ORIGINAL RESEARCH

Addressing Inpatient Crowding by Smoothing Occupancy at Children's Hospitals

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OBJECTIVE: To quantify the difference in weekday versus weekend occupancy, and the opportunity to smooth inpatient occupancy to reduce crowding at children's hospitals.

METHODS: Daily inpatient census data for 39 freestanding, tertiary-care children's hospitals were used to calculate occupancy and to model the impact of reducing variation in occupancy and the change in the number of patients, patient-days, and hospitals exposed to high occupancy pre- and post-smoothing. We also calculated the proportion of weekly admissions that would require different scheduling to achieve within-week smoothing.

RESULTS: Overall, hospitals' mean occupancy ranged from 70.9% to 108.1% on weekdays, and 65.7% to 94.9% on weekends. Weekday occupancy exceeded weekend occupancy with a median difference of 8.2% points. The mean post-smoothing reduction in weekly maximum occupancy across all hospitals was 6.6% points. Through smoothing, 39,607 patients from the 39 hospitals were removed from exposure to occupancy levels >95%. To achieve within-week smoothing, a median 2.6% of admissions would have to be scheduled on a different day of the week; this equates to a median of 7.4 patients per week (range: 2.3–14.4).

CONCLUSION: Hospitals do have substantial unused capacity, and smoothing occupancy over the course of a week could be a useful strategy that hospitals can use to reduce crowding and protect patients from crowded conditions. *Journal of Hospital Medicine* 2011;6:462–468. © 2011 Society of Hospital Medicine.

High levels of hospital occupancy are associated with compromises to quality of care and access (often referred to as "crowding"),[1–8] while low occupancy may be inefficient and also impact quality.[9,10] Despite this, hospitals typically have uneven occupancy. Although some demand for services is driven by factors beyond the control of a hospital (eg, seasonal variation in viral illness), approximately 15%–30% of admissions to children's hospitals are scheduled from days

to months in advance, with usual arrivals on week-days.[11–14] For example, of the 3.4 million "elective" admissions in the 2006 Healthcare Cost and Utilization Project Kids Inpatient Database (HCUP KID), only 13% were admitted on weekends.[14] Combined with short length of stay (LOS) for such patients, this leads to higher midweek and lower weekend occupancy.[12]

Hospitals respond to crowding in a number of ways, but often focus on reducing LOS to make room for new patients.[11,15,16] For hospitals that are relatively efficient in terms of LOS, efforts to reduce it may not increase functional capacity adequately. In children's hospitals, median lengths of stay are 2 to 3 days, and one-third of hospitalizations are 1 day or less.[17] Thus, even 10%–20% reductions in LOS trims hours, not days, from typical stays. Practical barriers (eg, reluctance to discharge in the middle of the night, or family preferences and work schedules) and undesired outcomes (eg, increased hospital re-visits) are additional pitfalls encountered by relying on throughput enhancement alone.

Managing scheduled admissions through "smoothing" is an alternative strategy to reduce variability and high occupancy.[6,12,18–20] The concept is to proactively control the entry of patients, when possible, to achieve more even levels of occupancy, instead of the peaks and troughs commonly encountered. Nonetheless, it is not a widely used approach.[18,20,21] We hypothesized that children's hospitals had substantial unused capacity that could be used to smooth occupancy, which would reduce weekday crowding. While it is obvious that smoothing will reduce peaks to average levels (and also raise troughs), we sought to quantify just how large this difference was—and thereby quantify the potential of smoothing to reduce inpatient crowding (or, conversely, expose more patients to high levels of occupancy). Is there enough variation to justify smoothing, and, if a hospital does smooth, what is the expected result? If the number of patients removed from exposure to high occupancy is not substantial, other means to address inpatient crowding might be of more value. Our aims were to quantify the difference in weekday versus weekend occupancy, report on mathematical feasibility of such an approach, and determine the difference in number of patients exposed to various levels of high occupancy.

METHODS
Data Source

This retrospective study was conducted with resource-utilization data from 39 freestanding, tertiary-care children's hospitals in the Pediatric Health Information System (PHIS). Participating hospitals are located in noncompeting markets of 23 states, plus the District of Columbia, and affiliated with the Child Health Corporation of America (CHCA, Shawnee Mission, KS). They account for 80% of freestanding, and 20% of all general, tertiary-care children's hospitals. Data quality and reliability are assured through joint ongoing, systematic monitoring. The Children's Hospital of Philadelphia Committees for the Protection of Human Subjects approved the protocol with a waiver of informed consent.

