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Lean Methods to Optimize Operations in Emergency Departments During the Height of the COVID-19 Pandemic

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Abstract

Across the world, hospitals faced a crisis in personnel and supply chain management during the height of the COVID-19 pandemic. While demand for nurses was at an all-time high, hospital staff, especially in emergency departments, were frequently exposed to the virus causing additional shortages due to illness. Personal Protective Equipment (PPE) designed for sterile environments and single use conditions were now limited or completely out-of-stock. At one flagship emergency department in the Midwest, lean techniques were utilized to increase the safety of employees, while mitigating other risks such as personnel fatigue, cross-contamination, supply chain shortages and virus spread. This work demonstrates the effectiveness and speed with which lean techniques can be implemented to support appropriate staffing levels and balancing of workflow, flow of inventory, and facility layout using tools such as 5S, Kanban systems, visual management and resource allocation.

This presentation will provide the audience with an overview of the lean methodologies used, as well as a review of the data analysis after implementation. Those who attend the presentation will also be provided with a copy of a case study prepared for classroom use illustrating concepts in lean healthcare, operations management and safe operations in pandemic conditions.

Introduction and Background

Across the world, hospitals faced a crisis in personnel and supply chain management during the height of the COVID-19 pandemic. While demand for nurses was at an all-time high, hospital staff, especially in emergency departments, were frequently exposed to the virus causing additional shortages due to illness. Personal Protective Equipment (PPE) designed for sterile environments and single-use conditions were now limited or completely out-of-stock. At one flagship emergency department in the Midwest, lean techniques were utilized to increase the safety of employees, while mitigating other risks such as personnel fatigue, cross-contamination, supply chain shortages and virus spread. This work demonstrates the effectiveness and speed with which lean techniques can be implemented to support appropriate staffing levels and balancing of workflow, flow of inventory, and facility layout using tools such as 5S, Kanban systems, visual management and resource allocation.

The hospital studied was a flagship location serving a tri-state area of primarily rural communities and townships. The campus includes an Acute Care hospital with over 200 beds, as well as thirteen other specialty facilities. The Emergency Department at the campus is available 24 hours a day, 7 days a week and recognized as an Emergency Department approved for Pediatrics (EDAP) and HFPA Certified Primary Stroke Center.

The hospital system uses multiple quality approaches to ensure that patient care holds to the highest standard of quality, while implementing systems that are efficient, effective and meet performance needs. In 2003, the hospital expanded their quality systems to include a Six Sigma method. Their corporate-specific Six Sigma method includes work using DMAIC, Lean

practices, Change Acceleration Process ("CAP") and Work-Out. The quality team works in all regional locations to improve patient care. The nursing staff of the hospital system also use an evidence-based practice model (EDPM) called DEAC, which stands for Discussion, Evidence, Application and Conclusion. This system was developed by the Nursing and Evidence Based Practice and Research Council to better implement changes to nursing practice within the facility to improve patient care. Through this system, health care professionals are able to examine opportunities for continuous improvement, evaluate relevant literature and documented best practices in the nursing community, and implement new procedures through changes in policy and practice.

These internal quality systems demonstrate the value the administration places on quality and continuous improvement for their patients and employees. However, as with most large organizations, there are more opportunities for improvement than there is time or staff to implement them. While there are ample opportunities to improve operations in the Emergency Department, the limited time and resources of the internal Six Sigma and quality improvement teams make it difficult to pursue many of the potential opportunities in existence. This circumstance was exacerbated by the COVID-19 pandemic when all hospital systems were overloaded beyond their intended capacity. As the only major healthcare facility within a 2 to 3-hour drive for a majority of tri-state residents, there were no other health care options to be diverted to.

