Reserved Bed Program Reduces Neurosciences Intensive Care Unit Capacity Strain: An Implementation Study

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BACKGROUND: Neurosciences intensive care units (NICUs) provide institutional centers for specialized care. Despite a demonstrable reduction in morbidity and mortality, NICUs may experience significant capacity strain with resulting supraoptimal utilization and diseconomies of scale. We present an implementation study in the recognition and management of capacity strain within a large NICU in the United States. Excessive resource demand in an NICU creates significant operational issues.

OBJECTIVE: To evaluate the efficacy of a Reserved Bed Pilot Program (RBPP), implemented to maximize economies of scale, to reduce transfer declines due to lack of capacity, and to increase transfer volume for the neurosciences service-line.

METHODS: Key performance indicators (KPIs) were created to evaluate RBPP efficacy with respect to primary (strategic) objectives. Operational KPIs were established to evaluate changes in operational throughput for the neurosciences and other service-lines. For each KPI, pilot-period data were compared to the previous fiscal year.

RESULTS: RBPP implementation resulted in a significant increase in accepted transfer volume to the neurosciences service-line ($P = .02$). Transfer declines due to capacity decreased significantly ($P = .01$). Unit utilization significantly improved across service-line units relative to theoretical optima ($P < .03$). Care regionalization was achieved through a significant reduction in "off-service" patient placement ($P = .01$). Negative externalities were minimized, with no significant negative impact in the operational KPIs of other evaluated service-lines ($P = .11$).

CONCLUSION: Capacity strain is a significant issue for hospital units. Reducing capacity strain can increase unit efficiency, improve resource utilization, and augment service-line throughput. RBPP implementation resulted in a significant improvement in service-line operations, regional access to care, and resource efficiency, with minimal externalities at the institutional level.

KEY WORDS: Neurosciences intensive care unit, Capacity strain, Neurocritical care, Key performance indicator, Quality improvement

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The care for patients with neurological disease has evolved substantially over the last 30 yr. Improved understanding of neurological pathophysiology, as well as technological advancements in diagnosis and treatment of various neurological diseases, has resulted in an increasingly complex standard of care. Concomitantly, the management of critically ill neurological patients has become progressively more specialized. Neurosciences intensive care units (NICUs) are now commonplace at academic medical centers, and more common in community hospitals as well.

ABBREVIATIONS: ED, emergency department; **KPI,** key performance indicator; **LOS,** length of stay; **LWBS,** leave without being seen; **MET,** Medical Emergency Team; **NCC,** Neuro-Critical Care; **NICU,** neurosciences intensive care units; **PACU,** post-anesthesia care unit; **RBPP,** Reserved Bed Pilot Program

NICUs provide an institutional center for specialized and more complex critical care provided by a multidisciplinary team comprised neurosurgeons, neurologists, intensivists, and specialty-trained neurosciences nurses. Working collaboratively, these teams provide a comprehensive approach, including a detailed understanding of the neurological examination and pathophysiology associated with neurological disease, as well as general systems dysfunction. The anticipated reduction in morbidity and mortality of patients under the care of specially-trained individuals with dedicated resources remains the justification for specialty-specific ICUs.[1,2]

The NICU at the University of Alabama at Birmingham (UAB) University Hospital is one of the largest NICUs in the United States. With over 2700 admissions annually, it provides tertiary and quaternary neurological critical care services for a multi-state catchment area. Despite high capacity and relative efficiency, excessive demand for unit services created significant logistical issues. Congestion with "off-service" (non-neurosciences) patients, combined with a significant elective neurosurgical volume and robust Emergency Department (ED)/Level I Trauma Center admissions, resulted in frequent capacity closures and diversion of patients to other facilities. Diseconomies of scale secondary to a consistent supraoptimal unit census further exacerbated these logistical issues. The following represents an implementation study in the recognition and management of capacity strain within a large NICU in the United States. The Standards for Reporting Implementation Studies checklist was followed.[3]