Patients

Patients admitted January 1–December 31, 2007 were eligible for inclusion. Due to variation in the presence of birthing, neonatal intensive care, and behavioral health units across hospitals, these beds and associated patients were excluded. Inpatients enter hospitals either as scheduled (often referred to as "elective") or unscheduled (emergent or urgent) admissions. Because PHIS does not include these data, KID was used to standardize the PHIS data for proportion of scheduled admissions.[22] (KID is a healthcare database of 2–3 million pediatric inpatient discharges developed through federal–state–industry partnership, and sponsored by the Agency for Healthcare Research and Quality [AHRQ].) Each encounter in KID includes a principal International Classification of Diseases, 9th revision (ICD-9) discharge diagnosis code, and is designated by the hospital as "elective" (ranging from chemotherapy to tonsillectomy) or not elective. Because admissions, rather than diagnoses, are scheduled, a proportion of patients with each primary diagnosis in KID are scheduled (eg, 28% of patients with a primary diagnosis of esophageal reflux). Proportions in KID were matched to principal diagnoses in PHIS.

Definitions

The census was the number of patients registered as inpatients (including those physically in the emergency department [ED] from time of ED arrival)—whether observation or inpatient status—at midnight, the conclusion of the day. Hospital capacity was set using CHCA data (and confirmed by each hospital's administrative personnel) as the number of licensed in-service beds available for patients in 2007; we assumed beds were staffed and capacity fixed for the year. *Occupancy* was calculated by dividing census by capacity. Maximum occupancy in a week referred to the highest occupancy level achieved in a seven-day period (Monday–Sunday). We analyzed a set of thresholds for high-occupancy (85%, 90%, 95%, and 100%), because there is no consistent definition for when hospitals are at high occupancy or when crowding occurs, though crowding has been described as starting at 85% occupancy.[23–25]

Analysis

The hospital was the unit of analysis. We report hospital characteristics, including capacity, number of discharges, and census region, and annual standardized length of stay ratio (SLOSR) as observed-to-expected LOS.

Smoothing Technique

A retrospective smoothing algorithm set each hospital's daily occupancy during a week to that hospital's mean occupancy for the week; effectively spreading the week's volume of patients evenly across the days of the week. While inter-week and inter-month smoothing were considered, intra-week smoothing was deemed more practical for the largest number of patients, as it would not mean delaying care by more than one week. In the case of a planned treatment course (eg, chemotherapy), only intra-week smoothing would maintain the necessary scheduled intervals of treatment.

Mathematical Feasibility

To approximate the number of patient admissions that would require different scheduling during a particular week to achieve smoothed weekly occupancy, we determined the total number of patient-days in the week that required different scheduling and divided by the average LOS for the week. We then divided the number of admissions-to-move by total weekly

admissions to compute the percentage at each hospital across 52 weeks of the year.

Measuring the Impact of Smoothing

We focused on the frequency and severity of high occupancy and the number of patients exposed to it. This framework led to 4 measures that assess the opportunity and effect of smoothing:

1. *Difference in hospital weekday–weekend occupancy*: Equal to 12-month median of difference between mean weekday occupancy and mean weekend occupancy for each hospital-week.
2. *Difference in hospital maximum–mean occupancy*: Equal to median of difference between maximum one-day occupancy and weekly mean (smoothed) occupancy for each hospital-week. A regression line was derived from the data for the 39 hospitals to report expected reduction in peak occupancy based on the magnitude of the difference between weekday and weekend occupancy.
3. *Difference in number of hospitals exposed to above-threshold occupancy*: Equal to difference, pre- and post-smoothing, in number of hospitals facing high-occupancy conditions on an average of at least one weekday midnight per week during the year at different occupancy thresholds.
4. *Difference in number of patients exposed to above-threshold occupancy*: Equal to difference, pre- and post-smoothing, in number of patients exposed to hospital midnight occupancy at the thresholds. We utilized patient-days for the calculation to avoid double-counting, and divided this by average LOS, in order to determine the number of patients who would no longer be exposed to over-threshold occupancy after smoothing, while also adjusting for patients newly exposed to over-threshold occupancy levels.

