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Using incentives to improve resource utilization: a quasi-experimental evaluation of an ICU quality improvement program

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Abstract

Objective—Healthcare systems strive to provide quality care at lower cost. Arterial blood gas testing (ABGs), chest radiographs (CXR), and red blood cell transfusions (RBCs) provide an important example of opportunities to reduce excess resource utilization within the ICU. We describe the effect of a multifaceted quality improvement program designed to decrease avoidable ABGs, CXRs, and RBCs utilization on utilization of these resources and patient outcomes.

Design—Prospective pre-post cohort study

Setting—Seven ICUs in an academic healthcare system

Patients—All adult ICU patients admitted to study ICUs during consecutive baseline (n=7,357), intervention (n=7,553), and follow up (n=7,657) years between September 2010 and August 2013.

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Interventions—A multifaceted quality improvement program including provider education, audit and feedback, and unit-based provider financial incentives targeting ABG, CXR, and RBC utilization.

Measurements and Main Results—The primary outcome was the number of orders for ABGs, CXRs, and RBCs per patient. Compared to the baseline period, unadjusted ABG, CXR, and RBC utilization in the intervention period was reduced by 42%, 26%, and 17%, respectively ($p<0.01$). After adjusting for potentially relevant patient factors, the intervention was associated with 128 fewer ABGs, 73 fewer CXRs, and 16 fewer RBCs per 100 patients ($p<0.01$). This effect was durable during the follow up year. This reduction yielded an approximate net savings of \$1.5 M in direct costs over the intervention and follow-up years after accounting for the direct costs of the program. Unadjusted hospital mortality decreased from 7% in the baseline period to 5.2% in the intervention period ($p<0.01$). This reduction remained significant after adjusting for patient factors (OR= 0.43, $P<0.01$).

Conclusions—Implementation of a multifaceted quality improvement program including financial incentives was associated with significant improvements in resource utilization. Our findings provide evidence supporting the safety, effectiveness, and sustainability of incentive-based quality improvement interventions.

Keywords

Quality of Health Care; Outcome and Process Assessment; Evidence-based Practice; Intensive Care Unit; Organizational Efficiency; Physician Incentive Plans

INTRODUCTION

Critical care services account for nearly 1% of the US gross domestic product and over 13% of hospital costs.¹ While progress has been made,² critical care continues to be challenged by high rates of adverse events and inconsistent adherence to evidence based practices.^{3–5} Innovative approaches are sorely needed to improve adherence to best practices, improve patient outcomes, and decrease health care costs in intensive care units (ICUs).

Translating research evidence into standard clinical practice is commonly a slow and challenging process,⁶ in part because many behaviors are deeply ingrained by the environment in which they are practiced and learned.⁷ Given this complexity, changes on both individual and organizational levels are needed to align practice patterns with research evidence. Thus, identifying effective strategies to realize organizational change has become a major focus in quality improvement.⁸

The burden of unnecessary diagnostic tests and therapies represent a potential quality improvement area in critical care.⁹ Chest radiographs (CXRs), arterial blood gas tests (ABGs), and red blood cell transfusions (RBCs) represent important examples to reduce excess utilization in the ICU, as evidence supports more conservative utilization.^{10–13}

In our hospital system, we observed relatively high and potentially avoidable utilization of these diagnostic tests and therapeutic interventions. Thus, we developed a multifaceted quality improvement intervention including provider education, audit and feedback, and

pay-for-performance incentives to improve adherence to best practices related to ABG, CXR, and RBC use. We report the results of a prospective before and after study evaluating the effect of this intervention on targeted resource utilization and patient outcomes.

MATERIALS AND METHODS

Study Design

We conducted a quasi-experimental cohort study using a before-after study with prolonged follow up period analyses to evaluate the effectiveness and sustainability of the multifaceted intervention.

Setting and Study Population

The study was conducted in 7 ICUs within the Emory Critical Care Center (ECCC) for three consecutive 12-month periods (i.e. baseline, intervention, follow-up) from September 2010 – August 2013. Representing 123 ICU beds, these units include two cardiothoracic, two neuroscience, two medical, and one surgical ICU at two university hospitals. Throughout the study, ECCC units were staffed following a high intensity staffing model with intensivists, advanced practice providers (i.e. nurse practitioners, physician assistants), and physicians in training.¹⁴ Additional organizational attributes including ICU leadership, ordering systems, and availability of intermediate care units did not change substantially between study periods.