METHODS

Background to the Program

The Bruno Family NICU at the University of Alabama at Birmingham (UAB) University Hospital utilizes a hybrid, cooperative management strategy. The NICU is staffed by a Neuro-Critical Care (NCC) team comprised fellowship-trained critical-care anesthesiologists and neurologists, who help provide care to more than 2700 admissions annually. Acting in a hands-on consult capacity, the NCC team augments the primary service team (eg, Neurosurgery), providing expertise in the management of cardiopulmonary and hemodynamic derangements associated with neurological disease. In January 2015, the capacity of the NICU was expanded from 28 to 36 beds, along with a concomitant expansion in specialty-specific resources, including dedicated neurosciences nurses and support staff. Despite a large capacity, persistent supraoptimal unit utilization potentiated logistical issues that ultimately resulted in a decrease in transfer volume to the neurosciences service-line, an increase in transfer declines due to lack of capacity, and worsening NICU capacity strain. These issues were due, in part, to the use of the NICU for "off-service" patient care (ie, patients without neurological or neurosurgical pathology).

Prior to April 2017, the UAB NICU utilized an unreserved resource format, providing overflow for the Medical, Surgical, and Heart Transplant ICUs as well as the Medical Emergency Team (MET). Providing general critical care services in a specialty ICU carries an opportunity cost of fewer in-specialty admissions or transfers. In April 2017, we implemented a Reserved Bed Pilot Program (RBPP) to maximize specialty-specific economies of scale (ie, reduce "off-service" patient volume), reduce transfer declines due to lack of capacity, and increase transfer volume for the neurosciences service-line.

Details of the Program

The RBPP was implemented in coordination with the UAB University Hospital Center for Patient Flow (bed control). The NICU was reserved primarily for patients with neurological conditions, including neurology, neurological surgery, and neuro-trauma patients. "Off-service" patients (those with non-neurosciences primary pathology) were diverted to other ICUs, unless actively followed in consultation by a clinical neurosciences service. The post-anesthesia care unit (PACU) acted as a contingency overflow unit for the non-neurosciences ICUs in the event that they all reached capacity. With this contingency plan in place, beds within the NICU remained open (reserved) for patients with neurological pathology, regardless of capacity issues in the non-neurosciences ICUs, in an effort to promote utilization of neurosciences-specific resources and expertise.

Key Performance Indicators

Several key performance indicators (KPIs) were created to evaluate the RBPP. In particular, strategic KPIs were created to evaluate the efficacy of the RBPP with respect to its primary objectives (reducing transfer declines due to lack of capacity and increasing transfer volume for the neurosciences service-line). Total transfers requested were defined as all potential and realized transfer requests involving an aggregate measure of transfers accepted, transfers declined due to lack of capacity, transfers declined due to reasons other than capacity, and consults. Each subcategory was also reported individually (Table 1).

Service-line-specific operational KPIs were established to evaluate the efficacy of the RBPP with respect to operational throughput for the neurosciences service-line, including throughput information from the ICU, intermediate care unit, and acute care floors. Average neurosciences service-line length of stay (LOS) was computed. Average percent occupancy at midnight was obtained for the NICU, intermediate care unit, and acute care units. To control for elective clinical practice and internal referral volume, metrics were utilized to evaluate service-line productivity for each portal of entry. Volume by Portal of Entry for Internal Referral, Elective Clinical Practice, and Outside Hospital Transfer were calculated as monthly averages for the prepilot and pilot periods. ICU throughput was measured by proxy using average order to assigned bed time. This was defined as the average time from placement of transfer order to bed assignment (on intermediate care or acute care floor). An "off-service placement" metric was created to evaluate the percentage of total unit patient days per month devoted to care of non-neurosciences service-line patients (Table 2).

Hospital operations impact KPIs were created to evaluate the effect of the RBPP on the operational throughput of other service-lines. The ED was thought to be the most vulnerable to negative externalities associated with the RBPP due to its significant volume of neurological patients and existing resource utilization profile. Several metrics were created to monitor ED throughput compared to the prepilot period. ED leave without being seen (LWBS) rate was defined as the percentage of patients who left the ED without being seen by a physician or midlevel provider. ED overall LOS was calculated for all patients seen in the ED from check-in to check-out. Average LOS was also calculated for those patients with an admission request order (LOS admitted inpatients). ED-boarded patients were defined as those patients who were admitted and waited for an inpatient bed for at least 4 h. Patient count and total boarding hours were calculated for ED boarded patients (Table 3).