All analyses were performed separately for each hospital for the entire year and then for winter (December–March), the period during which most crowding occurred. Analyses were performed using SAS (version 9.2, SAS Institute, Inc, Cary, NC); *P* values <0.05 were considered statistically significant.

RESULTS

The characteristics of the 39 hospitals are provided in Table 1. Based on standardization with KID, 23.6% of PHIS admissions were scheduled (range: 18.1%–35.8%) or a median of 81.5 scheduled admissions per week per hospital; 26.6% of weekday admissions were scheduled versus 16.1% for weekends. Overall, 12.4% of scheduled admissions entered on weekends. For all patients, median LOS was three days (interquartile range [IQR]: two–five days), but median LOS for scheduled admissions was two days (IQR: one–four days). The median LOS and IQR were the same by day of admission for all days of the week. Most hospitals had an overall SLOSR close to one (median:

TABLE 1. Characteristics of Hospitals and Admissions for 2007

Characteristics	No. (%)
Licensed in-service beds	n = 39 hospitals
<200 beds	6 (15.4)
200–249 beds	10 (25.6)
250–300 beds	14 (35.9)
>300 beds	9 (23.1)
No. of discharges	
<10,000	5 (12.8)
10,000–13,999	14 (35.9)
14,000–17,999	11 (28.2)
>18,000	9 (23.1)
Census region	
West	9 (23.1)
Midwest	11 (28.2)
Northeast	6 (15.4)
South	13 (33.3)
Admissions	n = 590,352 admissions
Medical scheduled admissions*	79,683
Surgical scheduled admissions*	59,640
Total scheduled admissions* (% of all admissions)	139,323 (23.6)
Weekend medical scheduled admissions* (% of all medical scheduled admissions)	13,546 (17.0)
Weekend surgical scheduled admissions* (% of all surgical scheduled admissions)	3,757 (6.3)
Weekend total scheduled admissions* (% of total scheduled admissions)	17,276 (12.4)

*Scheduled designation based on standardization with the Healthcare Cost and Utilization Project Kids Inpatient Database (HCUP KID).

0.9, IQR: 0.9–1.1). Overall, hospital mean midnight occupancy ranged from 70.9% to 108.1% on weekdays and 65.7% to 94.9% on weekends. Uniformly, weekday occupancy exceeded weekend occupancy, with a median difference of 8.2% points (IQR: 7.2%–9.5% points). There was a wide range of median hospital weekday–weekend occupancy differences across hospitals (Figure 1). The overall difference was less in winter (median difference: 7.7% points; IQR: 6.3%–8.8% points) than in summer (median difference: 8.6% points; IQR: 7.4%–9.8% points (Wilcoxon Sign Rank test, *P* < 0.001). Thirty-five hospitals (89.7%) exceeded the 85% occupancy threshold and 29 (74.4%) exceeded the 95% occupancy threshold on at least 20% of weekdays (Table 2). Across all the hospitals, the median difference in weekly maximum and weekly mean occupancy was 6.6% points (IQR: 6.2%–7.4% points) (Figure 2).

Smoothing reduced the number of hospitals at each occupancy threshold, except 85% (Table 2). As a linear relationship, the reduction in weekday peak occupancy (y) based on a hospital's median difference in weekly maximum and weekly mean occupancy (x) was $y = 2.69 + 0.48x$. Thus, a hospital with a 10% point difference between weekday and weekend occupancy could reduce weekday peak by 7.5% points.

Smoothing increased the number of patients exposed to the lower thresholds (85% and 90%), but decreased the number of patients exposed to >95%

occupancy (Table 2). For example, smoothing at the 95% threshold resulted in 630 fewer patients per hospital exposed to that threshold. If all 39 hospitals had within-week smoothing, a net of 39,607 patients would have been protected from exposure to >95% occupancy and a net of 50,079 patients from 100% occupancy.

To demonstrate the varied effects of smoothing, Table 3 and Figure 3 present representative categories of response to smoothing depending on pre-smoothing patterns. While not all hospitals decreased occupancy to below thresholds after smoothing (Types B and D), the overall occupancy was reduced and fewer patients were exposed to extreme levels of high occupancy (eg, >100%).

