 Hospitalizations Across Time by Different Regions in the U.S.

On the sub-state level, we consolidate data of each metric for all data-available states and show them in a separate dashboard view as presented in Figure 5. Users can choose metrics and states to show in the map and the table by making selections through the bottom right drop-down menu (Figure 5(1)). The displays of the map and table are connected. Similar to state-level data, we also provide a sorted table (Figure 5(2)) of raw data for each metric by sub-state on the left and embed the geographic map [11] (Figure 5(3)) with color-coding to indicate the magnitude difference. When users move their mouse over a particular county/region, bubble pop-ups (Figure 5(4)) will show up display the county/region's data.

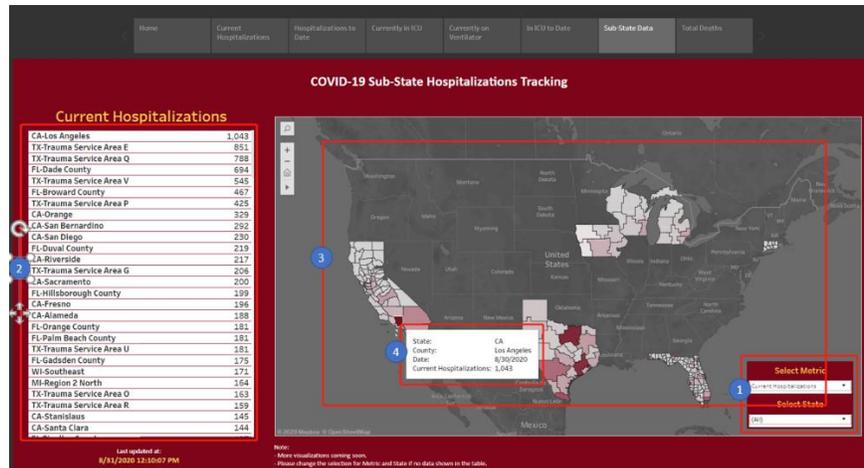


Figure 5. Screenshot of Dashboard for the Sub-State Data Exhibition

5. Discussion

In the absence of a comprehensive source that informs the COVID-19 hospitalization situation of all states and sub-state areas in the U.S., this work provides important information to researchers, policymakers, and healthcare professionals that can enhance their understanding of the current COVID-19 hospitalizations situation. Several news media outlets [14,15] and Universities [16,17] collaborated with our research team and used data from our dashboard to inform news reports and research papers.

Our work also highlights several data-related challenges that the U.S. needs to overcome to tackle the pandemic. First, all states should begin or continue to provide consistent and regular public reporting on these six metrics. Back in March, only 23 states were reporting hospitalization data of any kind, whereas as of August 31, all the 50 states and the District of Columbia report at least one category of data from the six metrics. Second, all states should define and report the metrics in a standardized way. For example, some states report both the potential and confirmed COVID-19 hospitalizations, while others only report the confirmed patients. Third, all states should report data at comparable geographic granularity. Some states report sub-state data by regions covering multiple counties, but having county-level data for each state will be richer from an informational perspective. Fourth, while many states provide information based on age and gender, they should also report the metrics by race and ethnicity to help devise policies that can address disparities in health outcomes of more severely affected communities.

As discussed above, our dashboard is useful for analyzing hospitalization trends across the states/sub-states and allows users to compare different states/substates across time. More importantly, it informs the users of the current situation of hospitalization in the country, so that they can remain alert of the pandemic. This data can be useful for several research projects, e.g., to study the association between the stay-at-home (or reopening) order and the change of hospitalizations [3], the association between the hospital capacity and mortality rate, the discrepancies between hospitalization trends in urban and rural areas, etc.

Given the importance of curating COVID-19 hospitalization data, we plan to continue hosting and managing the dashboard throughout the entire COVID-19 outbreak. Currently, the sub-state data is still sparse. As more states begin to report data at the sub-state level, we will include more sub-state data on the dashboard and provide trend analyses similar to what we did for the state data. We believe tracking the hospitalizations daily across different geographies (states, hospital referral regions, counties) is necessary for researchers to estimate the demand for hospital beds, ICUs, ventilators, and other hospital resources and proactively plan, mobilize and allocate resources. This information would also be important for developing technology platforms that share data in real-time across geographic areas and hospitals.

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