For each KPI, a monthly average was calculated for the 6-mo pilot period (April-September 2017). These were compared to the monthly

TABLE 1. Strategic Key Performance Indicators

Key Performance Indicator	Definition	Prepilot monthly average/benchmark	Pilot period monthly average	*P* value
Total requested transfers	All transfer requests, including accepted, declined, and consults	196 requests	197 requests	.93
Accepted transfers	Count of requests with disposition of “accepted”	117 transfers	133 transfers	.02[a]
Declined transfers (capacity)	Count of requests with disposition of declined and a decline reason of insufficient capacity	23 declines	10 declines	.01[a]
Declined transfers (other)	Count of requests with disposition of declined and a decline reason other than insufficient capacity	28 declines	19 declines	.06

[a] $P < .05$ considered statistically significant.

TABLE 2. Service-line Operational Key Performance Indicators

Key Performance Indicator	Definition	Prepilot monthly average/benchmark	Pilot period monthly average	*P* value
Service-line average length of stay	Average length of stay for all patients on neurological service-line	5.5 d	5.5 d	.87
Census of intensive care unit	Average percent occupancy of neurological intensive care unit (measured daily at midnight)	91.9% (3 open beds)	87.9% (4 open beds)	.03[a]
Census of immediate care unit	Average percent occupancy of neurological intermediate care unit (measured daily at midnight)	91.0% (3 open beds)	85.5% (4 open beds)	.002[a]
Census of acute care unit	Average percent occupancy neurological acute care units (measured daily at midnight)	89.7% (2 open beds) 78.0% (4 open beds)	85.4% (2 open beds) 72.0% (5 open beds)	.03[a] .01[a]
Volume by portal of entry (internal referral)	Average monthly internal referrals, including ED admissions and consults	141	154	.01[a]
Volume by portal of entry (elective clinical practice)	Average monthly elective clinical volume, including direct admissions from clinic and elective operative volume	228	236	.64
Volume by portal of entry (outside hospital transfer)	Average monthly accepted and completed transfers	51	65	.01[a]
ICU throughput proxy	Average time for patients with orders to transfer from ICU to intermediate care or acute care units	210 minutes	240 minutes	.14
Off-service placement	Percentage of total unit patient days occupied by patients who are deemed “off-service”	7.0%	2.7%	.01[a]

[a] $P < .05$ considered statistically significant.
ED—Emergency department; ICU—intensive care unit.

average for each KPI from the previous fiscal year (October 2015-September 2016) prior to the implementation of the RBPP, along with national benchmark data, when available. Relative growth or decline for each KPI was calculated using the prepilot numbers as a baseline. Independent *t*-tests were conducted on each KPI, with $P < .05$ indicating statistical significance.

RESULTS

Strategic KPIs

Average monthly total transfer requests remained stable throughout the RBPP period compared to prepilot data (197 vs 196, $P = .93$). The average number of accepted transfers increased from 117 to 133 ($P = .02$). This translates to a 9% increase in accepted transfer volume during the pilot period. The acceptance *rate* for the prepilot and pilot periods was 59% and 68%, respectively. Transfers declined due to reasons other than capacity decreased modestly from 28 to 19 ($P = .06$). Declines due to capacity decreased significantly, from 23 to 10 ($P = .01$). This translates to a 56% decrease in declines due to capacity, as well as a decrease in the declines due to capacity *rate* from 12% to 5%.

