

ORIGINAL RESEARCH

Direct Observation of Bed Utilization in the Pediatric Intensive Care Unit

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BACKGROUND: The pediatric intensive care unit (PICU), with limited number of beds and resource-intensive services, is a key component of patient flow. Because the PICU is a crossroads for many patients, transfer or discharge delays can negatively impact a patient's clinical status and efficiency.

OBJECTIVE: The objective of this study was to describe, using direct observation, PICU bed utilization.

METHODS: We conducted a real-time, prospective observational study in a convenience sample of days in the PICU of an urban, tertiary-care children's hospital.

RESULTS: Among 824 observed hours, 19,887 bed-hours were recorded, with 82% being for critical care services and 18% for non-critical care services. Fourteen activities accounted for 95% of bed-hours. Among 200 hours when

the PICU was at full capacity, 75% of the time included at least 1 bed that was used for non-critical care services; 37% of the time at least 2 beds. The mean waiting time for a floor bed assignment was 9 hours (median, 5.5 hours) and accounted for 4.62% of all bed-hours observed.

CONCLUSIONS: The PICU delivered critical care services most of the time, but periods of non-critical care services represented a significant amount of time. In particular, periods with no bed available for new patients were associated with at least 1 or more PICU beds being used for non-critical care activities. The method should be reproducible in other settings to learn more about the structure and processes of care and patient flow and to make improvements. *Journal of Hospital Medicine* 2012;7:318–324. © 2011 Society of Hospital Medicine

Patient flow refers to the management and movement of patients in health care settings and is linked to quality, safety, and cost.^{1–6} The intensive care unit (ICU) is crucial in patient flow.^{7,8} The limited number of beds and the resource-intensive services and staffing associated with them require that hospitals optimize their utilization, as is increasingly true of all hospital resources. To maximize delivery of services to patients who need them and minimize real and opportunity losses (eg, postponed surgery, diverted transports, or inability to accept patients), patients in ICU beds should receive critical care medicine/nursing services while there and be transferred or discharged when appropriate.

The time between arrival and departure from any area of the hospital, including the ICU, is considered

the time when a patient is receiving needed clinical care—the “value-added” portion of health care operations—and time waiting to move on to the next step.^{9–11} This period includes both necessary logistics (eg, signing out a patient or waiting a reasonable amount of time for room cleaning) and non-value-added time (eg, an excessively long amount of time for room cleaning). Operations management labels non-value-added time as “waste,” and its reduction is vital for high-quality health care.^{9,12,13} As in other industries, one important way to understand value versus waste is through direct observation.^{11,14} Although operating rooms have been the subject of several published process improvement projects to improve efficiency,^{15–18} inpatient beds have not been the subject of such scrutiny. The objectives of this study were to generate a direct observation method and use it to describe pediatric ICU (PICU) bed utilization from a value-added perspective.

METHODS

An interdisciplinary work group of physicians, nurses, quality improvement specialists, and 1 operations management expert developed an Excel spreadsheet to categorize hour-by-hour status of PICU beds. The clinicians generated a list of 27 activities. A critical

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TABLE 1. Activities Observed Over 5 Weeks of Observation

