Contents lists available at ScienceDirect

Academic Pathology 11/2 (2024) 100113

Academic Pathology

journal homepage: www.journals.elsevier.com/academic-pathology

Regular Article

Intra- and post-pandemic impact of the COVID-19 outbreak on Stanford Health Care

Thanaphong Phongpreecha, PhD [a,b,c,*], Eloise Berson, PhD [a,b,c], Lei Xue, PhD [b,c,d], Sayane Shome, PhD [b,c,d], Geetha Saarunya, PhD [b,c,d], Jennifer Fralick, BA [e], Bernardita Guridi Ruiz-Tagle, MS [e], Andrew Foody, MBA [e], Alexander L. Chin, MD, MBA [e], Michael Lim, MD [f], Rudolph Arthofer, BS [e], Christopher Albini, MBA [e], Kathleen Montine, PhD [a], Ann K. Folkins, MD [a], Christina S. Kong, MD [a], Nima Aghaeepour, PhD [b,c,d], Thomas Montine, PhD [a], Alison Kerr, RN, MSN [e]

[a] *Department of Pathology, Stanford University, USA*
[b] *Department of Anesthesiology, Perioperative and Pain Medicine, Stanford University, USA*
[c] *Department of Biomedical Data Science, Stanford University, USA*
[d] *Department of Pediatrics, Stanford University, USA*
[e] *Stanford Health Care, USA*
[f] *Department of Neurosurgery, Stanford University, USA*

A B S T R A C T

Stanford Health Care, which provides about 7% of overall healthcare to approximately 9 million people in the San Francisco Bay Area, has undergone significant changes due to the opening of a second hospital in late 2019 and, more importantly, the COVID-19 pandemic. We examine the impact of these events on anatomic pathology (AP) cases, aiming to enhance operational efficiency in response to evolving healthcare demands. We extracted historical census, admission, lab tests, operation, and AP data since 2015. An approximately 45% increase in the volume of laboratory tests ($P < 0.0001$) and a 17% increase in AP cases ($P < 0.0001$) occurred post-pandemic. These increases were associated with progressively increasing ($P < 0.0001$) hospital census. Census increase stemmed from higher admission through the emergency department (ED), and longer lengths of stay mostly for transfer patients, likely due to the greater capability of the new ED and changes in regional and local practice patterns post-pandemic. Higher census led to overcapacity, which has an inverted U relationship that peaked at 103% capacity for AP cases and 114% capacity for laboratory tests. Overcapacity led to a lower capability to perform clinical activities, particularly those related to surgical procedures. We conclude by suggesting parameters for optimal operations in the post-pandemic era.

Keywords: Anatomic pathology, Hospital admission, Hospital census, Overcapacity, Surgery capability

Introduction

Healthcare systems in the USA are evolving rapidly in response to changing demographics and forces created by the pandemic and its consequences. Stanford Health Care operates in the San Francisco Bay Area, where it provides about 7% of overall healthcare to approximately 9 million people and is one of two major academic medical centers providing tertiary and quaternary care. Stanford Health Care is a Level 1 trauma center, comprehensive stroke center, and ST elevation myocardial Infarction (STEMI) receiving facility in addition to providing complex transplantation, cardiovascular, cancer, neuroscience, and orthopedic care. A dedicated life flight team serves the community by flying patients requiring high-level care.

Since 2015, Stanford Health Care has never experienced major changes like over the last four years because of two events: opening a second hospital and the consequences of the COVID-19 pandemic, all of which has a critical impact on clinical laboratory test and anatomic pathology (AP) cases (Fig. 1). As we appear now to be stabilizing into a new normal, we broadly reviewed Stanford Health Care overall clinical and surgical activity to understand better the impact of these major changes and to gain insight into optimizing operations for the new status quo. The opening of the second hospital and the pandemic mark four phases for Stanford Health Care: Phase I is baseline data before these major changes and reflects status quo ante operations, a period of relative stability during which the original Stanford Hospital operated under a licensed bed capacity of 614 with most rooms as double occupancy. Phase II began with the opening in November 2019 of an adjacent second hospital with a combined licensed bed capacity of 604 single occupancy rooms, a project almost a decade in the making.[1] Within months of opening the second hospital, Phase III began with the onset of COVID-19 pandemic restrictions in March 2020. During that time,

* Corresponding author. Stanford University, 300 Pasteur Dr Rm L235. MC 5324, Stanford, CA 94305, USA.
E-mail address: tpjoe@stanford.edu (T. Phongpreecha).

https://doi.org/10.1016/j.acpath.2024.100113
Received 23 September 2023; Received in revised form 12 January 2024; Accepted 3 February 2024, Available online xxxx