Service-Line-Specific Operational KPIs

Service-line LOS did not change during the pilot period (5.5 d, $P = .87$). Average midnight occupancy rate for the NICU declined from 91.9% to 87.9% ($P = .03$). This translates to 1 additional open NICU bed per day. Average midnight occupancy rate for the intermediate care unit declined from 91% to 85.5%

TABLE 3. Hospital Operations Key Performance Indicators

Key performance indicator	Definition	Prepilot monthly average/benchmark	Pilot period monthly average	*P* value
ED leave without being seen	Percent of patients who leave the ED without being seen by a provider	7.3%	4.9%	.01[a]
ED LOS (admitted patients)	Average length of stay for all ED patients with an admission request	8.2 h	7.7 h	.003[a]
ED LOS (overall)	Average length of stay for all ED patients (from check-in to check-out)	5.9 h	5.6 h	.01[a]
ED boarded patient count	Number of ED patients per month with an admission request and waiting on bed >4 h	845 patients	820 patients	.54
ED boarding hours	Total number of hours boarded per month for ED boarded patients	6246 h	7353 h	.11

[a] $P < .05$ considered statistically significant.
ED—Emergency department; LOS—length of stay.

($P < .01$). This translates to 1 additional open intermediate care bed per day. Average midnight occupancy rate for the neurological surgery acute care unit declined from 89.7% to 85.4% ($P = .03$). Average midnight occupancy rate for the neurology acute care unit decreased from 78% to 72% ($P = .01$). This translates to 1 additional open neurology acute care bed per day, with no change in neurological surgery acute care bed availability.

Volume by portal of entry data revealed a significant overall increase in service-line productivity during the RBPP. Internal referrals increased significantly from 141 to 154 ($P = .01$). Elective clinical volume increased insignificantly from 228 to 236 ($P = .64$). Outside hospital transfer volume increased significantly from 51 to 65 ($P = .01$).

ICU throughput, as measured by time to transfer, was stable during the pilot period. Average time from transfer order placement to patient transfer (from ICU to intermediate care unit or acute care floor) increased insignificantly from 210 to 240 min ($P = .14$). Service-specific unit utilization improved significantly during the pilot period, as evidenced by a significant reduction in the percentage of total unit patient days dedicated to "off-service" patient care from 7% to 2.7% ($P = .01$).

Hospital Operations Impact KPIs

The RBPP did not have a significant negative effect on the operational throughput of other service-lines. ED operational KPIs failed to reveal any significant operational negative externality. ED LWBS rate actually improved, with a decrease from 7.3% to 4.9% ($P = .01$). In addition, overall ED LOS decreased from 5.9 to 5.6 h ($P = .01$). Average LOS of admitted inpatients decreased from 8.2 to 7.7 h ($P < .01$). The average number of ED boarded patients decreased slightly from 845 to 820 ($P = .54$). The average number of ED boarding hours increased from 6246 to 7353 ($P = .11$). Qualitatively, the number of PACU boarding patients and average number of PACU boarding hours increased during the pilot period as well.

DISCUSSION

Increasingly, complex standards of care and practice guidelines have led to the creation of specialized ICUs at many institutions. In theory, aggregation of specialty resources results in economies of scale and improved patient outcome.[2] In practice, the creation of specialized NICUs has resulted in a decrease in morbidity and mortality for many neurological disease states, as well as an improvement in resource utilization efficiency.[4–7] Despite an improvement in outcome metrics, specialized ICUs are subject to capacity strain.[8]

Increasing demand for specialized ICU resources combined with relatively fixed unit capacities result in increasing stress on physical and human resources. Over time, these stressors result in unit capacity strain, which may be defined operationally as lost productivity (especially with respect to patient care/service provided) or throughput as a result of excessive resource demand.[9] Practically, capacity strain has been correlated with adverse patient outcomes across a wide variety of hospital units,[10] and, within specialized ICUs, may offset the coordinated resource advantage.

Optimal unit capacity has been described previously.[11] Suboptimal unit utilization fails to take advantage of economies of scale. Supraoptimal unit utilization results in diseconomies of scale and capacity strain. Improving unit resource utilization will increase unit efficiency and throughput, while maintaining or improving patient outcome.[12,13] Despite a 29% increase in capacity in 2015, the NICU at UAB University Hospital has maintained supraoptimal capacity since that time. Institutionally, capacity strain has resulted in diminished unit and service-line throughput (compared to theoretical optima). Because this unit represents the regional neurosciences tertiary referral center, capacity strain resulted in negative societal ramifications as well. Significant declines due to lack of capacity reveal suboptimal regional access to care. In an effort to improve service-line and unit throughput, we implemented a RBPP from April to September 2017. While several authors have evaluated the effects of unit architecture (eg, open vs closed ICU structure[1,14]), our efforts represent the largest case study to date for the utilization of a reserved resource program in a specialized ICU to improve unit and service-line throughput as well as regional access to care.