Activity Description	Activity Code	Total Hours Over 5 Weeks	% Total Hours Over 5 Weeks*	Mean Hours per Week*
Ventilated patient	Vent	8996	45	1799
CCSs not otherwise specified†	NOS	2982	15	596
Neurosurgery patient with ICU needs	NeurosurgICU	1534	8	307
Room empty and unassigned	Empty-unassigned	1511	8	302
Patient on continuous infusion	ContInfus	958	5	192
Awaiting floor bed assignment	Floorbedassign	919	5	184
Patient with arterial line	ArtLine	508	3	102
Patient on high-flow nasal cannula	HFNC	475	2	95
Room cleaning	EVS	318	2	64
Patient <12 hours after extubation	PostVent	226	1	45
Patient in OR, bed being held	OR	210	1	42
Neurosurgery patient, post-ICU needs	NeurosurgPostICU	164	0.8	33
No clear ICU need, but no other accepting floor or service	Unclear	163	0.8	33
Patient at procedure, bed being held	Proced	133	0.7	27
Patient awaiting a rehabilitation bed	Rehab	99	0.5	20
Patient with ventriculostomy	Ventriculostomy	82	0.4	16
Patient eligible to be in NICU	NICU	76	0.4	15
Patient awaiting social work, case management, prescriptions before discharge	AwaitingOtherServ	66	0.3	13
Empty bed, assigned to ED patient	Empty-ED	40	0.2	8
Empty bed, assigned to incoming transport patient	Empty-Transport	37	0.2	7
Patient awaiting transport to another facility	Transport	37	0.2	7
Patient awaiting consult to determine transfer	Consult	33	0.2	7
Patient awaiting physician or NP sign-out to floor before transfer	CallMDNP	30	0.2	6
PICU room needs a bed for next patient	Bed	26	0.1	5
Patient eligible to be in CCU	CCU	24	0.1	5
Patient eligible to be in CICU	CICU	24	0.1	5
Patient awaiting laboratory result to determine transfer or discharge	LabResult	21	0.1	4
Patient awaiting a ride home	Ride	21	0.1	4
Empty bed, assigned to floor patient	Empty-floor	19	0.1	4
Patient awaiting nursing report to floor for transfer	CallNurse	18	0.1	4
Patient eligible to be in PCU	PCU	18	0.1	4
Patient on cardiac pressor	Pressor	16	0.1	3
Patient actively coding	Code	15	0.1	3
Patient on continuous veno-venous hemofiltration	CVVH	15	0.1	3
Nursing work needed to enable transfer out	Nursing	11	0.1	2
Patient awaiting order for transfer to floor	Order	11	0.1	2
Patient in interventional radiology, bed being held	IR	10	0.1	2
Patient deceased in PICU room	Deceased	9	0.1	2
Awaiting radiology result to clear transfer or discharge	RadResult	9	0.1	2
Patient awaiting a floor bed to be cleaned for transfer out	Floorbedclean	7	<0.1	1
Other logistical need for an empty room	Logistics	7	<0.1	1
Disagreement among services for disposition	Disagreement	4	<0.1	1
Family request to stay in PICU	Family	3	<0.1	1
Awaiting accepting attending/fellow for transfer out	Accept	1	<0.1	<1
PICU room needs a crib for next patient	Crib	1	<0.1	<1
Patient with preventable reason for being in PICU	Prev	0	0	0
PICU room needs specialty bed for next patient	SpecialBed	0	0	0
Total		19,887	100	—

NOTE: This table presents the 47 activities on the observation list, the total time each activity occurred over the 5 weeks of observation, the percentage of total time on that activity, and the mean hours per week for each activity. **Abbreviations:** CCS, critical care service; CCU, cardiac care unit; CICU, cardiac intensive care unit; ED, emergency department; ICU, intensive care unit; NICU, neonatal intensive care unit; NP, nurse practitioner; OR, operating room; PCU, progressive care unit; PICU, pediatric intensive care unit. *Summary may be greater than 100% due to rounding. †In many cases, this includes very complex patients who were not deemed appropriate for a regular medical or surgical floor by PICU staff or the regular floor staff, but were not receiving a typical critical care service. This also includes patients requiring frequent monitoring for potential respiratory, cardiac, or neurological failure, which would not be deemed appropriate on the floor.

care nurse trained in quality improvement piloted the list for 3 separate 4-hour blocks over 2 weeks adding 18 activities; 2 additional activities were added during the 5 weeks of observation (Table 1). (The recording tool is provided in the Supporting Information Appendix.) Three observers with knowledge of medical terminology (2 third-year medical students and 1 pre-medical student with years of experience as an emergency medical technician) were trained over 12

hours to conduct the observations. Prior to the observations, the 3 observers also spent time in the PICU, and terminology used for recordings was reviewed. Interobserver reliability was checked during 3 sets of observation circuits by all 3 observers and the principal investigator, as well as by spot checks during the study.