To achieve within-week smoothing, a median of 7.4 patient-admissions per week (range: 2.3–14.4) would have to be scheduled on a different day of the week. This equates to a median of 2.6% (IQR: 2.25%,
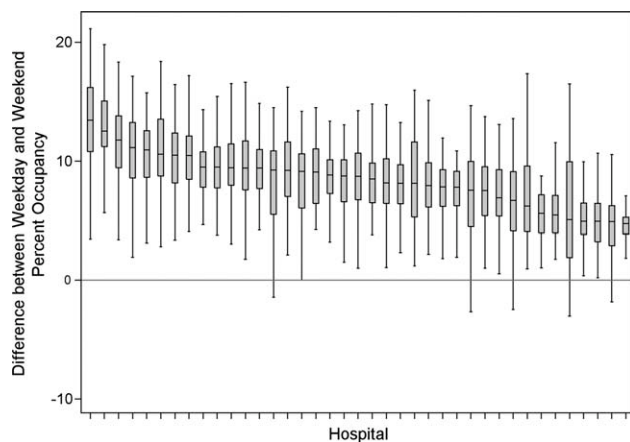

FIG. 1. Differences between weekday and weekend percent occupancy by hospital for each week in 2007. Each box represents data from one participating hospital. On each boxplot, the box spans the interquartile range for differences between weekday and weekend occupancy while the line through the box denotes the median value. The vertical lines or "whiskers" extend upward or downward up to 1.5 times the interquartile range.

2.99%; range: 0.02%–9.2%) of all admissions—or 9% of a typical hospital-week's scheduled admissions.

DISCUSSION

This analysis of 39 children's hospitals found high levels of occupancy and weekend occupancy lower than weekday occupancy (median difference: 8.2% points). Only 12.4% of scheduled admissions entered on weekends. Thus, weekend capacity is available to offset high weekday occupancy. Hospitals at the higher end of the occupancy thresholds (95%, 100%) would reduce the number of days operating at very high occupancy and the number of patients exposed to such levels by smoothing. This change is mathematically feasible, as a median of 7.4 patients would have to be proactively scheduled differently each week, just under one-tenth of scheduled admissions. Since LOS by day of admission was the same (median: two days), the opportunity to affect occupancy by shifting patients should be relatively similar for all days of the week. In addition, these admissions were short, conferring greater flexibility. Implementing smoothing over the course of the week does not necessarily require admitting patients on weekends. For example, Monday admissions with an anticipated three-day LOS could enter on Friday with anticipated discharge on Monday to alleviate midweek crowding and take advantage of unoccupied weekend beds.[26]

At the highest levels of occupancy, smoothing reduces the frequency of reaching these maximum levels, but can have the effect of actually exposing more patient-days to a higher occupancy. For example, for nine hospitals in our analysis with >20% of days over 100%, smoothing decreased days over 100%, but exposed weekend patients to higher levels of occupancy (Figure 3). Since most admissions are short and most scheduled admissions currently occur on weekdays, the number of individual patients (not patient-days) newly exposed to such high occupancy may not increase much after

TABLE 2. Opportunity to Decrease High Occupancy at Different Thresholds Based on Smoothing Occupancy over Seven Days of the Week

Entire Year	>85%	>90%	>95%	>100%
		Occupancy Threshold		
No. of hospitals (n = 39) with mean weekday occupancy above threshold				
Before smoothing (current state)	33	25	14	6
After smoothing	32	22	10	1
No. of hospitals (n = 39) above threshold ≥20% of weekdays				
Before smoothing (current state)	35	34	29	14
After smoothing	35	32	21	9
Median (IQR) no. of patient-days per hospital not exposed to occupancy above threshold by smoothing	−3,071 (−5,552, 919)	−281 (−5,288, 3,103)	3236 (0, 7,083)	3281 (962, 8,517)
Median (IQR) no. of patients per hospital not exposed to occupancy above threshold by smoothing	−596 (−1,190, 226)	−50 (−916, 752)	630 (0, 1,492)	804 (231, 2,195)

NOTE: Negative numbers indicate that more patients would be exposed to this level of hospital occupancy after smoothing. For example, at the 100% threshold, the number of hospitals with mean weekday occupancy over that level was reduced from 6 to 1 by smoothing. At this level, the number of hospitals with ≥20% of their weekdays above this threshold reduced from 14 to 9 as a result of smoothing. Finally, 3,281 patient-days and 804 individual patients were not exposed to this level of occupancy after smoothing.
Abbreviations: IQR, interquartile range.

smoothing at these facilities. Regardless, hospitals with such a pattern may not be able to rely solely on smoothing to avoid weekday crowding, and, if they are operating efficiently in terms of SLOSR, might be justified in building more capacity.