Literature Review

During the COVID-19 pandemic, there was a significant change to the types of visits to Emergency Departments at local hospitals across the United States, including an increase in visits associated with upper respiratory infections, shortness of breath and chest pain [1]. However, there was also a significant decrease in populations that typically visit the emergency department for non-life-threatening issues, including pediatric, geriatric and Medicare-based patients, causing concern that there are vulnerable patient populations foregoing necessary medical care [1, 2]. As the pandemic continued, hospitals needed to be able to accommodate both the traditional emergency department patients, as well as addressing patients suffering from COVID-19. As such, the overall patient census at local hospitals continued to increase, with staff addressing specific COVID-19 protocols for some patients while also addressing traditional visits such as trauma, cardiac distress, stroke victims and other emergency medical needs. At the Emergency Department investigated, the Intensive Care Unit (ICU) beds had an occupancy rate of above 90% during the height of the COVID pandemic (2020-2021) [3]. Many of these patients originated from the Emergency Department and were admitted to the ICU after being stabilized. The COVID-19 pandemic and corresponding increase in patient flow revealed new limitations of the hospital resources under traditional practices [4]. Lean healthcare has been proven in previous research to benefit healthcare operations by both identifying causes to issues within healthcare processes and aid in improving systems in a wide variety of medical contexts [5]. While lean healthcare techniques could assist in addressing shortages in resources brought about by the pandemic, the necessary expertise in both process improvement and medicine is rarely available to implement changes where they are needed. As previously stated, the existing quality teams were already overwhelmed with other projects even prior to the pandemic, making it

impossible to deploy resources to the Emergency Department to assist at the time of greatest need.

Prior to the COVID-19 pandemic, healthcare faced numerous problems in operational management, including factors associated with cost of care, staffing shortages and high demands for quality service [6]. Several principles and practices, originally associated with lean manufacturing and Six Sigma, have been found to be helpful in healthcare operations, including: elimination of waste, Ishikawa diagrams, spaghetti diagrams, value stream mapping, 5S and other tools [6, 7]. While many similarities exist between the implementation of lean in healthcare compared to other business sectors, regulations and lack of education in lean systems can cause a barrier to utilizing these tools to benefit patients and healthcare providers alike [5, 7]. However, for those places where lean tools have been successfully applied, organizations have seen increases in patient satisfaction, decrease in waiting times, reduction of costs, improved patient flow and other improvements [4, 5, 6 & 8].

Despite positive gains in patient satisfaction and operational metrics from lean implementation, lack of education amongst frontline workers (nurses, doctors, support staff) makes it difficult to apply lean solutions where they are needed most [5]. While lean tools could help to make systems more responsive and agile in the face of the pandemic, there was a shortage of application in complex environments or during times of crisis [6]. There was also a lack of data translating lean improvements into operational cost savings, making it difficult to justify work on special projects during a time when resources are already strained [8].

Hospitals across the world continue to face tremendous burdens on their resources and could benefit from lean tools to be more efficient and effective in their care of COVID and non-COVID patients. However, the expertise to apply such tools must come from outside the healthcare providers, who are unfamiliar with how to apply lean practices to daily operations. Studies such as these help to build a foundation of process improvement strategies in healthcare that are applicable to nearly any type of clinical setting.

Methodology

Working with a facility in a state of crisis required remaining unobtrusive and conducting research activities without diverting resources from patient care. As such, initial data gathering came through interviewing staff before or after their shifts, speaking to nurses and administrators on their days off (as willing and available) and analyzing data that was already being collected as part of normal operations. In accordance with HIPPA requirements, no personal identifiers were ever included in any information recorded about patient rooms, nor did the researcher have access to any patient data. The focus for data gathering included the experience of the staff, workplace organization and flow of people, materials and information to look for opportunities in process improvement which would ultimately better patient care and their overall experience.

As with many locations worldwide, the emergency department quickly reorganized the suite of rooms to group the COVID rooms to a specific area of the department to limit cross contamination [9]. This movement, while helpful in limiting exposure to the virus, became a central issue both in personnel flow (patient and staff) as well as a difficulty in resource management for supplies. The shortage of personal protection equipment (PPE) was not unique

to this location, but also a globally experienced difficulty [10]. Locating the COVID rooms in a single area aimed to reduce the number of times specialty PPE would be donned and doffed, to reduce the Tyvek® suits, respirators or N-95 masks, and other required protection for those being exposed to the virus. Hospital administration was simultaneously trying to limit consumption of goods that could no longer easily be replaced due to supply chain shortages while protect their staff to prevent additional staffing shortages due to their own contraction of the illness.

With a dedicated individual and support person allocated to the COVID suite of rooms, staffing models were adjusted from an industry standard of three-room assignments per nurse, to a weighted model in which some nurses maintained a three-room assignment, some nurses maintained a four-room assignment and some nurses were in a three-room COVID assignment. Additional nurses who had served as "floaters" to support breaks, lunches, ambulances, and other situations were no longer assigned. While on paper this seemed to balance the schedule, immediate problems were evident, as certain procedures, including conscious sedation, stroke monitoring, cardiac arrest and other specialty conditions require a one-on-one approach, where the nurse assigned to three or four rooms is now occupied for several hours with one specific patient and there is no longer a "floater" nurse to help cover these additional rooms. This meant that even nurses with three-room assignments were often covering more than the rooms documented on the white board at the nursing station.