The targeted area included 24 single-patient rooms. The activity of each bed was recorded hourly. Real-

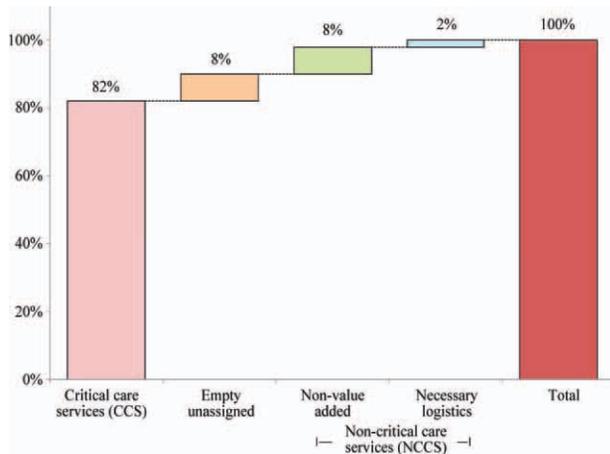


FIG. 2. Proportion of hours by category of room use. Waterfall chart displaying cumulative sequence across all rooms for the entire period of observation.

and the median was 2 hours. (There were 136 recorded instances of room cleaning and 10 additional episodes that were not recorded but had to be completed for the room to turnover from one patient to the next, yielding a total of 146 instances of cleaning.)

From the 824 hours of recording, we identified 200 hours (25% of time) when there were zero empty unassigned beds available in the section of the PICU being observed. Episodes of full occupancy occurred mostly on weekdays, with 23% of hours of full capacity on Thursdays, 21% on Mondays, and 21% on Wednesdays; only 8% were on Saturdays and <1% on Sundays. These 200 hours fell into 36 separate episodes of complete occupancy, each lasting 1–22 hours. Each patient, on average, received 3.1 hours of NCCS during each episode of full occupancy (range, 1–11 hours). Within these 200 hours at capacity, we identified only 15 hours (8%) when all 24 beds were used for CCS. For 72% of the time, there was at least 1 bed with NCCS, and for 37% at least 2 beds. A small portion of the time (7%), the lack of beds was affected by occupancy by patients who should have been in the NICU, CICU, CCU, or PCU.

Data collected through direct observation can be used to understand aggregated and averaged experiences, but also more specific time periods. For example, we identified 1 week with the highest consistent level of occupancy and turnover: March 9–15 had empty unassigned beds for only 4% of the week. Of the 168 hours in the week, 68 (40%) had full capacity. However, for 90% of the time, at least 1 bed was used for a NCCS. Other analytic options included varying the assumptions around time needed for logistics. Overall, NCCS time on necessary logistics changes from 23% to 46% using 1 hour versus 2 hours as the cutoff. For floor bed assignments, assuming that the first hour of this activity is necessary logistics and any hour thereafter is not, 817 hours were “wasted.” Even after assuming 2 hours of necessary logistical time (which

may also include steps such as nursing and physician sign-out to the receiving team, often not recorded in the observations), this left 715 hours of NCCS time in which patients waited to be placed elsewhere in the hospital. For room cleaning, because recordings were hourly, but room cleaning could take less time, we performed a sensitivity analysis, converting all 1-hour recordings to half-hour recordings to half-hour recordings (an exaggerated shortening since industry-standard cleaning may take longer).

Of the 219 patients directly observed, 15 were noted to be waiting for a transfer out of the PICU but experienced a change in disposition before the transfer. On average, these patients waited 8 hours for a floor bed assignment (range, 2–21) before reverting to a CCS, which then lasted an average of 16.5 hours (range, 1–49). (Included in this group are 2 patients who experienced this change in disposition twice.) In *post hoc* review across the 5 weeks, no patients were transferred back to the PICU within 48 hours after being transferred out. During the study period, 19 patients were discharged directly from the PICU (8 to home, 7 by transport to another facility, and 4 to rehabilitation). One patient returned to the hospital (but not the PICU) within 48 hours of being discharged home from the PICU.

During the study period, using the highest census value for recorded for each 24-hour period and the number of beds available that day, median hospital-wide occupancy was 93% (interquartile range, 90%–96%). During the 35 days of observation, 71% of the days had occupancy >90%, 29% of days had occupancy >95%, and 3% of days had occupancy >100%.