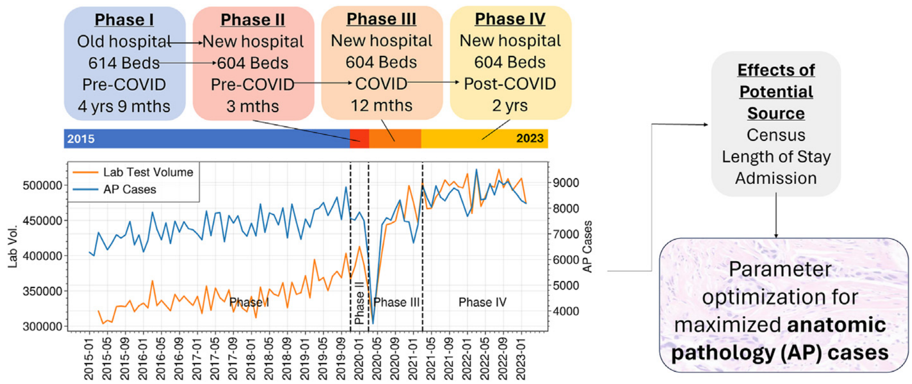

Fig. 1. Overview of the study. Monthly anatomical pathology (AP) case counts and laboratory test numbers are plotted over time. During COVID-19, the trend changed when the increase in laboratory test volume became greater. This suggests lower surgical operations and this study aims to study effects from potential sources of changes, including census, length of stay, and admission, and then optimize these parameters for maximizing AP cases.

Stanford Health Care was a major care center for Covid patients needing ECMO (extracorporeal membrane oxygenation), transplantation evaluation/intervention, neurosurgery or cardiothoracic surgery, as well as for other high acuity medicine/surgery COVID patients. Phase IV began with a return to a relatively stable new state of hospital operations post-pandemic.

We used clinical laboratory test and AP test numbers as estimates of overall clinical activity and overall procedural activity, respectively, and combined these with hospital census and other data to determine the key features of each of the four phases of operations and to guide Stanford Health Care management in the post-pandemic status quo (Fig. 1).

Materials and methods

All laboratory tests in Stanford Health Care are evaluated in a single clinical laboratory so the total laboratory test number (approximately 16 million in 2022) provides an integrated measure of overall clinical activity deriving from the number of inpatients reflected by hospital census, diagnostic difficulty, and disease acuity. We used AP case numbers as an estimate of the surgical activity because of their close coupling. The data were obtained from available records in Stanford Health Care and were aggregated to monthly values. The datasets include total census (01/2016), census data stratified by sources (01/2016), admission data stratified by sources (12/2019), total lab test volume (03/2015), individual lab test volume (03/2020), AP case number (02/2015), and surgery count data stratified by departments (12/2019). The date in the parentheses denotes the starting collection date of the dataset.

Average length of stay (LOS) was defined using the following formula:

$$LOS = \frac{Total\ Monthly\ Census}{Total\ Monthly\ Admission}$$

Additionally, the % capacity of the hospital was defined as monthly by:

% Capacity = Total Monthly Census / (30 × No. of Licensed Beds) × 100

where the no. of licensed beds is 614 in phase I and 604 in any other phases.

The % contribution from a factor (LOS or admission) was calculated by:

$$\%\ Contribution\ Admission = \frac{Total\ Admissio\ n_x * Avg.\ LOS_{[II,III]}\ -\ Avg.\ Initial\ Census_I}{Avg.\ Initial\ Census_I} \times 100\%$$

$$\%\ Contribution\ LOS = \frac{LOS_x * Avg.\ Admissio\ n_{[II,III]}\ -\ Avg.\ Initial\ Census_I}{Avg.\ Initial\ Census_I} \times 100\%$$

where $Total\ Admission_x$ is total admission of month x, $Avg.\ LOS_{[II,III]}$ is the average LOS in phase II and III (these were used as substitutes of phase I data as it was not available), $Avg.\ Admission_{[II,III]}$ is the average total monthly admission in phase II and III, and $Avg.\ Initial\ Census_I$ is the average monthly census in phase I.

Statistical analyses were performed using the statsmodel and scikit-posthocs packages[2,3] from Python and GraphPad Prism[4] (San Diego, CA) with appropriate multiple comparison corrections.