The primary objectives of the RBPP were to decrease declines due to lack of capacity and increase transfer volume. After implementation of the RBPP, the absolute number of declines due to transfer decreased significantly (from 23 to 10 per month on average). Because total transfer requests remained stable, the decline due to capacity rate decreased by more than 58%. Conversely, the absolute number of accepted transfers increased during the RBPP period (from 117 to 133 per month on average). This translates to a 13% increase in the transfer acceptance rate during the RBPP period. The RBPP was successful with respect to all preplanned primary goals and endpoints.

The pilot program was aimed at maintenance or improvement of service-line and unit efficiency in the face of increasing transfer volume. Several authors have reported optimal unit utilization at 80% to 85% of capacity.[15,16] Efficient units maintain an average census within this range to maximize economies of scale and resource utilization efficiency. Prior to the RBPP, we maintained a consistently supraoptimal census in the NICU (91.9% of capacity), intermediate care unit (91%), and neurosurgical acute care unit (89.7%). During the same time period, the neurology acute care unit maintained a slightly suboptimal average census (78%). After implementation of the RBPP, we observed an improvement in unit utilization of the NICU (average census 87.9% of capacity) as well as both the neurosurgical intermediate care (85.5%) and acute care units (85.4%). The average census for the neurology acute care unit remained below the optimal range (72% of capacity). The improvement in transfer volume and unit utilization was evaluated relative to the neurosciences elective clinical practice. Outside hospital transfer volume and internal referral volume increased without a significant change in elective clinical volume during the pilot period. These results indicate that the RBPP was successful at improving unit and service-line efficiency without compromising care to the local and elective patient populations, thereby supporting the service mission of participating departments.

Prior to implementation of the RBPP, "off-service" patient placement contributed to supraoptimal unit utilization and resource inefficiency. At 36 beds, the NICU is the largest ICU at UAB University Hospital. With 3 open ("unutilized") beds per day on average, the NICU was a frequent recipient of medical or surgical ICU overflow, as well as MET call general medicine patients who required ICU-level care for non-neurological reasons. Prior to the RBPP period, "off-service" patients accounted for 7% of total unit patient days per month. Utilizing specialized resources for general medical care is inefficient. It comes at the added opportunity cost of neurosciences patients who are declined transfer due to lack of capacity. After RBPP implementation, "off-service" patients accounted for only 2.7% of total unit patient days per month. Theoretically, the benchmark value for this metric is 0% (maximized specialization and resource efficiency). Review of the residual "off-service" cases indicate that most of these were patients with secondary neurological issues requiring frequent neurological monitoring by specialized nursing staff. Practically, the RBPP eliminated "off-service" patient placement within the NICU, increasing unit and service-line productivity while improving access to specialized resources for patients with specialized needs.

Resource reservation may present an ethical dilemma regarding access to care and resource utilization. Is it appropriate to reserve resources for potential subspecialty patients who may request transfer from external, community hospitals in the face of the present and real needs of any current nonsubspecialty patients?[17] In an effort to minimize potential negative externalities, evaluation sought to quantify and monitor the effects of the RBPP on other departments and units. The ED and PACU appeared to be the most vulnerable units. In theory, the RBPP might increase capacity strain on these units, while improving resource utilization and care efficiency in the NICU. At the institutional level, there is little utility in trading a decrease in capacity strain in one unit for an increase in another.

It is conceivable that implementation of the RBPP might exacerbate capacity strain in the ED and PACU. Less critical patients might witness increased wait times, leading to a higher percentage of these patients leaving without proper evaluation or treatment. Surprisingly, the ED LWBS rate decreased significantly during the RBPP period. Similarly, LOS metrics for the overall and admitted patient populations improved significantly. The number of ED-boarded patients, total ED boarding hours, and PACU boarding hours did not significantly change during the RBPP period. While the number of ED boarding hours increased modestly, an internal review of these cases did not reveal the RBPP as the primary etiology. Concomitant changes in ED and PACU policies, as well as an increase in overall ED arrivals and patient acuity, confounded the hospital operations impact KPI measurements during the RBPP period.