Hospital admissions were the unit of analysis. We only observed records during the first ICU stay within a hospitalization since only a small proportion of this study's patients had more than one ICU stay and previous research has suggested that patients readmitted to an ICU have much higher severity of illness and are potentially less responsive to standard care.¹⁵

Intervention

The intervention included group-based financial incentives for attending physicians and advanced practice providers (APPs) supported by provider education and an audit and feedback mechanism. Provider education began at the start of the intervention period and was driven by ICU leaders. We disseminated relevant evidence and presented best practices for ordering ABGs, CXRs, and RBCs with the medical director and lead APP from each ICU.^{10–13} These ICU leaders shared this information with other providers electronically and during staff meetings. The audit and feedback mechanism entailed ICUs receiving monthly reports presenting their individual unit-level change in utilization and relative to other ICUs. These reports included information on the targeted resources during the intervention period.

The group-based financial incentive was offered to prescribing providers (i.e. physicians and APP). Establishing the incentive targets relied on input from ICU leaders, who communicated goals balancing meaningful reductions with feasibility.¹⁶ The resulting target for ABGs and RBCs was a 20% reduction in the mean number of orders per patient-day from the previous year. For CXR orders, the goal was a 10% reduction. Each ICU was observed and awarded as a whole based on the unit's performance during the intervention

period rather than on individual provider performance. The all-or-nothing incentives were identical for all targets, paying \$2,500 per full time equivalent (FTE) per 6 months for APPs and \$300 per covered week for physicians.

Variables

The primary outcome variables were the number of ABGs, number of CXRs, and number of RBC units ordered per ICU admission. Hospital and ICU mortality were observed as secondary outcome variables. The primary independent variable was an indicator for the study period in which a patient was admitted to the ICU. We included other potentially relevant covariates including patient demographics (age, sex, race), severity of illness (i.e. Charlson Comorbidity Index [CCI] score and Sequential Organ Failure Assessment [SOFA] score at ICU admission), and ICU length of stay.^{17–20}

Statistical Analysis

Data were extracted from electronic medical records for all patients admitted to the study ICUs during the 3-year study period. Unadjusted comparisons of descriptive characteristics and outcomes between the study periods were calculated using two-tailed t-tests and proportions tests. Two-part, multivariable regression models were constructed to provide adjusted estimates of the intervention effect independent of age, sex, race, CCI, SOFA, and first ICU length of stay.

We used a two-part model with logistic regression in Part 1 of the model and a negative binomial regression with a log link in Part 2. This model was chosen given the skewed distributions and a preponderance of observations with no utilization.^{21,22} The model facilitates two levels of inference: the probability of a patient receiving any orders, and the number of orders (i.e. volume) among those patients with at least one order. As a result, the two-part structure offers additional insight into two steps of the ordering decision process. First, providers identify patients for which a resource is ordered, then providers then decide how frequently or how much of the resource to use. Combined estimates, calculated using both parts, predict overall effects on utilization.

For ease of interpretation, we report marginal effect estimates for the average patient. Model-adjusted mean utilization (i.e. expected utilization for the average patient) was also estimated to provide reference points for effect size calculations. These model-adjusted mean utilization rates in each period were calculated using the baseline period predicted mean and incorporating the marginal effect estimates for the subsequent periods.

Adjusted estimates of the independent intervention effect on ICU and hospital mortality were calculated using logistic regression. We estimated the direct financial impact by multiplying unit costs to utilization rates and model effect estimates. Based upon local data, ABG, CXR, and RBC direct hospital unit costs were \$14, \$105, and \$213, respectively.

Data cleaning and statistical analysis were conducted using Stata SE 13 (StataCorp, College Station, TX). Effects with a probability <0.05 were considered statistically significant. This study was approved by the Emory Internal Review Board.

RESULTS

Patient Characteristics

A total of 22,567 patients were admitted to the study ICUs during the study (Table 1). Patient demographic characteristics and chronic comorbidities were similar throughout the study. Acute severity of illness increased over the three years with the mean (SD) ICU admission SOFA score rising from 3.7 (3.1) at baseline to 5.3 (3.7) during the intervention period and again to 5.7 (3.6) during the follow-up period ($p<0.01$ for all comparisons).