Consistent with our findings, the Institute for Healthcare Improvement, the Institute for Healthcare Optimization, and the American Hospital Association Quality Center stress that addressing "artificial variability" of scheduled admissions is a "critical first step" to improving patient flow and quality of care while reducing costs.[18,21,27] Our study suggests that small numbers of patients need to be proactively scheduled differently to decrease midweek peak occupancy, so only a small proportion of families would need to find this desirable to make it attractive for hospitals and patients. This type of proactive "smoothing" decreases peak occupancy on weekdays, reducing the safety risks associated with high occupancy, improving acute access for emergent

FIG. 2. Percent change in weekly hospital maximum occupancy after smoothing. Within the hospitals, each week's maximum occupancy was reduced by smoothing. The box plot displays the distribution of the reductions (in percentage points) across the 52 weeks of 2007. The midline of the box represents the median percentage point reduction in maximum occupancy, and the box comprises the 25th to 75th percentiles (ie, the interquartile range [IQR]). The whiskers extend to 1.5 times the IQR.

patients, shortening wait-times and loss of scheduled patients to another facility, and increasing procedure volume (3%–74% in one study).[28] Smoothing may also increase quality and safety on weekends, as emergent patients admitted on weekends experience more delays in necessary treatment and have worse outcomes.[29–32] In addition, increasing scheduled admissions to span weekends may appeal to some families wishing to avoid absence from work to be with their hospitalized child, to parents concerned about school performance—and may also appeal to staff members seeking flexible schedules. Increasing weekend hospital capacity is safe, feasible, and economical, even when considering the increased wages for weekend work.[33,34] Finally, smoothing over the whole week allows fixed costs (eg, surgical suites, imaging equipment) to be allocated over 7 days rather than 5, and allows for better matching of revenue to the fixed expenses.

Rather than a prescriptive approach, our work suggests hospitals need to identify only a small number of patients to proactively shift, providing them opportunities to adapt the approach to local circumstances. The particular patients to move around may also depend on the costs and benefits of services (eg, radiologic, laboratory, operative) and the hospital's existing patterns of staffing. A number of hospitals that have engaged in similar work have achieved sustainable results, such as Seattle Children's Hospital, Boston Medical Center, St. John's Regional Health Center, and New York University Langone Medical Center.[19,26,35–37] In these cases, proactive smoothing took advantage of unused capacity and decreased crowding on days that had been traditionally very full. Hospitals that rarely or never have high-occupancy days, and that do not expect growth in volume, may not need to employ smoothing, whereas others that have crowding issues primarily in the winter may wish to implement smoothing techniques seasonally.

Aside from attempting to reduce high-occupancy through modification of admission patterns, other proactive approaches include optimizing staffing and processes
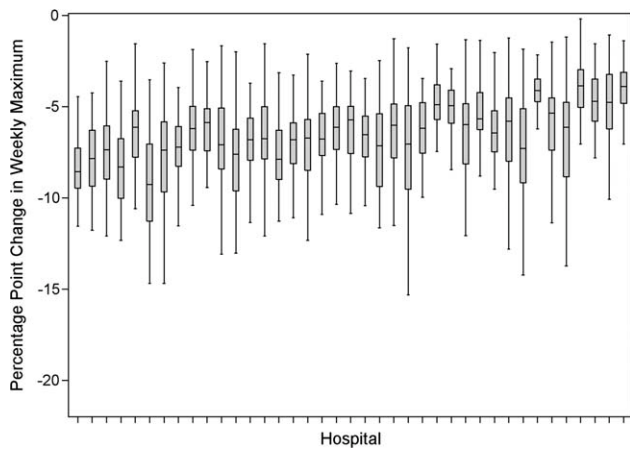
TABLE 3. Differential Effects of Smoothing Depending on Pre-Smoothing Patterns of Occupancy