At the time the project began, no personnel assignment data was recorded. Each day, the charge nurse would write the room assignments on the large white board by the nurses' station with the specific room assignments. Every 12 hours or so, the board would be erased and as the shifts changed, the data would be lost. As such, the first step of this project involved replicating the whiteboard data on a simple check sheet to record how personnel assignments were allocated. An example of this can be seen in Figure 1.

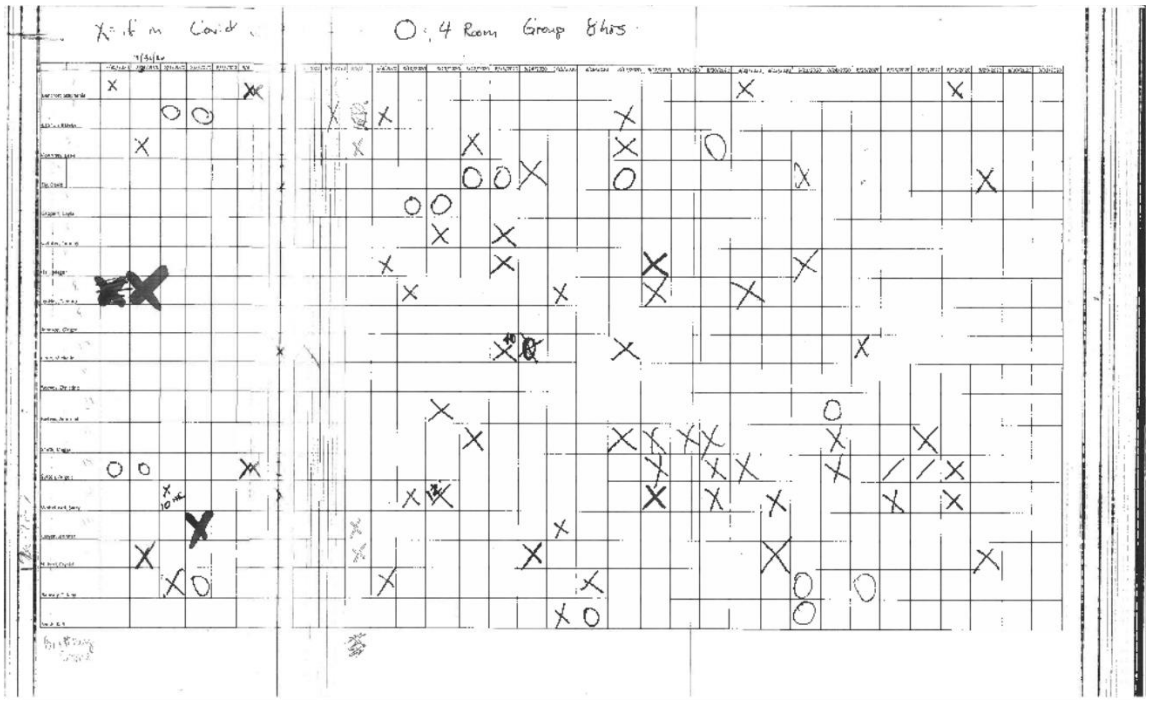

Figure 1: Data Capture for Room Assignments

In effort to better understand the desired process, the administration and charge nurses were interviewed and the assignment process was documented. Table 1 shows the desired staffing levels.

Table 1: Desired Staffing Levels

Nurses per Shift		Nurses per Time Period (24 hr cycle)	
7am – 7pm	6 nurses	7am – 11am	6 nurses
11am – 11pm	4 nurses	11am – 3pm	10 nurses
3pm – 3am	2 nurses	3pm – 7pm	12 nurses
7pm – 7am	5 nurses	7pm – 11pm	11 nurses
		11pm – 3am	7 nurses
		3am – 7am	5 nurses

Based on the above staffing levels and available full-time staff, a former charge nurse who now served as a full-time scheduling administrative position would create a six-week block. This six-week block would incorporate scheduled time off, maternity leave or other pre-established release time. Any gaps in the schedule could be claimed by part time nurses (PRN's) or by fully assigned nurses with approval from their supervisor for overtime pay. Paid-time off (PTO) requested after the schedule had been released (such as developing COVID or some other illness) and call-offs (absences with less than 24 hours' notice) would be addressed by texting all non-scheduled individuals with a request for assistance and information on any incentive pay associated with the hours (double or even triple pay rate). Long-term staffing needs were filled with travel nurses on limited-term contracts who were scheduled for 3 12-hour shifts per week.