Results

Overall clinical and surgical activities

Clinical laboratory test number and census were significantly positively correlated in each of the four phases, although the correlation varied across phases (Phase I: R = 0.63, P < 0.0001; Phase II: R = 1.00, P < 0.0001; Phase III: R = 0.93, P < 0.0001; Phase IV: R = 0.41, P < 0.05; Fig. 2A), supporting this as a dynamic metric of overall clinical activity. There was a very high correlation between surgery count and AP test count for all four phases (Fig. 2B, see Supplementary Figure 1 for further details). We prefer to use laboratory tests or AP case counts to census or surgery counts because to some extent the test count also reflects case complexity and not simply the number of patients. Fig. 1 plots monthly values for these two measures across the four phases of Stanford Health Care. Lab volume data was combined from both in- and outpatients to account for the total effect on AP case numbers; stratified analysis showed that both in- and outpatient numbers followed the same increasing trend (Supplementary Figure 2). Tests from Stanford Health Care's outreach program constitute approximately 6% of the total volume. Analysis of variance (ANOVA) for the number of total laboratory tests per month was significantly different for the four phases (P < 0.0001), and when compared to Phase I was significantly increased by about 25% in Phase III (P < 0.01, baseline vs COVID-19 pandemic) and about 45% in Phase IV (P < 0.0001, baseline vs post-COVID-19 pandemic) (Fig. 2C). At the peak month (2022–08), the capacity of the lab reached an average of 17,156 tests per day. The top three laboratory tests by number, from high to low, in Phase III were SARS-CoV-2 (9% of all lab tests at 37,168 per month on average), glucose, and complete

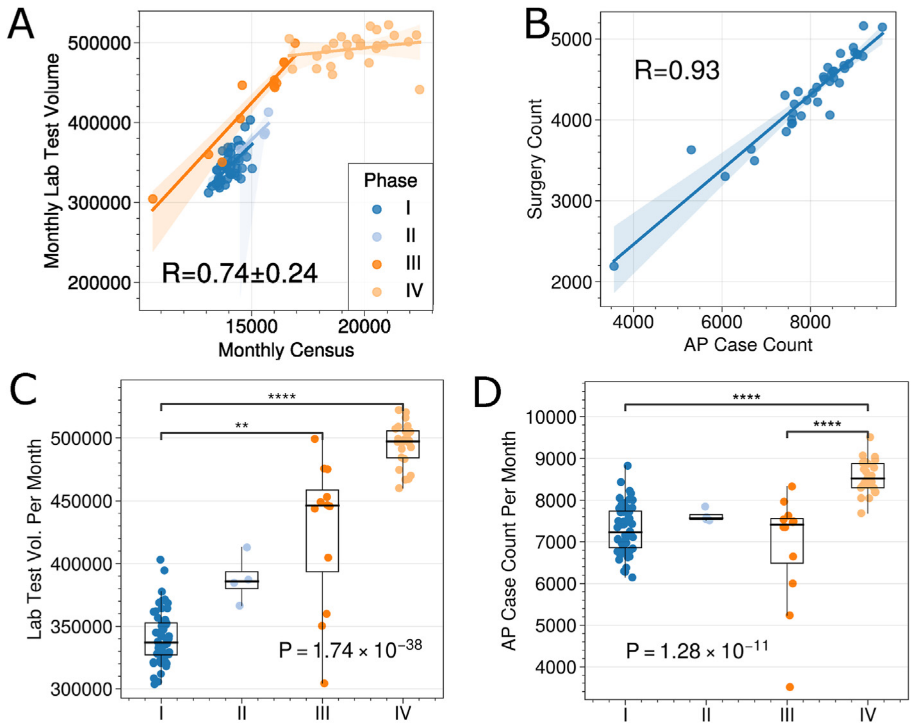

Fig. 2. Overview of the hospital activity during different phases. (**A**) Monthly census and laboratory test volume showed strong correlations in each phase supporting this as a dynamic measure of overall clinical activity. (**B**) The number of AP cases and surgery count showed a high correlation validating AP case count as a surrogate for surgery count. (**C**) One-way ANOVA of laboratory test volumes across phases ($P < 0.0001$) with corrected (Dunn's multiple comparisons) pairwise comparisons. (**D**) AP case counts across phases. One-way ANOVA of AP counts across phases ($P < 0.0001$) with corrected (Dunn's multiple comparisons) pairwise comparisons. **$P < 0.01$ and ****$P < 0.0001$.

blood count, while in Phase IV were glucose, complete blood count, and SARS-CoV-2 (5% of all tests at 19,543 per month; Supplementary Figure 1B). COVID-19 testing even significantly increased the number of lab tests per census, with Phase III showing 28 labs per patient compared to about 25 in Phase II (pre-COVID-19) and IV (post-COVID-19) (Supplementary Fig. 3). The ANOVA for the number of AP cases per month also was significantly different across phases ($P < 0.0001$); compared to Phase I, Phase IV was increased by about 17% ($P < 0.0001$; Fig. 2D). Overall, these analyses show a significant increase in overall clinical and surgical activities post-pandemic as assessed by the surrogate measures of total clinical laboratory tests and AP cases.

