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Restricting Daily Chest Radiography in the Intensive Care Unit: Implementing Evidence-Based Medicine to Decrease Utilizationt

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VISUAL ABSTRACT

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Abstract

Purpose: In this study, the authors applied evidence-based medicine to decrease the utilization of routine chest radiography in adult intensive care units and used time-driven activity-based costing to demonstrate cost savings.

Methods: A multidisciplinary team was formed with representatives from radiology, surgery, internal medicine, and nursing. The process of performing a portable chest radiographic examination was mapped, and time trials were performed by the radiology technologists and radiology resident. This information was used to determine the cost of performing portable intensive care unit (ICU) chest radiographic studies. The clinical team changed resident education, ordering protocols, and workflows to discontinue the use of routine daily chest radiography, emphasizing that it should be ordered only in specific situations, such as on admission or after central line placement. In addition, as a balancing measure, the team tracked complications such as unplanned extubations and ventilator days.

Results: Changing ordering practices in the adult ICUs to align with established evidence-based guidelines resulted in a 37% decrease in the utilization of portable chest radiography between June and December, without a concomitant increase in unplanned extubations or ventilator days. In addition, a proportionate cost savings was realized, as demonstrated by the application of time-driven activity-based costing.

Conclusions: This performance improvement initiative successfully increased the value of care delivered to ICU patients by aligning institutional clinical practice with evidence-based medicine. This resulted in decreased utilization and the cost associated with delivering care without a concomitant increase in complications.

Key Words: Time-driven activity-based costing, TDABC, ICU chest radiographs, utilization, implementation

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INTRODUCTION

A common, yet often overlooked, source of overutilization in radiology comes from daily portable chest radiography (CXR) in intensive care units (ICUs). A study performed by Clec'h et al [1] in 2007 showed that restrictive use of CXR in the ICU resulted in no difference in mortality, length of stay, or ventilator-free days compared with routine, daily use. A subsequent meta-analysis performed by Oba and Zaza [2] in 2010 arrived at the same conclusions. However, despite multiple studies with conclusive evidence, including the ACR's recommending against this practice, a restrictive, event-driven approach has not been uniformly accepted, and at many institutions daily CXR remains the standard [2].

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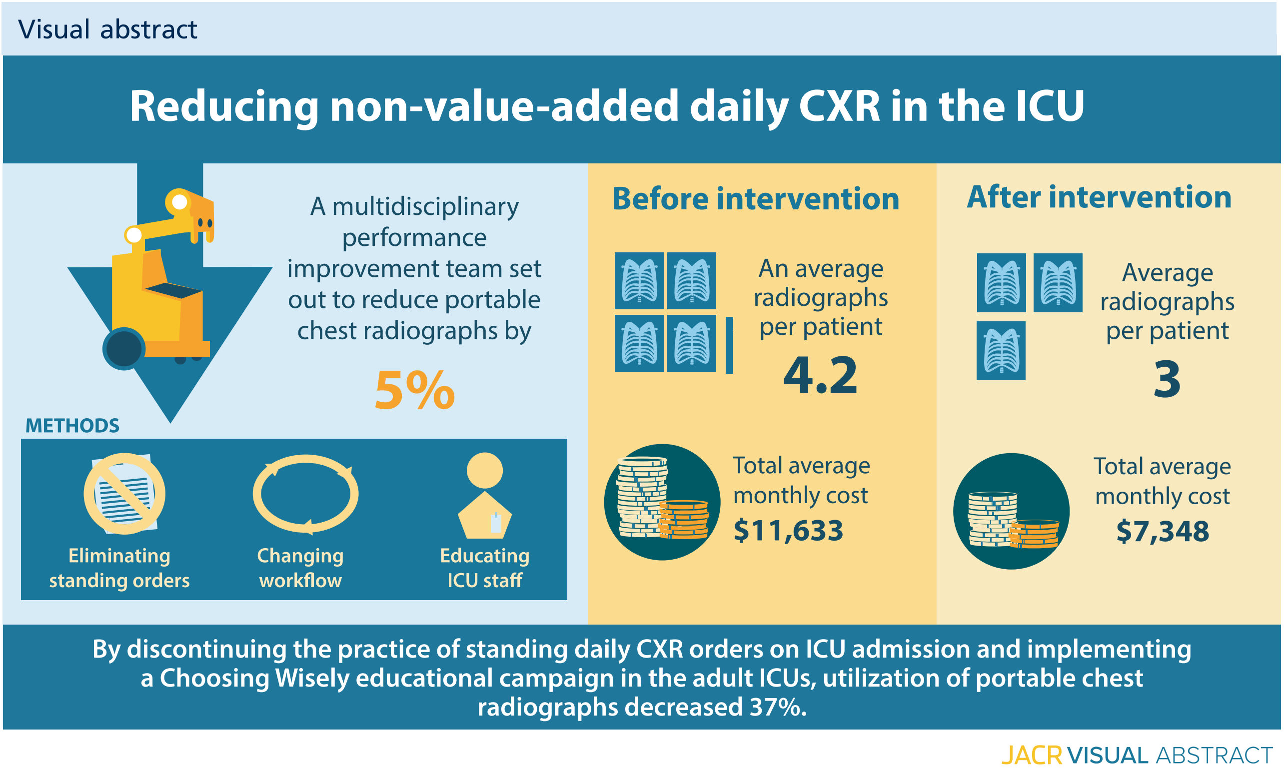