Daily staffing was addressed by the charge nurse of the given shift following the process illustrated in Figure 2.

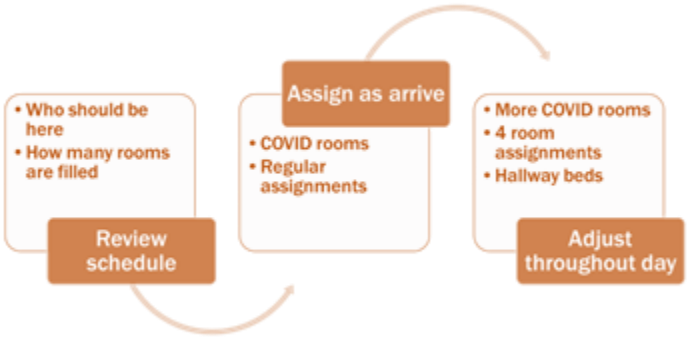

Figure 2: Daily Staffing Process

As shown in Figure 2, the first step of the charge nurse is to review the established schedule to determine who is scheduled to be present and review any absences from the established schedule, termed "last minute call-offs", typically due to illness or personal emergencies. Charge nurses use this information, as well as the current number of patients within the department, as well as recent daily trends to determine if additional staff could be helpful. If the charge nurse thinks additional staff would be helpful, a text message is sent out to individuals not scheduled for the day requesting assistance. Once the charge nurse has established the final personnel available for the shift, rooms assignments are made for each nurse present. Nurses were given a three-room assignment or a COVID assignment. As more patients arrived, some nurses had their three-room assignment increased to a four-room assignment and additional nurses were assigned to COVID rooms as needed. If all rooms were full to capacity, hallway beds were utilized, which were also assigned to nurses with either three or four room assignments. These assignments were adjusted throughout the day as each new shift of personnel came or left and as patients flowed in and out of the department.

As previously stated, all daily staffing decisions were captured on a whiteboard and then erased throughout the day with each shift change. Once the research project began, data was also collected on simple 8.5" x 14" paper with the nurse names recorded down the left side of the page and the dates running across the top of the page (Figure 1). The total staff of the department required the use of four 8.5' x 14" pages. COVID rooms were noted with an "X" and four-room assignments were noted with an "O". Individuals who worked a 3-room assignment had no special designation recorded. This system was established by the nursing staff and maintained by all nurses. While typically the charge nurses would make the room assignments, the nurses often checked the printed page to ensure their work was captured correctly before they ended their shift.

Many nurses assumed that the COVID and four-room assignments were being allocated in a way that was not proportional across all staff. To verify this, data was collected for a month and

compared to the six-week block assignment to determine the rate of COVID or 4-room assignments across individual nurses and specific shifts.

Presentation of Data and Data Analysis

The data collected was transferred from the paper documents to an Excel spreadsheet for ease of analysis. Part-time nurses, contract/travel nurses and nurses on vacation or leave during the period being reviewed were eliminated from the data analysis. All remaining nurses were full-time individuals, each assigned 12 shifts within the month data was collected. Each nurse was grouped by shift and assigned a number to remove personal identifiers. An sample of the raw data table can be seen in Table 2.

Table 2: Raw data for day shift nurses

Shift	Nurse	COVID	Overflow	% C	%O
Days	1	5	0	0.416667	0
	2	3	2	0.25	0.166667
	3	4	1	0.333333	0.083333
	4	3	3	0.25	0.25
	5	0	2	0	0.166667
	6	2	0	0.166667	0
	7	4	0	0.333333	0
	8	5	0	0.416667	0
	9	0	0	0	0
	10	5	0	0.416667	0
	11	0	0	0	0
	12	1	1	0.083333	0.083333
	13	7	0	0.583333	0
	14	6	3	0.5	0.25
	15	9	0	0.75	0
	16	3	0	0.25	0
	17	5	0	0.416667	0
Totals	**17**	**62**	**12**	**0.303922**	**0.058824**

After reviewing the data, the following was discovered. Table 3 summarizes the number of rooms assignments for COVID and 4-room assignments by shift over the period analyzed.

