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Brief Communications

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# Measure what matters: Counts of hospitalized patients are a better metric for health system capacity planning for a reopening

**Sehj Kashyap,[1,*] Saurabh Gombar,[1,3,*] Steve Yadlowsky,[2] Alison Callahan,[1] Jason Fries,[1] Benjamin A. Pinsky,[3] and Nigam H. Shah[1]**

[1]Stanford Center for Biomedical Informatics Research, Stanford University, Stanford, California, USA, [2]Deptartment of Electrical Engineering, Stanford University, Stanford, California, USA, and [3]Department of Pathology and Medicine, Stanford University School of Medicine, Stanford, California, USA

*These authors contributed equally.

Corresponding Author: Saurabh Gombar, Stanford Center for Biomedical Informatics Research, Medical School Office Building, Room x235, 1265 Welch Road, Stanford, CA 94305-5479, USA; sgombar@stanford.edu

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**ABSTRACT**

**Objective:** Responding to the COVID-19 pandemic requires accurate forecasting of health system capacity requirements using readily available inputs. We examined whether testing and hospitalization data could help quantify the anticipated burden on the health system given shelter-in-place (SIP) order.
**Materials and Methods:** 16,103 SARS-CoV-2 RT-PCR tests were performed on 15,807 patients at Stanford facilities between March 2 and April 11, 2020. We analyzed the fraction of tested patients that were confirmed positive for COVID-19, the fraction of those needing hospitalization, and the fraction requiring ICU admission over the 40 days between March 2nd and April 11th 2020.
**Results:** We find a marked slowdown in the hospitalization rate within ten days of SIP even as cases continued to rise. We also find a shift towards younger patients in the age distribution of those testing positive for COVID-19 over the four weeks of SIP. The impact of this shift is a divergence between increasing positive case confirmations and slowing new hospitalizations, both of which affects the demand on health systems.
**Conclusion:** Without using local hospitalization rates and the age distribution of positive patients, current models are likely to overestimate the resource burden of COVID-19. It is imperative that health systems start using these data to quantify effects of SIP and aid reopening planning.

**Key words**; COVID-19, surge models, capacity planning, electronic health records

## INTRODUCTION

In order to prepare for coronavirus disease 2019 (COVID-19), health system leaders and policymakers need to forecast future healthcare needs. A number of forecasting models have been developed and widely shared to help healthcare facilities and governments predict upcoming patient surges and plan accordingly.[1,2] These models take in a myriad of inputs, including population demographics, currently admitted patients, case doubling times, and the rate at which positive cases turn into hospitalizations, among others.[1,3–5] While there are enough models, guidance, and data to provide accurate inputs to these models remain lacking.[6–8] Currently, 95% of Americans have been asked to stay at home. Schools, businesses, and community gathering activities have been closed or curtailed, and plans of reopening hinge on demonstrated sustained reduction in cases, availability of testing, and enough health system capacity to treat patients requiring hospitalization without resorting to crisis standards of care.[9,10] The need to accurately plan health system capacity is 1 of the 6 indicators cited to guide the state of California's decision making around reopening the state's economy.[11] An important first step is taking stock of the currently available hospitalization and testing data and how it has evolved as the pandemic progresses.

Stanford Health Care (SHC), a large academic healthcare system, serves patients in the San Francisco Bay Area. The major hospitals that comprise SHC are located in Santa Clara County, which began mandated shelter in place (SIP) on midnight March 16, 2020, 26 days before we conducted the analysis presented here. SHC developed an in house Sars-CoV-2 and had extensive testing capacity starting on March 4, and afterward, tested anyone who had influenza-like infection symptoms, anyone who had known COVID-19–positive contact, and healthcare workers with a known exposure, or those who were referred by physician discretion. As of April 11, our laboratory had tested nearly 15,800 cases, and tracked hospitalization data of the test-confirmed COVID-19 cases.

Given our dual access to testing and hospitalization data, we examined whether we could reliably quantify the effects of state-mandated SIP using testing and hospitalization rates. This allowed us to quantify the divergence between the rates of positive case confirmations and hospitalizations. In addition, we identified a shift in the age distribution of new COVID-19–positive cases over the duration of the study.