Gershengorn et al [3] found that performing daily CXR, after adjustment for patient case mix and hospital factors, only minimally declined from 2008 to 2014, with a 0% to 3% relative reduction in the odds of use.

At Kings County Hospital (KCH) in Brooklyn, New York, a multidisciplinary performance improvement team was assembled with the aim of decreasing the utilization of portable CXR in the adult ICUs. The team aimed to decrease the utilization of portable CXR by 5% between June and December 2019.

METHODS

This performance improvement project was exempt from institutional review board approval at our institution.

Setting

KCH is an urban, level 1 trauma center in New York City and is 1 of 11 hospitals in NYC Health and Hospitals, the largest public health system in the country. It has both a medical ICU (MICU) and a surgical ICU (SICU). Routine daily radiography is performed between 2 AM and 4 AM to ensure that radiology reports are available for review during rounds. This is during “off hours” and coincides with shifts during which there are fewer radiology technologists (RTs) available because of the demand from the emergency department.

Team Formation and Project Charter

A multidisciplinary team was assembled that included stakeholders with interest in performance improvement and patient safety and/or with decision-making capacity. The project leader (first author) reached out directly to all team members, including the directors of the MICU and SICU, the ICU nursing director, the director of cardiothoracic imaging (second author), a radiology resident (third author), and a radiology supervisor. The project was managed by the radiology team, while medicine and surgery team members served as project champions.

To design the project charter members of the performance improvement team met to delineate what we were trying to accomplish, why the project was important, what changes could be made that would result in improvement; to identify barriers to success; to identify outcome measures and balancing measures; and to determine how to show that a change is an improvement. The team also formally identified the project sponsors, project leader, project champions, and team members. Finally, a time line was devised with target start and end dates. Once completed, the performance improvement team adopted the project charter by consensus. The charter established the total scope of the improvement effort (adult ICUs at KCH), defined the objectives (5% reduction of portable CXR utilization from June to December), and outlined the course of action required to achieve the objectives. It aligned with the strategic pillars of KCH, including quality and outcomes, care experience, financial sustainability, and a culture of safety.

Staff Education and Implementation of Evidence-Based Medicine

The project champions embarked on an education campaign targeting residents and critical care attending physicians. They emphasized that daily CXR rarely changes management; the significant disadvantages associated with this practice, including radiation exposure, sleep disturbances, equipment dislodgement, and skin shear injuries from positioning maneuvers; and more accurate and effective methods already in use to evaluate the same information garnered from CXR. For example, endotracheal tube position at the teeth is routinely documented at the time of intubation and daily by respiratory therapy, and central line insertion depth, visible through the dressing, is routinely documented by nursing. They advocated using body weight, fluid input and output data, and point-of-care ultrasound to ascertain fluid status [4]. Finally, instead of relying on CXR to evaluate the progression of pneumonia, clinical indicators such as temperature trends, hypoxemia, secretions, and changing ventilator requirements would be used as a more sensitive strategy to evaluate and track improvement [5].