Hospital census

We pursued potential drivers of the significant increase in clinical activity post-pandemic by examining the hospital monthly census over the four phases stratified by source: direct admissions, admissions for surgical procedures, admissions through the Emergency Department (ED), or transfers from other hospitals (Fig. 3A). The top census departments can be found in Supplementary Figure 1C. Two-way ANOVA for the monthly census by source and phase showed several significant changes among phases for the different sources; however, by far the largest increase was from the ED ($P < 0.001$), which had been largely stable through Phases I to III but then almost doubled during Phase IV (Fig. 3B) due to its significantly higher admissions post-COVID-19 (Fig. 3C). Next, we evaluated LOS, another key contributor to the hospital census. LOS data were not available from Phase I and only two months of Phase II (Fig. 3D). Therefore, we restricted our two-way ANOVA to Phases III and IV (Fig. 3E, $P < 0.0001$ for source, phase, and interaction). Of the different sources of admissions, LOS was significantly increased post-pandemic for transfer patients (21% increase, $P < 0.01$) and ED patients (12% increase, $P < 0.01$) (Fig. 3E). By holding total admissions or LOS constant, we estimated the % contribution to census by total admissions or LOS relative to Phase I (Fig. 3F). The % contribution to census by total admissions ($P < 0.001$) and by LOS ($P < 0.01$) was significantly increased in Phase IV (Fig. 3G); importantly, the average % contribution across all of Phase IV was approximately twice that of admissions from LOS (Fig. 3G). However, it should be noted that the contribution trend of admissions is gradual in Phase IV (Slope $= 0.40$; $P < 0.05$), whereas it is more pronounced for LOS (Slope $= 0.83$; $P < 0.001$), and the two % contributions nearly converge at the end of Phase IV. Although both admissions and LOS were significantly related and associated with hospital census, we observed that the variance in overall clinical and procedural activity, as measured by laboratory test and AP case counts, in Phase IV is better explained by total admissions than LOS (Fig. 3H).

In summary, so far our analysis shows that this significantly increased activity at Stanford Health Care post-pandemic was characterized by a significantly increased census driven by increased ED admissions likely a direct effect of opening the second hospital, and significantly increased LOS for transfer patients likely a reflection of changed regional and local practice patterns (Supplementary Figure 4).

Hospital capacity

Next, we undertook to provide context for census numbers by calculating an estimate of hospital capacity by normalizing hospital census to licensed bed numbers (614 in Phase I and 604 in Phases II to IV). There was a striking rise in % capacity from a stable, approximately 70 to 80% capacity during Phase I (slope of % capacity vs time $= -0.0032$, $P = 0.88$) to a steadily increasing % capacity during Phase IV (slope of % capacity vs time $= 1.0705$, $P = 2.39 \times 10^{-12}$)