## MATERIALS AND METHODS

A total of 16,103 severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) reverse-transcription polymerase chain reaction tests were performed on 15,807 patients at Stanford facilities between March 2 and April 11, 2020. Of these, 8309 tests were performed on 7929 patients in facilities in which the patient would have been admitted to our hospital if necessary. We analyzed the fraction of tested patients that were confirmed positive for COVID-19, the fraction of those needing hospitalization, and the fraction requiring intensive care unit (ICU) admission over the 40 days between March 2 and April 11, 2020.

Data were obtained from a combination of 2 sources: a daily refreshed snapshot of the health system's Enterprise Data Warehouse (EDW) and a twice-daily refreshed extract of all reverse-transcription polymerase chain reaction laboratory tests for SARS-CoV-2 at Stanford. Access to a view of the EDW was set up last year as part of Stanford Medicine's Program for Artificial Intelligence in Healthcare.[12] The EDW view consisted of 33 tables, containing demographics, diagnoses, procedures, labs, and orders. These tables were refreshed nightly with updated 1-year historical and current hospitalization information of patients admitted in the census of the hospital. The access to the laboratory testing was provided as part of Stanford's data science response to COVID-19.[13] The laboratory testing data consisted of details about the specimen collected, the result, the procedure of specimen collection, identifiers to link with EDW tables, and symptoms documented on admission. The project to track SARS-CoV-2 test positivity and hospitalization trends was initiated as a quality assurance project aimed at enabling hospital capacity planning, and institutional review board approval (protocol # 55544) was obtained prior to this submission summarizing the learning from this effort.

## RESULTS

### A total of 3.77% of COVID-19–positive patients required an ICU admission

As shown in Figure 1, of these 7929 tested patients, 451 (5.68%) tested positive for COVID-19, and of these 451 cases, 59 (13.08%) were hospitalized following their test. Among the 59 hospitalized cases, 17 (28.8% of hospitalized and 3.77% of all positive cases) required ICU care. Our observed case hospitalization rate is more in line with the 12% reported nationally than the 25.5% reported in New York City (as of April 7).[14,15] The higher case hospitalization rate in New York City may be due to the fact that low testing capacity to case numbers might have led to severe cases being prioritized for testing. Our ICU rate among confirmed cases similarly matches American national reports of 2.9%, compared with the 5% reported in China or 12% in Lombardy (Italy).[16,17]

### The hospitalization rate slowed within 10 days of SIP, even as confirmed cases continue to rise

Between March 2nd, 2020 and April 11th, 2020, we have continued to see new COVID-19 cases, hospitalizations, and ICU admissions; however, their rates have slowed (Figure 2). The doubling time for each metric increased from under 5 days on March 16 to over 25 days as of April 11. The slowdown in hospital admissions began within 10 days of SIP and was more dramatic than the slowdown of confirmed cases. Forecasting models should incorporate the divergence between the rate of new COVID-19 cases vs new hospitalizations to better forecast near-term demand on the health system.

Given that the test results and admissions data are available in nearly real time, health systems–based monitoring of admission rates and the doubling time of hospitalized patient counts can provide accurate data for both public health planning and epidemiological modeling.[3]

### Recently detected COVID-19 cases were younger than were those detected prior to social distancing measures

As shown in Figure 3, between weeks 11 and 14 of the epidemic, there was no significant shift in the age distribution of patients tested. However, the average age of COVID-19–positive patients decreased ($P$ = .0004) from 55.6 (95% confidence interval [CI], 53.0-58.3) years of age prior to social distancing (March 16, week 11) to 49.8 (95% CI 47.9—51.7) years of age after 2 weeks of social distancing (March 30, week 14).

### Characteristics of COVID-19 cases hospitalized later were the same as those hospitalized earlier

Compared with before social distancing, the mean length of stay of hospitalized cases and rate of ICU admission was not significantly different (1.73 [95% CI, -2.16 to 5.62] days shorter and 4.1% absolute increase [95% CI, -30% to 38%], respectively) than 2 weeks after social distancing (difference in means $P$ = .378 and .810, respectively) (Table 1). Because the length of stay was right-censored for patients still in the hospital, these estimates were corrected for censoring.