House staff education was a particular challenge because each month brought a new cohort of residents and interns. Weekly e-mail reminders were sent to residents, and faculty members were tasked with emphasizing the new approach to patient care during rotation orientation and reemphasizing these strategies in daily rounds. In addition, visual cues deployed at workstations served as reminders of the new, restrictive, event-driven approach to ordering radiographs.

Workflow Alterations

The practice of standing daily CXR orders on ICU admission was discontinued. Instead, the need for CXR was determined only after examining the patient or on the basis of clinical events such as placement of a line, desaturation, or fever. A hard stop preventing this practice could not be deployed with the electronic health record (EHR) system, so fidelity to the new workflow and practices relied heavily on continuous education and feedback. Project champions adopted an iterative strategy of auditing the ICU census list frequently and providing immediate feedback to the critical care teams.

Process Map and Steps in Performing Time-Driven Activity-Based Costing

Several steps were undertaken in applying time-driven activity-based costing (TDABC) to this performance improvement initiative.

Step 1: Construct Process Map. A detailed process map for performing portable CXR in the ICUs was developed by our RTs (Fig. 1). In general, process maps should include all resources directly and indirectly required in each step of the process, including personnel, facilities, and equipment [6]. For simplicity and the purposes of our initiative, we focused on the RT cost. Physician, facilities, and equipment resources were not factored into our assessment.

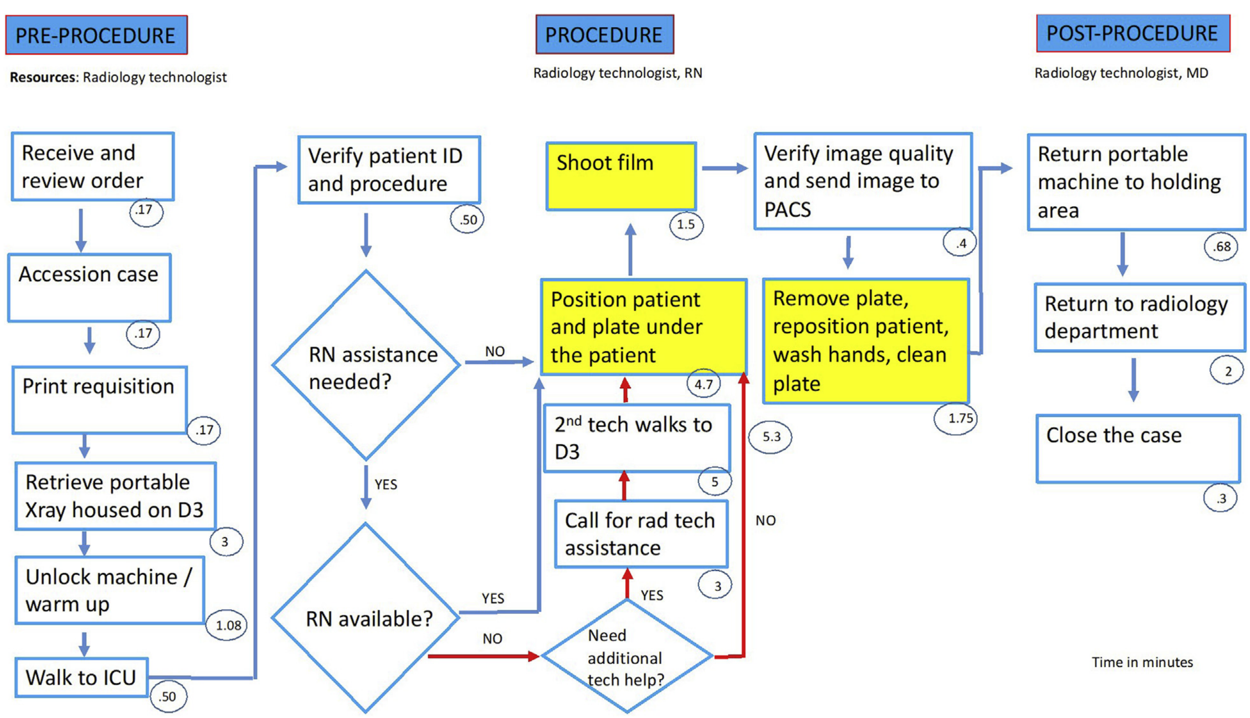

Fig 1. Steps 1 and 2: timed process map for portable chest radiography (CXR). Figure 1 illustrates the steps in performing CXR in the adult intensive care units (ICUs). The average time required for each step was recorded by the timekeeper (radiology resident) and is shown in the bubbles. rad tech = radiology technologist; RN = registered nurse.