DISCUSSION

In this direct observation of a PICU, we found high usage of beds for delivery of CCS. We identified many episodes in which the half of the PICU we observed was fully occupied (200 of 824 hours), but not necessarily delivering PICU-level care to all patients. In fact, 75% of the full-capacity hours had at least 1 patient receiving NCCS and 37% had at least 2. Patients waiting for a floor bed assignment represented nearly 5% of bed-hours observed (mean 9 hours per patient). That full occupancy was not random, but rather clustered on weekdays, is consistent with other work showing that hospitals are at greater risk for midweek crowding due to the way in which scheduled admissions enter and leave.^{19–25}

Our methods provide the basis for operational analysis and improvement to patient flow, such as value stream mapping.^{9,26} Process improvement work could be directed to areas of delay uncovered through this analysis and inform clinical and nonclinical management. For example, one of the key problems faced by the PICU was finding floor bed assignments for patients leaving the unit. Simply building more beds

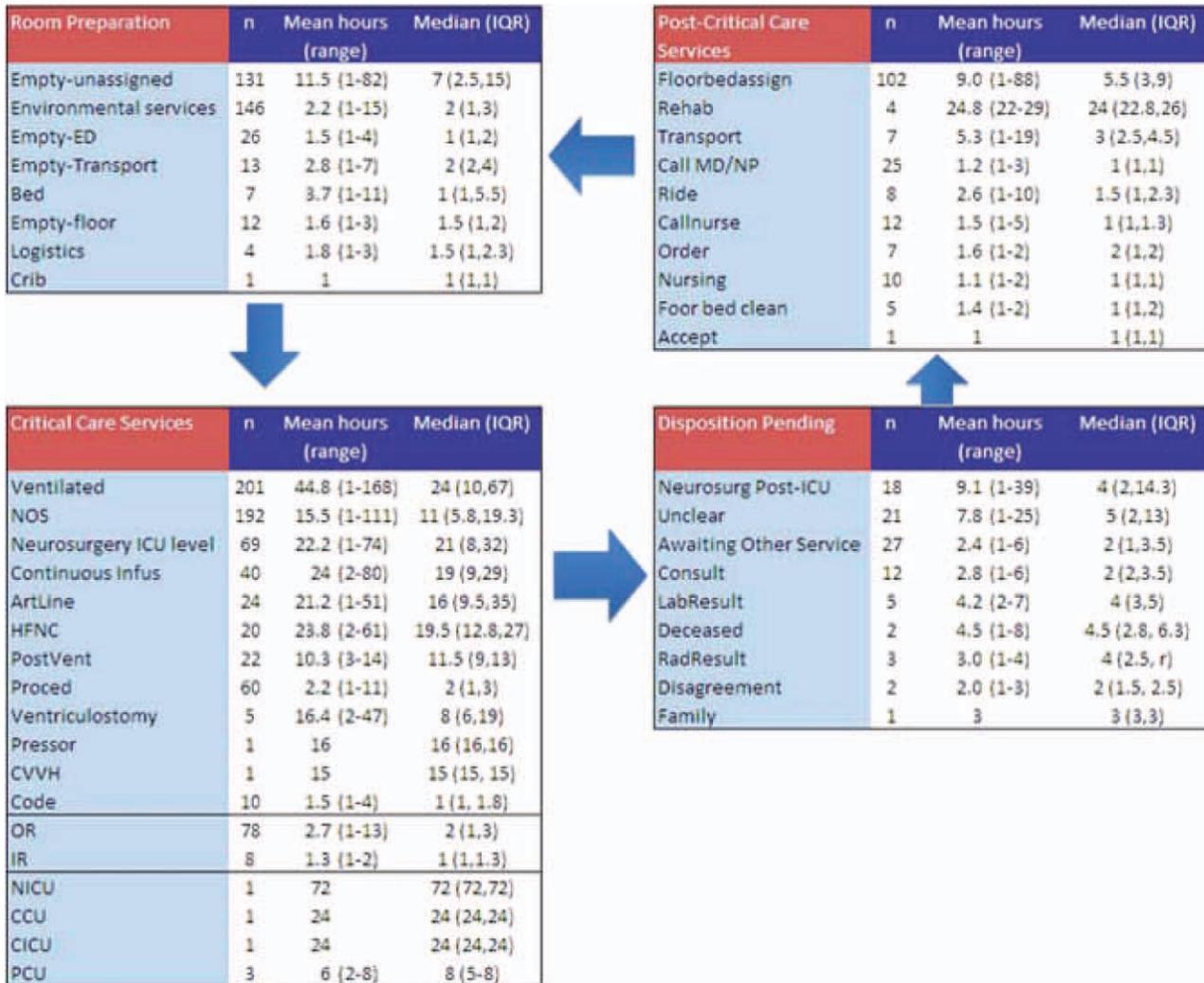


FIG. 3. Tabular-graphic cycling of bed utilization in a PICU over 5 noncontiguous weeks. Activities are divided into 4 categories. The number (n) of observations for each activity is reported, along with the mean hours and range and the median hours and interquartile range (IQR) each activity took for each observation. For example, there were 102 instances of patients waiting for a floor bed assignment (“floorbedassign”), with a mean of 9 hours and a median of 5.5 hours across those instances.