Table 3: Room Assignment Analysis

Shift	# of COVID	Percent of COVID	# of 4-room	Percent of 4-room
Day (7a – 7p)	62	51%	12	43%
Mid (11a – 11p)	19	16%	7	25%
Mid (3a – 3p)	16	13%	5	18%
Night (7p – 7a)	24	20%	4	14%

Overall, the day shift team received the most difficult assignments, while mid-shift (11am and 3pm) often created opportunities for additional rooms to open, yielding additional 3-room assignments, but not changing COVID assignments or existing 4-room assignments. The night shift (7pm) room assignments were more balanced due to lower patient volume.

More interesting is the individual nurse assignment for COVID or 4-room assignments. These results are seen below in Tables 4 and 5.

Table 4: COVID Assignment by Nurse

COVID ROOM ASSIGNMENTS	
7 am shift	81% COVID by 51% of nurses
11 am shift	79% COVID by 49% of nurses
3 pm shift	88% COVID by 43% of nurses
7 am shift	75% COVID by 50% of nurses

Table 5: Four-Room Assignment by Nurse

Four-ROOM ASSIGNMENTS	
7 am shift	100% 4-room by 35% of nurses
11 am shift	100% 4-room by 36% of nurses
3 pm shift	100% 4-room by 43% of nurses
7 am shift	100% 4-room by 40% of nurses

Results

In reviewing Table 3, the COVID room assignments, one can see that there is a bias present towards specific nurses, supporting their anecdotal evidence that charge nurses are selecting the same individuals for less desirable assignments numerous times within the same six-week cycle. This leads to an additional decline in morale, beyond those already documented within the industry as a whole [1, 2, 9, 10] as well as potential personnel turnover, thus worsening an already desperate staffing situation. When reviewed by the charge nurses, the selections were defended, citing special circumstances like preexisting health concerns for nurses (chronic or immunocompromising health conditions and pregnancy), as well as levels of experience in working within the COVID treatment area. Experience was important due to the often-changing protocols, as the hospital adjusted policies as more was learned about the virus. This too was not unique, but typical of all emergency departments around the world, as guidance from the CDC and other health organizations evolved over time [10].

For the four-room assignments, presented in Table 4, special protocols and changing policies were not a factor, nor was preexisting health concerns. However, the four-room assignments were even more dramatic in the levels of consistency of personnel allocation. The charge nurses explained that these assignments often correlated to levels of experience of the nursing staff, and their personal efficiency. While a particular nurse may be competent, they may not necessarily move as quickly as others in processing patients, ordering lab tests and managing the patient flow during their time in the emergency department. In this case, those nurses who were both competent and efficient were effectively penalized by perpetually receiving overloaded

assignments due to the fact that “they could handle it”. This too was documented in other hospital systems [1, 9, 10].

However, even with the unspoken intentional bias, when faced with the data, the charge nurses noted that the mid-shift nurses were being under-utilized most frequently, as room assignments would have been given prior to the arrival of the mid-shift nurses. Rather than supporting overloaded nurses, the nurses on mid-shift often operated in a traditional sense, managing their 3-room assignments, “feeling” fully loaded and therefore not looking for additional opportunities to help others with harder assignments. After discussing the data, specific tasks to support overloaded nurses were identified as support services that could be offered from the mid-shift nurses. This will be explored further in the “Additional Results” section.

After some discussion, it was decided that the room assignment sheet was the simplest way to continue to monitor nursing assignments to try balance responsibilities across as many nurses as possible. The continued use of the room assignment sheet with notation of COVID and four-room assignments allowed for a quick implementation of visual management techniques for resource allocation. This is similar to what we might expect to see in a line-balancing exercise in a manufacturing application.

Another key change was the direct coordination between housekeeping and the charge nurse. The Emergency Department rooms are cleaned by a housekeeping department after each patient is discharged. Much like the lean technique SMED (single minute exchange of dies), rapid changeovers are crucial to overall patient flow allowing for more patients to be seen in a timely fashion. Typically, the housekeeping manager would look at the computer system to see which rooms required cleaning and assign janitorial staff to empty rooms without additional guidance from the nursing staff. In effort to level staffing loads, the housekeeping manager agreed to coordinate assignments based on priority assigned by the charge nurse, rather than making assignments on their own. The charge nurse, using the white board of daily assignments and the paper check sheet of COVID and 4-room assignments could then better balance room scheduling and prevent a single nurse from being overloaded while another nurse is simply waiting for a room to be cleaned before being able to care for another patient. The visual management of room assignments provided a mechanism for a form of “line balancing” in conjunction with housekeeping services. This multi-department coordination would have been impossible without the new visual system.