Table 1. Total elapsed time before, during, and after procedure		
	Minutes	Hours
Preprocedure	5.59	0.09
Procedure	8.95	0.15
Postprocedure	2.98	0.05
Total	17.52	0.29

Step 2: Time Each Step in the Process Map. Information on the duration of each step in the process map was obtained through direct visualization (Fig. 1). The radiology resident (third author) performed timed trials and recorded the time required at each step (Table 1). It should be noted that during the time trials, and the most common scenario in general, nurses and additional RTs were not available to assist the RT performing the examination.

Step 3: Calculate Capacity Cost Rate for Resource. The capacity cost rate is defined as how much it costs a hospital for a resource to be available for direct patient care [6] (Table 2). This is calculated by dividing the expenses attributable to the resource by the available capacity of the resource. In our scenario, the numerator was equated to the expenses of a staff RT incurred by the hospital (monthly total cost [MTC]), and the denominator was the availability of the RT for patient care (monthly capacity [MC]).

Calculate MTC of a RT: To calculate the MTC, we determined the full annual compensation of the RTs, including salary, benefits, health insurance, pension, and payroll taxes [6] (Table 2). We then added to this figure

Table 2. CCR for resource and cost of performing a single chest radiographic examination

Step 3: calculate CCR for resource				
Days per year		Days	Hours per day	Hours
Start with		365	Start with	8
Less weekends		104	Less scheduled breaks	0.5
Less vacation		15	Daily huddle	0.17
Less holidays		11	Available clinical hours	7.33
Less sick days		5		
Total days worked		235	MC	144
Days per month		19.58		
Step 4: calculate the cost of performing a single chest radiographic examination				
Radiology technologist cost				
Annual compensation*	$87,100			
Supervision cost	$3,575			
Technology and support	$2,925			
ATC	$93,600			
	ATC/12			
MTC	$7,800			
	MTC/MC			
CCR	$54			
	CCR*Total elapsed time			
Cost of a single chest radiographic examination	$15.87			

Note: ATC = annual total cost; CCR = capacity cost rate; MC = monthly capacity; MTC = monthly total cost.
*Includes benefits, payroll tax, health insurance, and pension.

other costs that allow RTs to perform their duties, such as supervision costs and IT. This figure was then divided by 12 to arrive at the MTC, that is, how much it costs the system per month to have an RT available.

Calculate MC of a RT: This figure was determined by subtracting from 365 days all the time the RT is not available for work during the year, including sick days, vacation days, and holidays (Table 2). This was then divided by 12 to determine the days per month that the RT is available. From a standard 8-hour day at our institution, we subtracted the time the RT is not available for patient care, including lunch breaks and daily huddles: the available clinical hours. Finally, the MC was calculated by multiplying the days per month by the available clinical hours.

Step 4: Calculate the Cost of Performing Portable CXR. The cost of performing a single chest radiographic examination was calculated by multiplying the capacity cost rate by the total time used by the RT (Table 2).

RESULTS

Our team aimed for 5% reduction of ICU portable CXR utilization between June and December 2019. After the performance improvement initiative, there was a 37% decrease in the average monthly number of portable chest radiographic examinations performed, from 733 to 463 (Fig. 2). When the number of chest radiographic examinations is normalized to ventilator days, there was still a decrease, from an average of 1.5 before the intervention to 1.1 after the intervention, a change of 27% (Fig. 3). Normalized to the volume of patients, before the intervention, there was an average of 4.2 radiographic examinations per patient and 3 per patient after the intervention, representing a 29% decrease (Fig. 3).

Unit-specific pre- and postintervention data demonstrated decreases in utilization from a monthly average of 310 to 177 in the MICU, a 43% decrease (Fig. 4), and from 361 to 253 in the SICU, a 30% decrease (Fig. 4). During this period, no increase in ventilator days or the incidence of unplanned extubations was observed (Fig. 3).