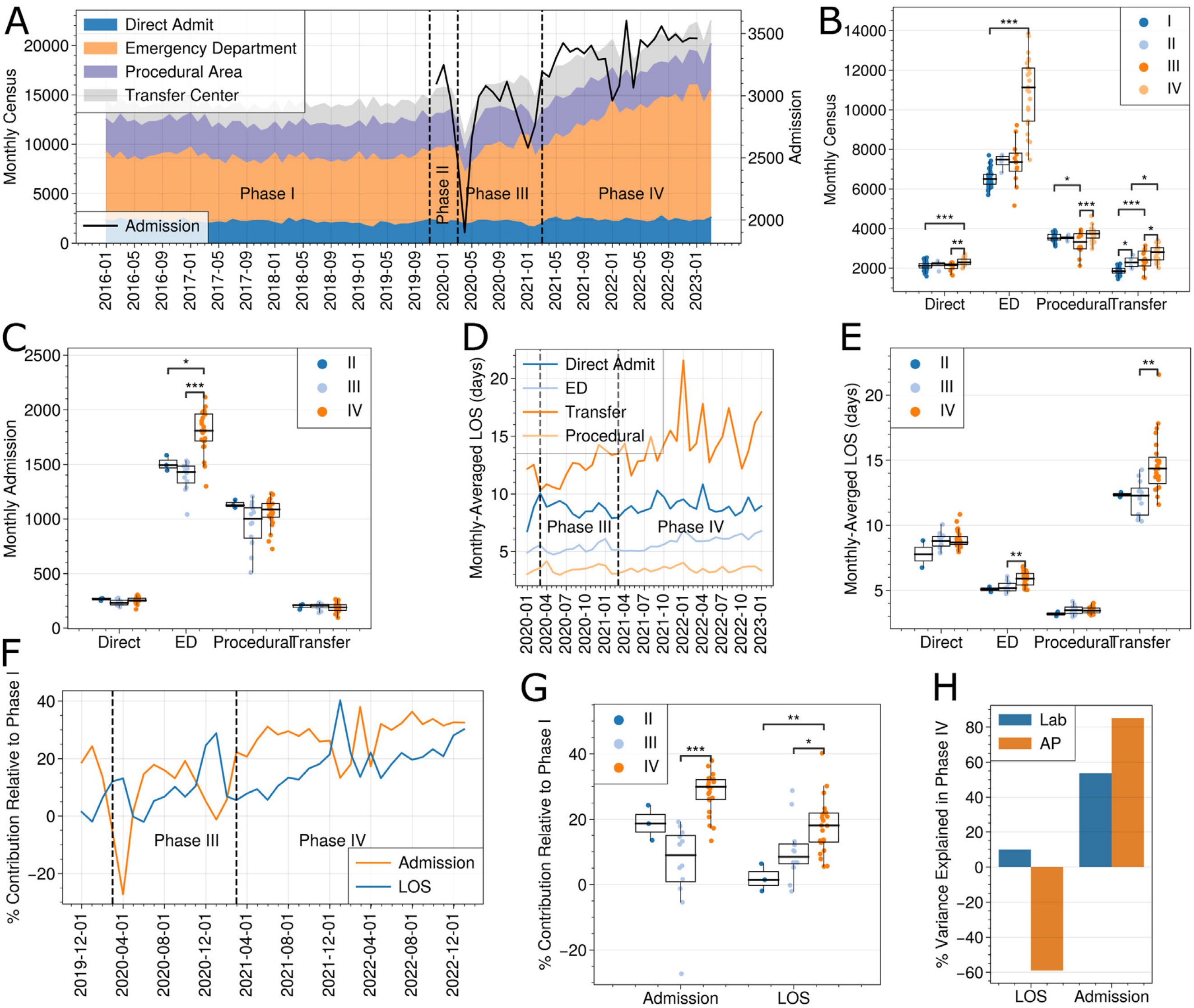

Fig. 3. Increased admission and census over time, and their potential drivers. (**A**) Monthly census and admissions over time show the increase mostly stemmed from the increase in emergency department (ED) admissions. (**B**) There were multiple significant increases in the census from different admission sources across the phases (Two-way ANOVA $P < 0.0001$, Tukey's corrected pairwise comparisons), but ED had the greatest increase. (**C**) Similar to (**B**), the increase in admission was significant for the ED only (**D**) Average length of stay (LOS) plotted by month over Phases II to IV. (**E**) Two-way ANOVA with Tukey's corrected pairwise comparisons showed a significant increase in LOS for ED patients and, to a larger extent, transfer patients. (**F**) The % contribution from total admission and length of stay on census from its average in Phase I. (**G**) Two-way ANOVA with Tukey's corrected pairwise comparisons showed a significant increase in the contribution of admission and LOS on the increase of census relative to Phase I. (**H**) The percent variance explained in lab test volume and AP cases during Phase IV by LOS and admission. *$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$.

(Fig. 4A). We hypothesized that capacity and clinical activity (clinical laboratory test) will rise together up to a point where the census nears capacity, after which we hypothesized that AP cases, but not total laboratory tests, will decline because hospital overcrowding will impede scheduled surgical admissions while non-procedural care continues. Fig. 4B plots % capacity vs clinical laboratory test number and AP case number. As expected, % capacity vs AP case number has an initially positive correlation that begins to plateau at approximately 85% to 90%

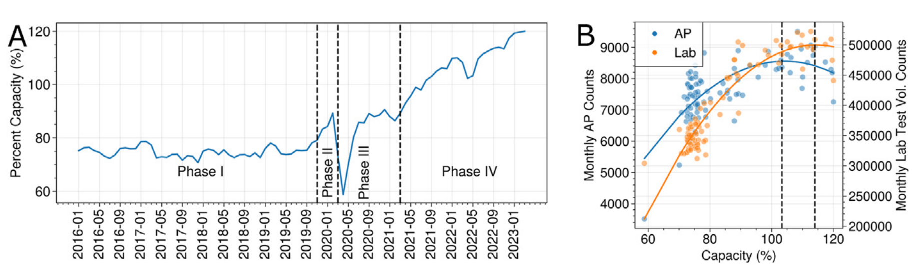

Fig. 4. Capacity. (**A**) Estimate of % capacity plotted by month across the four phases. (**B**) The effect of capacity on clinical laboratory tests and AP case counts. The dashed black lines indicate the point where % capacity reaches the maximum for AP cases and then the laboratory test number.