in the PICU will not solve this problem—and at an estimated cost of \$2 million to add a bed, it is likely not an efficient means of responding to poor flow. In these cases, the problem seems to lie downstream, and could suggest shortage of regular floor beds or inefficient bed assignment procedures within the hospital. The output also suggests that variation in nonclinical processes should be a target for improvement, such as time to clean rooms, because variation is known to be a source of non-value-added time in many operations.^{9,26} High occupancy on weekdays but low occupancy on weekends also emphasizes the potential for smoothing occupancy to reduce the risk of midweek crowding and to better manage bed utilization and staffing.^{24,25}

When seeking to reduce non-value-added time, one must weigh the risks of increased efficiency against clinical outcomes. For example, if patients could be transferred out of the PICU faster, would the risk of returns to the PICU be higher? In this study, 15

patients (7%) had a change in disposition from awaiting transfer back to a CCS. The fact that transfers did not happen instantaneously may serve as a safety check to reduce rapid returns, but it is not possible for us to evaluate the reasons why patients did not actually complete the pending transfers. Specifically, we cannot determine whether the patient’s clinical status objectively deteriorated, the ICU team made a judgment call to hold the patient, or the floor team refused to accept the transfer. Given this fact, although it appears in this study (and in the health care system more broadly) that there are opportunities to increase efficiency and reduce non-value-added time, it is not realistic (nor advisable) that such time be reduced to zero. Along this line, one must consider separately purely nonclinical functions such as room cleaning and those that include some clinical element, such as time waiting for a patient to be transferred.

Beyond the direct findings of this study, the method should be replicable in other settings and can reveal

important information about health care efficiency, capacity, and flexibility. The bottlenecks identified would have been difficult to identify through administrative record review. The exact amount of time to spend on observation may vary from place to place and would depend on the expected variation over time and the level of detail sought. In general, the more common the event and the less variation, the less time needed to observe it.

This study has several limitations that should be considered in terms of interpreting the results and in seeking to reproduce the approach. First, hourly recordings may not be discrete enough for events that took less than 1 hour. To assess the degree to which this would affect our results, we reanalyzed all NCCS by subtracting 30 minutes (0.5 hour) from all recordings, which increased total CCS from 82% to 87% and decreased NCCS by the same 5 percentage points. In a related fashion, our recordings were truncated at the start and end of each 1-week period, so we could only observe a maximum of 168 hours for any given activity and did not record how long an activity was happening before or after the recordings started or stopped, respectively. Second, each recording could only be for 1 activity per hour. Separate from the level of granularity already noted, this also limits interpretation of critical care activities that may have been simultaneous. However, because the goal of the study was not to describe the provision of critical care services, but rather the times when they were not being delivered, this does not influence our conclusions. For movement of patients, however, we missed instances of physician and nursing calling sign-out on patients to receiving units, as these events last less than 1 hour (and in the case of surgical patients, generally do not occur as the team provides continuous coverage). The time for such events is then included in other activities. To the extent that this may influence the results, it would increase the perceived time for non-value-added services, but to a limited degree, and never by more than 59 minutes. Third, the overnight hours (11:00 PM to 8:00 AM) were not directly observed, but retrospectively recorded each morning by reviewing the records and discussing the overnight events with the clinical staff. For example, if a patient was intubated at 11:00 PM and at 8:00 AM, the observer would confirm this and record that status for the intervening hours. This is unlikely to result in a substantial impact on the findings, because the overnight hours have a relative degree of “stability” even for unstable patients in terms of their status of needing or not needing a CCS. Fourth, we did not evaluate the appropriateness of CCS delivered (eg, how long a patient was ventilated). Our definitions for CCS and NCCS were based on Children’s Hospital of Philadelphia practices, which may not be the same as those of other facilities. The categorization of CCS was objective for activities such as ventilation or continuous infusion, but was