Additional Results

The changes to the department layout to facilitate a dedicated COVID area were implemented quickly, without input from any nursing staff. The rooms selected to be dedicated COVID rooms had the necessary HVAC systems to support isolation and filtration protocols associated with contagious disease. Through discussion with personnel and evaluation of the new layout, several associated lean projects were implemented to support the new COVID layout. First, a new supply area was established to better support the COVID suite of rooms with materials commonly used by the COVID patients. This area was created after using a spaghetti diagram to determine the most frequently traveled pathways within the department after COVID area was established. The space had previously been utilized as office space, but additional office space was available in a less traveled area of the department, allowing supplies to be stored more

conveniently for the nursing staff. This demonstrates the use lean tools to eliminate the classic waste of excess movement and transport. This area and the main supply room were restocked by mid-shifters, who had additional time to perform these support functions. Mid-shifters were able to use visual management tools to follow a Kanban system for maintaining proper stocking levels of critical items. These two initiatives reduced travel time to obtain necessary materials and reduced the frequency of missing supplies when a patient was in need of a specific item.

Implications for Classroom Instruction

There are several opportunities for using this case study within Industrial Engineering classrooms. First, students could be invited to observe the correlations between lean solutions in health care and manufacturing, and further extend those to other types of industries to relate how continuous improvement applies to business sectors of every variety. Applying lean solutions in administrative settings (such as academia) would provide students an opportunity to identify waste in process workflows, utilize problems solving tools like Ishikawa diagrams, 5-Why's for campus problems they identify and other lean techniques could connect these concepts with non-manufacturing settings that they interact with on a daily basis.

From a managerial perspective, this case study highlights the inherent bias that can impact workplaces and cause places of inequity that may seem counterintuitive to a student but are more common than one might expect. Many supervisors struggle to avoid "punishing" good performers with more work, assigning the most difficult tasks to the most competent employees and using some individuals with greater frequency than others. This case provides opportunities for discussion about team dynamics, the value of cross training and the use of standardized practices for optimal performance; each of which is a foundational concept for world class companies.

Finally, this case could be used for modeling interarrival times of patients to validate staffing procedures based on the given staffing levels. Using either a Poisson or Nonhomogenous Poisson process with a given interarrival time, students could test the established staffing levels per shift to see if the practices are sound. Additionally, students could investigate what sort of staffing adjustments would need to be made to increase COVID capacity or decrease 4-room assignments, depending on the desired exercise.

Conclusion

COVID-19 impacted every industry in a multitude of ways, but the frontline healthcare workers experienced a greater stress in having to simultaneously offer care for a new illness, at previously unexperienced volumes with no time to train in new procedures, plan for optimal methodologies or pursue best practices. This was new territory for everyone.

After the COVID-19 pandemic slowed, the hospital maintained the visual management systems implemented during this project to attempt to ensure a balance of room allocations even as room assignments were more consistent with the 3-room assignment pre-COVID standards. The COVID suite of rooms was maintained, requiring the maintenance of the newly created supply area and restocking system by mid-shift nurses. As volumes decreased, charge nurses noted the value of training nurses of more efficient techniques to increase the speed of care for all patients. This not only assists with patient satisfaction but also helps to prepare for future times of crisis.

This case presents several opportunities to teach students about lean techniques in non-manufacturing environments, as well as discuss important concepts in resource management.

Lean techniques were effective in supporting personnel and material flow, even in the midst of specialty operations due to the pandemic and unanticipated patient volume. It is important to note that, like many operations, a time of crisis may not feel like an appropriate time for continuous improvement, and yet, that is exactly when solutions have the greatest value. The nurses were validated by the data collected, which created data-driven decisions by the administration, demonstrating new policies and procedures supporting the staff in ways that would not have been considered otherwise. Taiichi Ohno said "Where there is no standard, there can be no improvement." Without data, the standard operating procedure was inherently flawed, yet while the nurses could "feel it", no one could prove it. Making the process visible allowed for process improvement during a time that seemed to have stretched the personnel beyond their limits.

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