The RBPP was successful with respect to all strategic endpoints. Resource reservation within the NICU increased transfer volume and decreased declines for transfer due to lack of capacity with negligible change in elective clinical volume. Operationally, the RBPP had a positive impact on work flow. Service-line efficiency metrics improved substantially. At the hospital level, negative externalities impacting other departments and units were minimized with no negative outcomes attributable to resource reservation or the RBPP. While our case study represents the largest of its kind, and its success has modified our standard operating procedure for neurosciences platform resource utilization, validation in other institutions' specialized ICUs is warranted and encouraged. Posthoc financial analysis may strengthen the argument for resource reservation protocols at the institutional level.

CONCLUSION

Capacity strain is a significant and perennial issue for hospital units. Evaluation of the causes and ramifications of capacity strain may provide directions for improvement measures. Reducing capacity strain can increase unit efficiency, improve resource utilization, and augment service-line throughput. This case study, the largest of its kind to date, evaluates the recognition and management of capacity strain in a large NICU in the United States. Implementation of a RBPP resulted in a significant reduction in declines due to capacity and a significant increase in transfer volume, with minimal negative externalities at this institutional level. This program was successful with respect to all preplanned endpoints. Its implementation has improved access to care throughout a large geographical area, while improving resource utilization and care efficiency at the institutional and service-line levels. Additional prospective evaluation of reserved bed policies at other institutions will improve the generalizability of our results. Cost-benefit analysis is prudent to quantify the financial impact of such policies on the unit, service-line, and hospital system.

Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENT

In this article, the authors make a case for what amounts to reserving beds specifically for neurologically impaired patients—the ultimate in a "closed unit". Of course, this is an ideal logistical situation for specialty beds in a multidisciplinary facility. Those caring for such specialty patients reside in those areas, focusing expert care where it's needed. But this idea needs to be viewed in wider perspective.

These results are not necessarily applicable to the big picture. A modern medical center is not an island unto itself. Most are in competition for patients with other such local facilities. The worst thing that an administrator can think of is an empty bed. Huge overhead in such facilities must be paid no matter what the occupancy is, and an empty bed soaks up resources but contributes nothing. Administrators create strategies to fill their beds, often by out-competing other facilities. "We accept everything, no questions asked". If a specialty section of a facility "reserves" beds for "their" patients, the reality is that sometimes there will not be enough specialty patients to fill those beds.

So as a practical matter, triage officers will usually admit incoming patients to wherever a bed can be found, at least temporarily, if for no other reason than to deny another facility that patient filling a bed. That means, rather than being diverted to another facility, straight up medical patients will be admitted to wherever a bed can be found including specialty areas, especially at night. If a medical ICU bed is not available, straight up medical patients will fill whatever bed is available, even in the NICU.

Again, as a purely practical matter, it's unusual to find a completely "closed" NICU. Most contain multidisciplinary neurointensivists, trained to deal with neuro issues but also competent to deal with virtually any medical emergency, at least as a temporary stopgap. It's usually a handshake arrangement between neurological specialists and NICU intensivists who agree to share responsibilities. The occasional medical patient admitted to the NICU isn't an unqualified disaster.

It is at this wider view of the practical reality of hospital admission triage that the author's otherwise good idea about a true "closed unit" collapses as soon as the first open bed anywhere is found for an incoming patient. Refusing a generic patient because an appropriate specialty patient might arrive at some time in the future is bad bed triage if for no other reason than it's costly in a world of thin operating margins. The reserved bed plan depends wholly on the availability of alternative bed availability, which simply doesn't work in many hospitals that run on full occupancy. Moving them to post-anesthesia recovery rooms and emergency departments awaiting a bed will be greeted by howls and probably suboptimal care.

So the solution for overcrowding in NICUs is one that works in a perfect world, and our world is anything but perfect. It should be explored more completely in the wide world, rather than an isolated one.

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