Category	Before Smoothing Hospital Description	After Smoothing Hospital Description	No. of Hospitals at 85% Threshold (n = 39)	No. of Hospitals at 95% Threshold (n = 39)
Type A	Weekdays above threshold Weekends below threshold	All days below threshold, resulting in net decrease in patients exposed to occupancies above threshold	3	1
Type B	Weekdays above threshold Weekends below threshold	All days above threshold, resulting in net increase in patients exposed to occupancies above threshold	12	18
Type C	All days of week below threshold	All days of week below threshold	6	19
Type D	All days of week above threshold	All days of week above threshold, resulting in net decrease in patients exposed to extreme high occupancy	18	1

NOTE: The number of hospitals in each category varies based on the threshold. For example, for Type A hospitals (3 at 85%, 1 at 95%), smoothing reduces the net number of patients exposed to above-threshold occupancy and brings all days below threshold. In contrast, Type B hospitals have similar profiles before smoothing, but after smoothing, weekend occupancy rises so that all days of the week have occupancies above the threshold (not just weekdays). For these, however, the overall occupancy height is reduced and fewer patients are exposed to extreme levels of high occupancy on the busiest days of the week. For Type D hospitals (18 at 85%, 1 at 95%), there is above-threshold weekday and weekend occupancy, and no decrease in weekend occupancy to below-threshold levels after smoothing. Again, the overall occupancy height is reduced, and fewer patients are exposed to extreme levels of high occupancy (such as >100%) on the busiest days of the week.
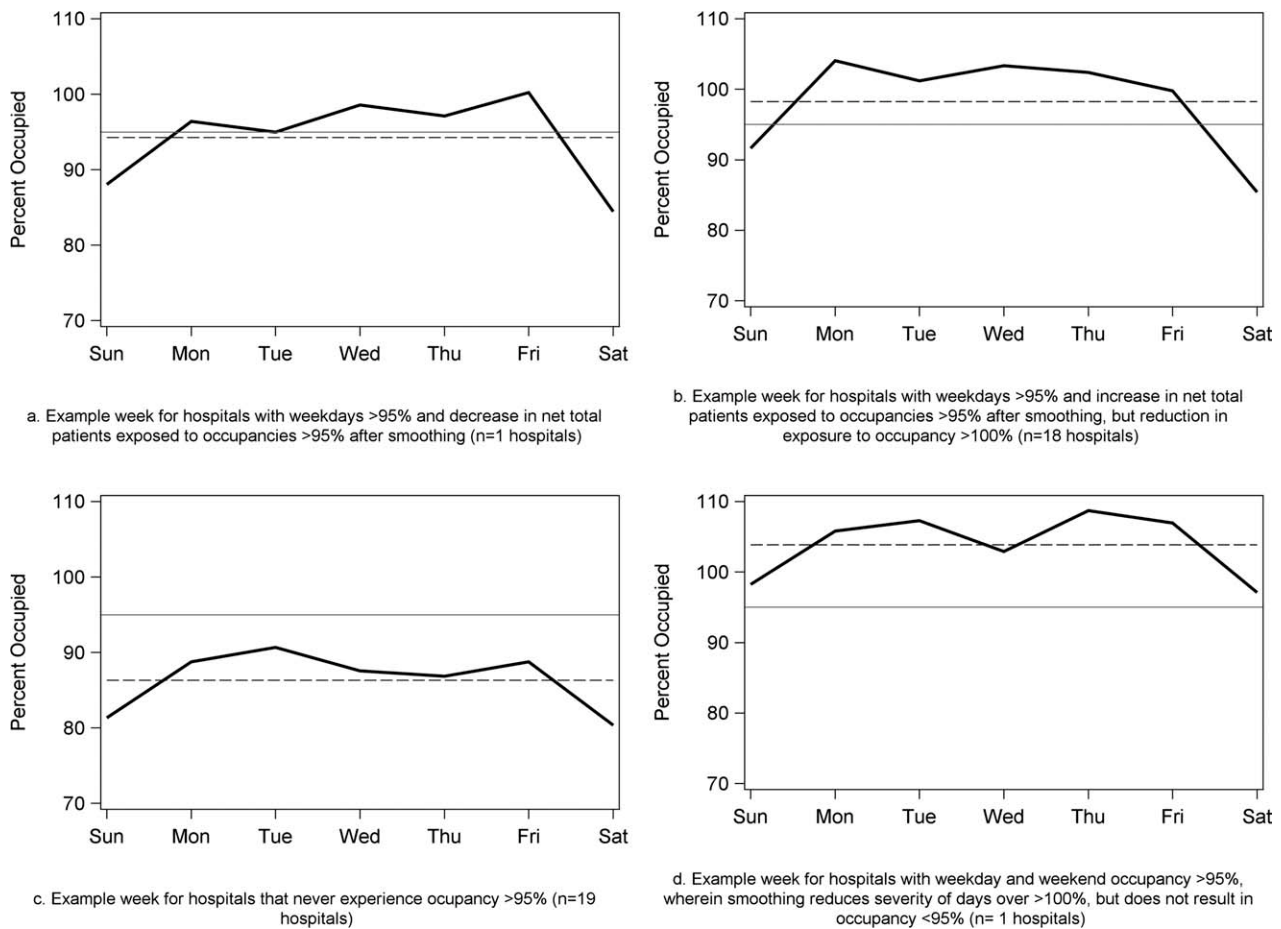
a. Example week for hospitals with weekdays >95% and decrease in net total patients exposed to occupancies >95% after smoothing (n=1 hospitals)