less clear for the “not otherwise specified” recordings, which represented patients with a complex illness or projected organ, respiratory, cardiac, or neurological failure. These patients were not receiving a specific critical care intervention, but were deemed to need to be in the PICU as opposed to a regular floor (eg, for frequent monitoring of potential respiratory failure). It would also include patients receiving combinations of therapies more efficiently delivered in the PICU. For that, the observers relied on the judgment of clinicians (primarily nurses) to determine whether the patient “needed” to be in the PICU or not; if no specific reason could be provided, “not otherwise specified” was applied. These 192 instances accounted for 2982 aggregate bed-hours (15% of total). It is difficult to judge the direction of bias, because overestimation of need to be in the PICU may be as likely to occur as underestimation. Fifth, the very presence of the observers may have changed behavior. Knowing that they were being observed staff may have acted with greater efficiency than otherwise. We expect that such a finding would lead to less time appearing as necessary logistics or NCCS. Finally, results may not be generalizable to other hospitals or hospital settings. There are clearly important contextual factors, not only for the location but also for the duration. For example, staffing was never an issue during the 5 weeks of observation, but there are locations where an empty bed is not necessarily usable due to lack of staffing. Nonetheless, we believe the results provide a generalizable approach and methodology for other settings (and staffing could be a reason for an empty bed).

In terms of the setting, as noted, we observed one discrete 24-bed unit, which comprises half of the total PICU. Thus, statements that the PICU was at full capacity must be interpreted in the context that additional rooms may have been available on the other side. Patients are generally admitted alternately to each unit, so the occupancies should parallel each other. We recorded the census every 4 hours for both sides from the electronic system (Sunrise Clinical Manager [SCM]). However, this only accounts for patients physically in beds, not beds held for patients in other locations. Thus, we would expect a discrepancy between direct observation and the SCM value. Through analysis of the entire pediatric intensive care unit,* that part

*In comparing direct observation to the SCM count, we found perfect concordance for 110 hours (55%) during which 0 beds were available. For the other 90 hours, SCM reported 1 bed being available in 46 hours (23%), 2 beds being available in 24 hours (12%), 3 beds being available in 17 hours (9%), and 4 beds being available in 3 hours (2%)—all while we directly observed 0 beds being available. Thus, cumulatively, 90% of the hours observed with no beds had an SCM report availability of 0–2 beds; 99% of the time that was 0–3 beds. Applying this rate of mismatch to the unit that we did not observe directly, SCM reported 0 beds for 46 (23%) of the 200 hours the observation unit was full; SCM reported 1 bed available in 70 hours (35%), 2 beds open in 42 hours (21%), 3 beds open in 26 hours (13%), and 4 beds open in 16 hours (8%). Cumulatively, that is 79% of the time with 0–2 beds and 92% at 0–3 beds. From this, we conclude that the combined PICU for both sides was likely functionally full at least 158 of the 200 hours that the side we observed was full (79% × 200 hours) and likely had very constrained capacity during the other 42 hours.

which observed directly, and that which we did not observe directly using census data, we think it reasonable to assert that both units of the total PICU had constrained capacity during the times we directly observed and recorded such constraint on one side.

This study demonstrates the use of direct observation for inpatient settings to learn about resource utilization and identification of value-added services. PubMed searches for the terms *efficiency*, *flow*, *process redesign*, and *time management* bring up many more references for operating rooms than for ICUs or inpatient beds. Some examples of ICU-directed work include videography of an ICU in Australia²⁷ and human factor analysis in ICU nursing.⁵ Time-motion studies have also been conducted on clinical staff, such as physicians.^{28,29}

In conclusion, we found that direct observation provided important insights into the utilization of patient rooms in an important inpatient setting. Data such as these are valuable for clinical and process improvement work, as well as understanding how best to match capacity to patient need. Finally, the methodology is reproducible for other settings and would be an additional tool to measuring and improving the efficiency and value of the health system. When appropriate, this approach can also evaluate the effectiveness of process improvement, help identify and reduce waste,¹³ and contribute to the growing field that merges operations management with hospital administration and clinical care: in other words, evidence-based management.³⁰

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