capacity and then turns to a negative correlation at 103% capacity. Contrary to expectation, the total laboratory test number also followed a similar relationship but shifted to the right such that the initial positive correlation with % capacity begins to plateau at about 95 to 100% capacity and turns to a negative correlation at 114% capacity. We speculate that this unanticipated inverse relationship between high % capacity and total clinical laboratory test number may be related to increased LOS for patients requiring less intensive medical care as they await transfer to less intensive healthcare facilities. Note that not only did the number of AP cases decrease due to overcapacity in Phase IV, the turnaround time from Phase III to IV also significantly increased by 17% on average (Supplementary Fig. 5).

These data indicate that both the number of AP cases and overall clinical laboratory tests decrease when capacity is exceeded and suggest that surgeries are more sensitive to the negative pressures from overcapacity than is medical care.

Hospital capacity, admissions, and LOS

Finally, we directly examined the trajectory of the relationship among % capacity, admissions, and LOS using heatmaps to visualize their interplay and identify the quickest path to ease patient overloading: the first plots the trajectory for overall admissions vs overall LOS (Fig. 5A), and the second plots the trajectory for ED admissions vs transfer LOS (Fig. 5B). Each heatmap shows the optimal range of daily admission given the LOS, and vice versa, to achieve a capacity between 95 and 105% (gray zone), which is maximal for AP case counts. The two heat maps show that Stanford Health Care passed optimal capacity around late 2021. The heatmaps also can be used to predict optimal future targets based on historical data. For example, if the healthcare system targets average LOS = 6 days, then based on past performance the monthly-averaged daily admissions need to be 93 to 107 to operate at maximal capacity without putting downward pressure on surgical procedures.

Discussion

Here we report the experience of a medium-sized research-intensive academic medical center from 2016 to early 2023. During this period, Stanford Health Care opened a second hospital in late 2019, began responding to the COVID-19 pandemic in March 2020, and returned to stable but changed operations in the spring of 2021 with increased capacity demands. These major events define four phases of Stanford Health Care. Status quo ante in Phase I (2016 to November 2019) was followed by two major events in close succession: a second hospital opened (Phase II from December 2019 to March 2020) and COVID-19 pandemic restrictions (Phase III from March 2020 to March 2021). The marked increase in AP volumes in Phase III derived not only from case backlog and restarting procedures supported by pre-procedural COVID-19 testing, but from an influx of new patients to Stanford Health Care's large ambulatory subspecialties that remained open during this time when other practices could not, and an increase in high acuity patients unable to receive care in their community who presented to the ED requiring admission and surgical intervention. Phase IV marks a return to stable operations post-pandemic (April 2021 to January 2023). Healthcare providers and administrators both perceive that, although returning to stable operations post-pandemic, the quantity and quality of the work had changed post-pandemic. We analyzed hospital operational data to gain quantitative insight into how healthcare has changed post-pandemic and to guide us in optimally managing operations in the new normal.

We used the total clinical laboratory test count as a measure of overall clinical activity and AP case count as a measure of overall surgical activity. As mentioned, we expect that these measures have added value over simply the number of patients because to some extent clinical laboratory test and AP case counts also reflect case complexity. Although there are limits to any surrogate measure, we validated these two by demonstrating their significant correlation with hospital census for overall clinical activity or surgery count for overall surgical activity. However, in some instances, it was not possible to link operational and laboratory, and here we used the census as an alternate significantly correlated measure of total clinical activity. Finally, we used licensed beds to normalize for % capacity. There are other measures of capacity but we selected licensed beds because it is concretely defined and readily translatable to others who may wish to replicate our analyses.