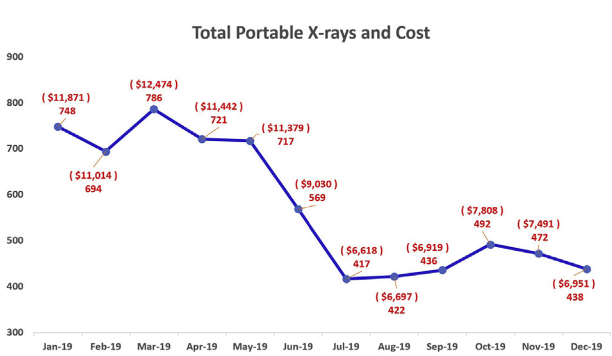

Fig 2. Total outcome measure chart. This chart illustrates the total number of chest radiographic examinations performed in the intensive care units each month with the associated cost before and after the intervention started in June. After the intervention, a sustained decrease in the number of radiographic examinations performed was observed.

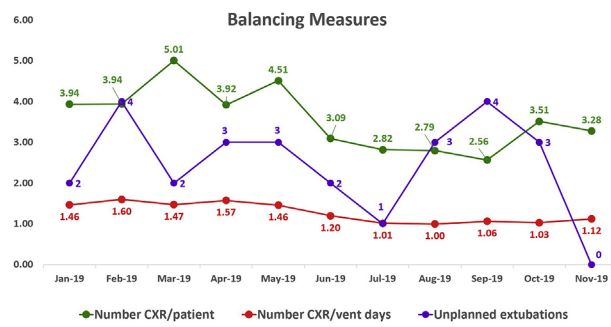

Fig 3. Balancing measure chart: number of chest radiographic examinations (CXR) per ventilator days, number per patient, and unplanned extubations. After the intervention in June, the number of chest radiographic examinations per ventilator day and the number of examinations performed per patient decreased, without an increase in the average number of unplanned extubations.

Furthermore, by using TDABC, we were able to determine the unit cost of performing a single portable chest radiographic examination at our institution as $15.87. Multiplying this by the total number of studies performed monthly gave the total monthly cost. As a direct result of our intervention, the total average monthly cost of portable CXR decreased from $11,633 before the intervention to $7,348 after the intervention, representing a 37% decrease (Fig. 2).

DISCUSSION

The implementation of a restrictive approach to ordering portable CXR in the adult ICUs decreased the utilization of portable CXR by 37%, without an increase in complications or unplanned extubations. To achieve our aim, we launched a Choose Wisely campaign in the ICUs, educated residents and

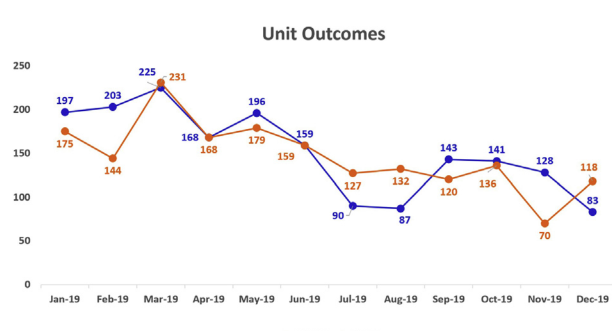

Fig 4. Unit-specific outcome measure chart. The number of chest radiographic examinations performed in the medical intensive care unit (MICU) and surgical intensive care unit (SICU) both decreased after the intervention in June.

attending physicians on the research regarding the utility of daily CXR in the ICU, discontinued the practice of daily standing orders for CXR, and changed the workflow such that CXR was ordered only after clinical determination of necessity.

Additional nonquantified benefits included decreased patient radiation exposure, reduced patient sleep disturbances, and decreased risk for tube dislodgement associated with positioning patients for portable radiography. Although the exposure to patients from a single chest radiographic examination is thought to be of minimal risk, cumulative radiation exposure may become significant because of the high frequency of this test [7]. Sleep disturbance is commonly encountered among ICU patients and has significant psychophysiological effects that protract recovery. Sleep disturbance has been found to promote delirium, a contributor to morbidity and mortality in the ICU [8,9]. A restrictive approach reduces the negative impact caused by sleep disturbance when patients undergo nighttime and early-morning CXR. In addition, bedside CXR is a source of discomfort for patients and carries the risk for accidental removal of devices (catheters, tubes) and microbial dissemination, all resulting in additional costs [10].