## DISCUSSION

While most epidemic simulation models use new case rates, no currently published model takes into account the shifts in demographics of positive patients, which is a major determinant of future hospital admission rates. If most new cases are younger, the corresponding need for hospitalizations will also be lower. Over the course of 5 weeks, we did not find a significant change in the age distribution of patients presenting with influenza-like illness (ILI) and who tested for COVID-19; however, we did find a significant shift toward younger patients in those testing positive for COVID-19. The simplest explanation for the shift toward younger patients testing posi-

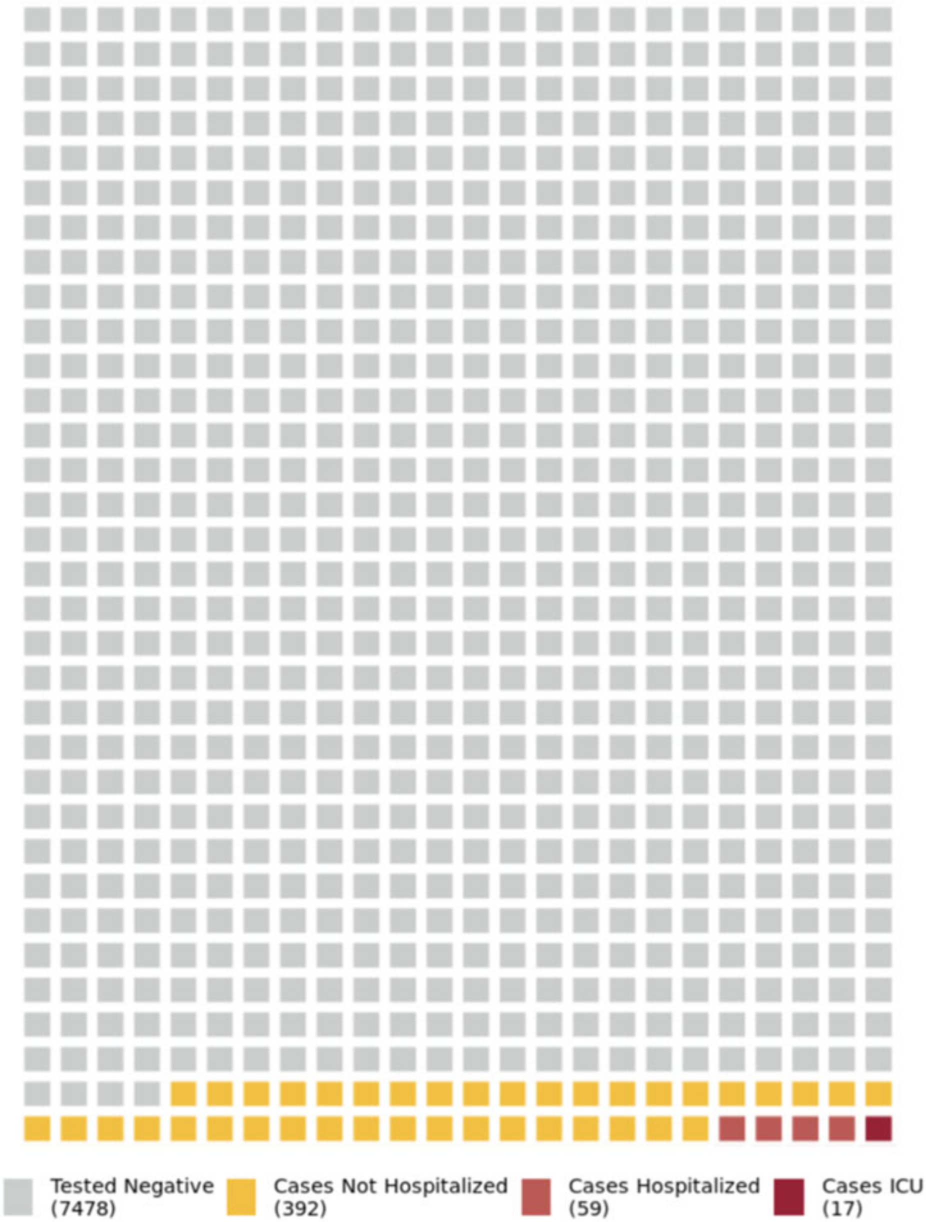


**Figure 1.** Test result as well as hospitalization outcomes of patients tested for severe acute respiratory syndrome coronavirus 2. Each box represents 10 patients. ICU: intensive care unit.

tive could be relaxing testing criteria. For example, guidelines at our institution went from requiring ILI symptoms and a known COVID-19 exposure to expressing symptoms consistent with ILI, to medical doctor discretion. However, this does not explain why there is no change in the demographics of patients getting tested for COVID-19. A more plausible explanation is that because of the SIP order, the at-risk elderly population is protected and hence less likely to contract COVID-19. This interpretation is supported by the fact that despite seeing a larger number of younger COVID-19–positive patients, those that need to be admitted have similar ages, rate of ICU admission, and length of stay as before the SIP order; now, we see fewer absolute numbers of such cases.