Our most important findings concern capacity and its impact on overall clinical and surgical activity. Post-pandemic Stanford Health Care has experienced progressively increasing % capacity, and for most of the post-pandemic period, it has operated at historically high % capacity, as reported by several academic medical centers in the US.[5–9] Combining these data from 2016 to the present, we observed that overall surgical activity is more sensitive to % capacity with the two increasing together till % capacity reaches 103% and then overall surgical activity begins to decline. Overall clinical activity is less sensitive to increasing % capacity and does not show a downward trend until 114% capacity. These quantitative estimates align with commonly voiced concerns post-pandemic about challenges finding available beds in-house for patients with scheduled procedures and challenges finding available beds in convalescent settings for patients that no longer require high-intensity care.[10–12] The heatmaps in Fig. 4 supply a tool to guide future management of the two significant drivers of % capacity,

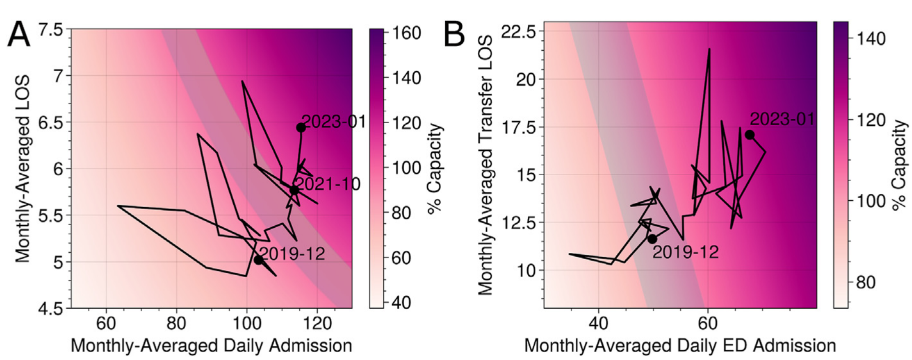

Fig. 5. Heatmaps showing the effects of LOS and admission on capacity. (**A**) The impact of monthly-averaged LOS and admission on capacity. The gray color zone depicts 95 to 105% capacity as calculated by the daily census divided by the number of licensed beds. The black line represents the trajectory of Stanford Hospital from Phases II to IV. (**B**) The impact of monthly-averaged LOS from transfer patients and monthly-averaged ED admissions on capacity. LOS and admission from other sources were kept constant using their average.

admissions, and LOS, with a target zone of optimal operations (as measured by using AP test as a proxy) at 95% to 105% capacity. With this tool, physicians and administrators can manage these two related variables to keep hospital operations within parameters that maximally support healthcare needs.

Our analysis quantified several changes in hospital operations post-pandemic. Compared to Phase I, overall clinical activity significantly increased by 25% in Phase III and 45% in Phase IV while overall surgical activity was significantly increased only in Phase IV by 17%, apparently reflecting the increased intensity of caring for severely medically ill patients during the pandemic and a fundamental change in practice patterns post-pandemic. Two factors significantly changed post-pandemic in Stanford Health Care were increased admissions, mostly via ED in Phase IV, and increased LOS, mostly for transfer patients in Phase IV. Given that there were no major contractual changes and that transfer patients did not go through the ED, the increased ED visits in Phase IV are consistent with behavioral changes where patients chose to visit the ED as their first option. We estimate that the impact of increased admissions was about twice that of LOS but also note that by the end of Phase IV, their two contributions had almost reached parity.

An important context for interpreting these results is the change in capacity upon the opening of the second hospital in November 2019. The number of licensed beds slightly decreased from 614 to 604 because at baseline most rooms had multiple beds and with the opening of the second hospital Stanford Health Care switched to all rooms with single beds. In addition, the Stanford Health Care ED relocated to the new hospital with 66 bays in Phases II to IV. The potential impact of ED expansion on hospital operations was not observed until post-pandemic (Phase IV), likely because of the brief period (Phase II) before COVID-19 restrictions (Phase III). It is important to note that Stanford Health Care routinely exceeded the number of licensed beds caring for patients in the SHC ED as “boarders” and caring for patients in alternative care areas as permitted by the Public Health Emergency (CA and Federal) declaration that recently expired May 11, 2023. LOS was significantly increased post-pandemic for both ED admissions and transfer patients but the magnitude of the increase was much greater for transfer patients. While ED expansion might again explain the smaller increase in LOS for ED patients, the factors driving the larger increase in LOS for transfer patients are less clear but likely are multifactorial and interrelated reflecting changes in regional practice patterns, the high complexity care required, and more restricted options post-pandemic for placement in skilled nursing facilities and long-term acute care facilities.

Conclusion

Stanford Health Care has experienced major changes in operations during the COVID-19 era, a challenging period coincident with major infrastructure changes from opening a second hospital and a “halo” effect from Stanford Health Care's outsized role during the pandemic.[13] Moreover, many local and regional hospitals in the San Francisco Bay Area struggled during this period with adequately staffing hospital beds producing more demand on Stanford Health Care which were not severely affected by nursing staffing or lab supplies shortages. Stanford had ongoing recruitment and relationships with other labs and hospitals to secure supplies.[14,15] In aggregate, this confluence of local and regional forces has created a new status quo with Stanford Health Care routinely operating at over-capacity. Our analysis provides specific targets for optimal operations and indicates that management of admissions from the ED and LOS for transfer patients are the most effective strategies going forward in the post-pandemic era.