Overall, we were able to diminish non-value-added work in the department such that overnight RTs, residents, and attending physicians felt an immediate and positive difference in their work: they were no longer inundated with ICU studies that did not influence patient care. Furthermore, we were able to deploy radiology resources more efficiently and effectively, because the restrictive approach allowed greater access to equipment and staff members for patients most at need, particularly during the period of high demand from the emergency department.

Ultimately, the impressive outcomes of this performance improvement initiative are related directly to the significant success the radiology department had assembling a multidisciplinary team of key stakeholders around a common goal and establishing "buy-in" from the clinicians. The project leader (first author) reached out to colleagues from both the MICU and SICU, who accepted that their practice was not reflective of current recommendations from the ACR and several critical care societies. They also recognized that the changes we proposed were not only appropriate on the basis of current recommendations but could be easily implemented. Although there is literature suggesting that a simple request from SICU and MICU directors has been shown to reduce imaging rates, without further intervention, ordering rates will begin to increase eventually [11]. The team understood that to sustain any improvements, a more comprehensive, systematic approach will be needed.

Project champions were invaluable in achieving the significant reach we realized throughout this effort. Their outreach and education efforts specifically targeted the critical care faculty, a total of 11 attending physicians, and resulted in 100% participation. Without this level of participation, the adoption of the new approach to care in the adult ICUs would have fallen short, and implementation efforts would have failed. It is important to note that the EHR during this period did not allow a change that would have blocked the old ordering practice, so it was imperative to achieve maximum reach and adoption for superior outcomes.

The results of this initiative also demonstrated a positive financial impact to ICU patient management. A similar study published by Keveson et al [12] addressed the financial benefit realized from a restrictive approach to CXR in the ICU. To demonstrate cost savings, they used internally generated estimates of direct and indirect costs as well as those in published literature. This project builds on that by concept by demonstrating another method of determining cost using TDABC, an approach pioneered by Kaplan and Porter [6]. This is meant to be a more accurate accounting of costs. They noted that there is an almost complete lack of understanding of how much it costs to deliver patient care and how it compares with outcomes achieved [6]. Using TDABC can help providers and institutions understand the cost of providing care and can link cost to process improvements and outcomes measures ultimately promoting systemic and sustainable cost reductions [6]. The use of TDABC has been increasing because it is recognized as an essential tool in process improvement and management [13].

As a result of the success of this initiative at KCH, the other 10 acute care hospitals in the enterprise are updating their practice to conform to a restrictive model. By applying the principles of TDABC, we were able to determine that the restrictive model can potentially save the institution about $4,000 a month or $48,000 annually. If the success of this initiative is extrapolated throughout the enterprise, the system can potentially realize savings of about $5 million over the next 10 years. Given the challenges of delivering care in the setting of a safety net organization, this represents a significant amount of savings.

The success of this project also represents an opportunity for our department to examine the utility of CXR in other clinical scenarios to determine if the institution's practices align with evidence-based medicine, including routine preadmission or preoperative "clearance" CXR. Applying TDABC to these scenarios can be a powerful tool to link process improvement and improved utilization to cost savings for the institution.

Limitations

The availability of data made it challenging to analyze and report to the stakeholders and team in a timely manner. Data were reported every 4 to 6 weeks, potentially adversely affecting our level of engagement and our ability to continuously engage the team to push beyond "quick wins" into sustainability. Furthermore, toward the end of this project, the hospital migrated to a new EHR, which disrupted the project's flow and the availability of data.

Another limitation of this study is that data were not collected that delineated the impact of the education campaign and workflow change separately. For example, the exact number of e-mail reminders sent, opened, and read and the exact number of times residents received education on the new approach were not documented. As a result, it is difficult to independently evaluate how much each intervention contributed to the outcomes we observed.