Our analysis spanning 26 days after SIP clearly demonstrates that the rate of confirmed cases, hospitalizations, and ICU admissions for COVID-19 has flattened. The decrease in the rate of new hospitalizations began within 10 days after SIP was initiated and continues today. Despite the decrease in hospitalizations, we continue to see new patients presenting with ILI and younger patients testing positive for COVID-19, indicating ongoing community spread but perhaps in a lower-risk population.

This analysis demonstrates how, compared with new case counts, new hospitalizations is a better metric both for detecting the effect of SIP and for estimating the anticipated burden on the health system.[10,11,18] Our findings also suggest that existing surge planning efforts should frequently recompute hospitalization doubling time because the change can be swift, as seen in our data.[19] Models that do not use local hospitalization rates as well as the age distribution of the positive patients are likely to overestimate the resource burden of COVID-19.

Investments made in setting up data feeds prior to and immediately at the outset of this crisis were critical to accessing such data quickly. Additionally, a unification of our information technology organizations across the School of Medicine and the Healthcare Sys-

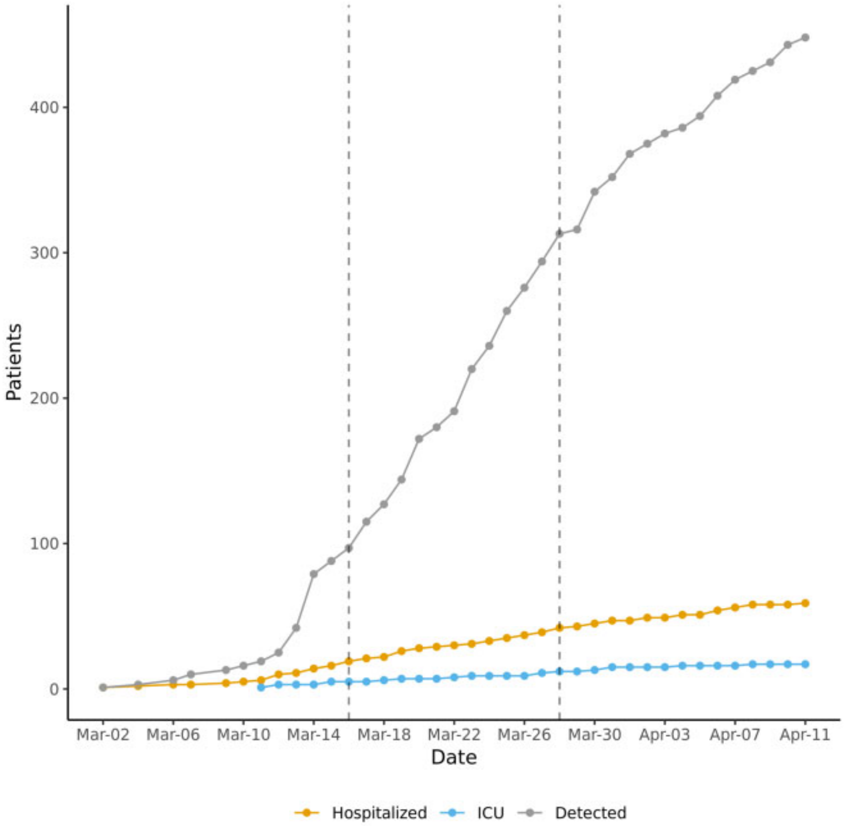


**Figure 2.** Slowed growth in total cases detected, hospitalized, and admitted to the intensive care unit (ICU) is seen after the shelter-in-place order (first dashed line). The prolongation of the doubling time of hospitalizations (yellow) happens faster and earlier than cases detected (gray). The divergence between the rate of cases detected and slower rate of hospitalizations is seen within 10 days of the shelter-in-place order. Doubling times calculated over a 7-day sliding window show that by March 28 (second dashed line), cases were doubling every 9 days, but hospitalizations were doubling every 13 days.