Data availability

Due to legal restrictions, supporting data is not available.

Funding

This study was funded by the National Institute of General Medical Sciences (NIGMS) grant number R35GM138353 (Nima Aghaeepour).

Declaration of competing interest

The authors declare no competing interests.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.acpath.2024.100113.

References

1. Stanford Health Care Officially Opens Doors to New Stanford Hospital. News Center. Published November 4, 2019. Accessed July 27, 2023. http://med.stanford.edu/news/all-news/2019/11/stanford-health-care-officially-opens-doors-to-new-hospital.html.
2. Seabold S, Perktold J. Statsmodels: econometric and statistical modeling with python. *Proc 9th Python Sci Conf.* 2010;57(61).
3. Terpilowski MA. Scikit-posthocs: pairwise multiple comparison tests in Python. *J Open Source Softw*. 2019;4(36):1169. doi:10.21105/joss.01169.
4. Swift ML. GraphPad prism, data analysis, and scientific graphing. *J Chem Inf Comput Sci.* 1997;37(2):411–412. doi:10.1021/ci960402j.
5. McPhillips D. Hospitals in the US Are the Fullest They've Been throughout the Pandemic – but It's Not Just Covid. CNN. Published December 8, 2022. Accessed July 27, 2023. https://www.cnn.com/2022/12/08/health/hospitals-full-not-just-covid/index.html.
6. Crompton J. New Hampshire Hospitals Near, over Capacity as Flu, COVID-19 Cases Rise. WMUR. Published December 19, 2022. Accessed July 27, 2023. https://www.wmur.com/article/new-hampshire-hospitals-capacity-flu-covid-121922/42288535.
7. Rochester-area ambulances forced to wait hours to unload patients at local hospitals - WHEC.com. Accessed July 27, 2023. https://www.whec.com/local/rochester-area-ambulances-forced-to-wait-hours-to-unload-patients-at-local-hospitals/.
8. Nzanga M. Hospital Association: With Another Uptick in COVID Cases, Hospitals Are Nearing Capacity. Maryland Matters. Published January 7, 2023. Accessed July 27, 2023. https://www.marylandmatters.org/2023/01/06/hospital-association-with-another-uptick-in-covid-cases-hospitals-are-nearing-capacity/.
9. Wirtz T. Lee Health Hospitals Nearing Capacity; Non-emergency Patients Urged to Go Elsewhere. WINK News. Published January 11, 2023. Accessed July 27, 2023. https://winknews.com/2023/01/11/lee-health-hospitals-nearing-capacity-non-emergency-patients-urged-to-go-elsewhere/.
10. Balstar B, Volkmar L, Wicker T. Hospitals Face Increased Need amid Pandemic to Improve Patient Throughput. HFMA. Published March 1, 2023. Accessed July 27, 2023. https://www.hfma.org/operations-management/hospitals-face-increased-need-amid-pandemic-to-improve-patient-throughput/.
11. Hospitals across the country running out of beds, reducing surgeries amid latest COVID surge. Fierce Healthcare. Published December 12, 2021. Accessed July 27, 2023. https://www.fiercehealthcare.com/hospitals/hospitals-across-country-running-out-beds-reducing-surgeries-amid-latest-covid-surge.
12. Dai Z, Wang JJ, (Junmin) Shi J. How does the hospital make a safe and stable elective surgery plan during COVID-19 pandemic? *Comput Ind Eng.* 2022;169, 108210. doi:10.1016/j.cie.2022.108210.
13. Vohra AS, Khullar D, Kaushal R, Schpero WL. Many intensive care units were overloaded while nearby hospitals had excess capacity during the COVID-19 pandemic. *Health Aff.* 2023;42(7):937–945. doi:10.1377/hlthaff.2022.01657.
14. Multiple Bay Area Health Care Strikes Reflect a Workforce under Increasing Strain. KQED. Published October 25, 2022. Accessed July 27, 2023. https://www.kqed.org/news/11929860/multiple-strikes-in-bay-area-health-care-reflect-a-workforce-decimated-by-labor-shortage.
15. How North Bay Hospitals Are Tackling the Nursing Shortage Made Worse by the Pandemic. Published June 5, 2023. Accessed July 27, 2023. https://www.northbaybusinessjournal.com/article/industrynews/how-north-bay-hospitals-are-tackling-the-nursing-shortage-made-worse-by-the/.