b. Example week for hospitals with weekdays >95% and increase in net total patients exposed to occupancies >95% after smoothing, but reduction in exposure to occupancy >100% (n=18 hospitals)

c. Example week for hospitals that never experience occupancy >95% (n=19 hospitals)

d. Example week for hospitals with weekday and weekend occupancy >95%, wherein smoothing reduces severity of days over >100%, but does not result in occupancy <95% (n= 1 hospitals)

FIG. 3. (a–d) Categories of hospitals by occupancy and effect of smoothing at 95% threshold. The solid, gray, horizontal line indicates 95% occupancy; the solid black line indicates pre-smoothing occupancy; and the dashed line represents post-smoothing occupancy.

around care, improving efficiency of care, and building additional beds.[16,25,38,39] However, the expense of construction and the scarcity of capital often preclude this last option. Among children's hospitals, with SLOSR close to one, implementing strategies to reduce the LOS during periods of high occupancy may not result in meaningful reductions in LOS, as such approaches would only decrease the typical child's hospitalization by hours, not days. In addition to proactive strategies, hospitals also rely on reactive approaches, such as ED boarding, placing patients in hallways on units, diverting ambulances or transfers, or canceling scheduled admissions at the last moment, to decrease crowding.[16,39,40]

This study has several limitations. First, use of administrative data precluded modeling all responses. For example, some hospitals may be better able to accommodate fluctuations in census or high occupancy without compromising quality or access. Second, we only considered intra-week smoothing, but hospitals may benefit from smoothing over longer periods of time, especially since children's hospitals are busier in winter months, but incoming scheduled volume is often not reduced.[11] Hospitals with large occupancy variations across months may want to consider broadening the

time horizon for smoothing, and weigh the costs and benefits over that period of time, including parental and clinician concerns and preferences for not delaying treatment. At the individual hospital level, discrete-event simulation would likely be useful to consider the trade-offs of smoothing to different levels and over different periods of time. Third, we assumed a fixed number of beds for the year, an approach that may not accurately reflect actual available beds on specific days. This limitation was minimized by counting all beds for each hospital as available for all the days of the year, so that hospitals with a high census when all available beds are included would have an even higher percent occupancy if some of those beds were not actually open. In a related way, then, we also do not consider how staffing may need to be altered or augmented to care for additional patients on certain days. Fourth, midnight census, the only universally available measure, was used to determine occupancy rather than peak census. Midnight census provides a standard snapshot, but is lower than mid-day peak census.[41] In order to account for these limitations, we considered several different thresholds of high occupancy. Fifth, we smoothed at the hospital level, but differential effects may exist at the unit level.

Sixth, to determine proportion of scheduled admissions, we used HCUP KID proportions on PHIS admissions. Overall, this approach likely overestimated scheduled medical admissions on weekends, thus biasing our result towards the null hypothesis. Finally, only freestanding children's hospitals were included in this study. While this may limit generalizability, the general concept of smoothing occupancy should apply in any setting with substantial and consistent variation.

In summary, our study revealed that children's hospitals often face high midweek occupancy, but also have substantial unused weekend capacity. Hospitals facing challenges with high weekday occupancy could proactively use a smoothing approach to decrease the frequency and severity of high occupancy. Further qualitative evaluation is also warranted around child, family, and staff preferences concerning scheduled admissions, school, and work.

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