Although we maintained our improvement throughout the length of this project, there is a significant threat of losing these gains in the long term. The education campaign spearheaded by the medical and surgical directors on our team (project champions), though a weak intervention, was extremely successful and resulted in 100% faculty participation. The workflow change they successfully implemented was the stronger intervention and gained significant penetration. However, maintaining fidelity to both interventions (education and workflow change) required a labor-intensive, iterative approach that may not be easily sustainable over a longer period of time or during periods of crisis. For example, KCH has been significantly affected by coronavirus disease 2019 (COVID-19) and saw several nonfaculty, non–critical care physicians and even Navy personnel deployed to the critical care units to aid in the response. In addition, some units, like the postanesthesia care unit and medical floors, were converted to makeshift critical care units to accommodate an overwhelming demand for critical care resources. Although the impact of COVID-19 on this initiative is yet to be fully determined, it is a safe assumption that there was no time to thoroughly orient and educate these new teams on all the ICU practices, and as a result some physicians may have ordered unwarranted daily CXR. In addition to the already established benefits, this restricted approach would have been the best approach during this crisis to decrease virus transmission to other patients, medical staff members, and RTs. This example affirms that the strongest intervention that would allow better sustainability in the long term would be a change in the EHR that prevents standing orders for daily CXR.

TAKE-HOME POINTS

- Institutions can safely discontinue the practice of daily ICU CXR, in keeping with already established evidence-based guidelines.
- Weak interventions (education) should be coupled with stronger interventions (workflow and process changes and hard stops) for the best outcomes and sustainability.
- Tools such as TDABC can be used to determine cost as an outcome measure, gauge the utility of improvement initiatives, alter workflow, and communicate the value proposition to stakeholders.
- A multidisciplinary, team-based approach to performance improvement is imperative for superior outcomes in radiology.
- The value radiology departments bring to institutions should extend beyond image interpretation. Both radiology leadership and frontline staff members should take a central role in implementing already established, evidence-based practices in imaging.

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REFERENCES

1. Clec'h C, Simon P, Hamdi A, et al. Are daily routine chest radiographs useful in critically ill, mechanically ventilated patients? A randomized study. Intensive Care Med 2008;34:264-70.
2. Oba Y, Zaza T. Abandoning daily routine chest radiography in the intensive care unit: meta-analysis. Radiology 2010;255:386-95.
3. Gershengorn HB, Wunsch H, Scales DC, Rubenfeld GD. Trends in use of daily chest radiographs among US adults receiving mechanical ventilation. JAMA Netw Open 2018;1:e181119.
4. Pourmand A, Pyle M, Yamane D, Sumon K, Frasure SE. The utility of point-of-care ultrasound in the assessment of volume status in acute and critically ill patients. World J Emerg Med 2019;10:232-8.
5. Morris AC. Management of pneumonia in intensive care. J Emerg Crit Care Med 2018;2:101.
6. Kaplan RS, Porter ME. How to solve the cost crisis in health care. Harv Bus Rev 2011;89:46-61.
7. Ganapathy A, Adhikari NK, Spiegelman J, Scales DC. Routine chest x-rays in intensive care units: a systematic review and meta-analysis. Crit Care 2012;16:R68.
8. Delaney LJ, Van Haren F, Lopez V. Sleeping on a problem: the impact of sleep disturbance on intensive care patients—a clinical review. Ann Intensive Care 2015;5:3.
9. Girard TD, Pandharipande PP, Ely EW. Delirium in the intensive care unit. Crit Care 2008;12(suppl 3):S3.
10. Ioos V, Galbois A, Chalumeau-Lemoine L, Guidet B, Maury E, Hejblum G. An integrated approach for prescribing fewer chest x-rays in the ICU. Ann Intensive Care 2011;1:4.
11. Tonna JE, Kawamoto K, Presson AP, et al. Single intervention for a reduction in portable chest radiography (pCXR) in cardiovascular and surgical/trauma ICUs and associated outcomes. J Crit Care 2018;44:18-23.
12. Keveson B, Clouser RD, Hamlin MP, et al. Adding value to daily chest X-rays in the ICU through education, restricted daily orders and indication-based prompting. BMJ Open Qual 2017;6:e000072.
13. Shankar PR, Hayatghaibi SE, Anzai Y. Time-driven activity-based costing in radiology: an overview. J Am Coll Radiol 2020;17:125-30.