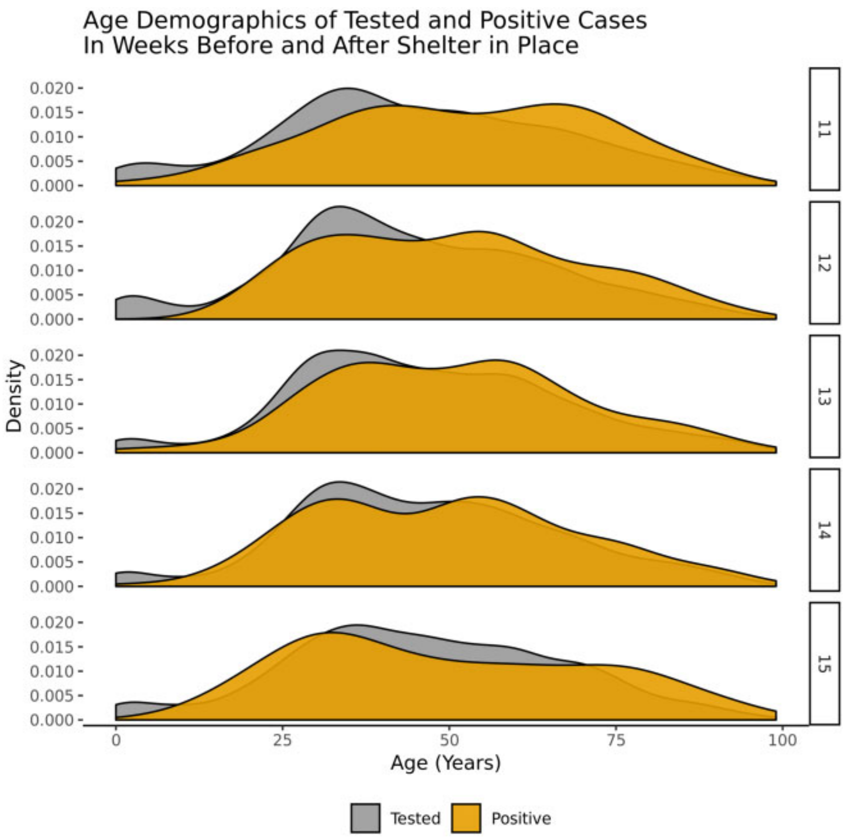


**Figure 3.** Change in age distribution of patients with positive severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) test (brown) compared with those tested for SARS-CoV-2 (gray) for 4 weeks after sheltering in place order.

**Table 1.** Characteristics of COVID-19–hospitalized cases around the state-mandated SIP ordered on March 16

| Period | Hospitalized Cases | Age (y) | Length of stay (d) | % Hospitalized Admitted to ICU | Transfer to ICU From Admission (d) |
|---|---|---|---|---|---|
| Pre-SIP | 16 | 58.1 ± 15.1 | 8.31 | 31.2 | 1.72 ± 1.4 |
| First 2 wk SIP | 28 | 59 ± 18.7 | 6.91 | 25 | 1.19 ± 1.7 |
| >2 wk SIP | 15 | 61.4 ± 19.1 | 6.58 | 33.3 | 0.76 ± 0.65 |

Values are mean ± SD, unless otherwise indicated. Length of stay is adjusted for censoring using the Kaplan-Meier curve and 14 day restricted mean length of stay.

COVID-19: coronavirus disease 2019; ICU: intensive care unit; SIP: shelter in place.

tem, which was completed in September 2019, proved to be immensely valuable enabling the setup of data access (such as to the laboratory testing data) in a timely manner.

## CONCLUSION

Given the relative ease of obtaining testing and admission data at a health system, these metrics can not only help quantify the effects of state-mandated SIP, but also enable better planning of health system capacity to aid any actions required to return to precrisis operations.[20] For any reopening scenario, accurate projections of near-term health system capacity requirements are essential.[21] Therefore, we must start using these easily available, and useful, inputs right away.

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## AUTHOR CONTRIBUTIONS

All authors were involved in drafting or critically revising the presented work, gave final approval of the submitted manuscript, and agree to be accountable for ensuring the integrity of the work. SG, SK, NHS and SY drafted the manuscript, which was reviewed and edited by all co-authors. SG, SK, NHS conceived of the analysis design. BAP acquired, helped interpret and analyze lab testing data. JAF and AC analyzed hospitalized patients' admission characteristics and presenting symptom severity. SG, SK and SY conducted statistical analysis of the data, and SY conducted additional statistical analyses to produce the censor-adjusted estimates.

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## CONFLICT OF INTEREST STATEMENT

The authors have no competing interests to declare.

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