Unadjusted Utilization

The mean (SD) ABG, CXR, and RBC utilization during the baseline period was 3.9 (9.3), 3.5 (6.9), and 0.6 (1.2) orders per ICU admission, respectively (Table 2). Compared to the baseline period, the intervention period was associated with a 42% decrease in ABGs (95% Confidence Interval [CI]: -45 to -38%), a 26% decrease in CXRs (95% CI: -29 to -22%), and a 17% decrease in RBCs (95% CI: -22 to -12%). The follow-up period revealed a continued 42% decrease in unadjusted ABG orders (95% CI: -48 to -35%), a 32% decrease in CXR orders per admission (95% CI: -37 to -27%), and a 9% decrease in RBC units (95% CI: -17 to -0.3%) relative to the baseline.

Adjusted Utilization

Adjusting for potentially relevant patient factors, the intervention was independently associated with 1.28 fewer ABG (59% reduction), 0.73 fewer CXR (35% reduction), and 0.16 fewer RBC (37% reduction) orders per admission relative to the baseline period ($p<0.01$ for all comparisons; Table 3). Furthermore, adjusted analyses revealed sustained intervention effects into the follow-up period on overall ABG, CXR, and RBC use (Figure 1). Compared to the baseline period, the post-intervention effect in the follow-up period continued to reduce utilization of ABGs, CXRs, and RBCs by 66% ($p<0.01$), 47% ($p<0.01$) and 50% ($p<0.01$), respectively.

Utilization patterns, as observed in our two-step ordering decision framework, differed between resources. For both ABGs and CXRs, the probability of any orders and the number of orders per patient with any orders significantly decreased to similar degrees (Table 3). For example, the average patient in the intervention period had 0.22 lower probability of receiving any ABGs, a 34% relative decrease ($p<0.01$). Similarly, the average patient among those with any ABGs received 1.88 fewer orders per admission, a 38% relative decrease ($p<0.01$).

In contrast, reductions in the probability of RBC transfusions were much larger than reductions in the number of transfused RBC units in patients receiving any transfusion. Specifically, the average intervention period patient had 0.10 lower probability of receiving any RBCs, a 33% relative decrease ($p<0.01$). However, among those patients who received at least one RBC, the average patient received only 0.07 fewer units, a 4% relative decrease ($p=0.02$). These patterns diverged further in the follow-up period when the probability of getting transfused decreased by 65% ($p<0.01$) and the number of units transfused per transfused patient increased by 49% ($p<0.01$) relative to baseline.

Figure 1 illustrates the three dimensions of unadjusted and adjusted utilization for each target resource across the three-year study period: the overall mean number of orders per ICU admission, the probability of receiving any orders during the ICU admission, and the mean number of orders per admission among those patients with at least 1 order. Model-adjusted utilization trends resembled unadjusted trends for the majority of measured dimensions for ABGs and CXRs, demonstrating a significant reduction in the intervention period that was sustained or further decreased into the follow-up period. RBC utilization in the follow-up period differed from this pattern with the divergence of adjusted and unadjusted overall utilization, the continued decrease in the probability of any transfusion, and an increase in utilization among patients with at least one order.

Direct Economic Effect of Intervention

Given observed reductions in all three resources, we estimate total gross direct cost savings of \$1,942,735 over the intervention and follow-up years directly attributable to reduced utilization of ABGs, CXRs, and RBCs. Accounting for \$398,640 paid out for provider incentives, we estimate net cost savings of \$1,544,095 over the intervention and follow-up periods, averaging approximately \$772,048 in net savings per year. However, this net savings estimate does not account for the timing of the incentive payout, made as a lump sum payment at the end of the intervention period, or other unobserved costs related to the intervention.

Patient Outcomes

Baseline unadjusted ICU and hospital mortality rates were 6.3% and 7.0%, respectively (Table 2). The intervention period observed a statistically significant decrease in both ICU and hospital mortality rates to 4.6% ($p<0.01$) and 5.2% ($p<0.01$), respectively. During the follow-up period, ICU mortality (5.1%) and hospital mortality (5.5%) remained below the baseline period ($p<0.001$). Adjusted estimates demonstrated the intervention period to be independently associated with lower ICU mortality (odds ratio=0.41; 95% Confidence Interval: 0.35 – 0.48; $p<0.01$) and hospital mortality (odds ratio=0.43; 95% Confidence Interval: 0.37 – 0.51; $p<0.01$), which were sustained through the follow-up period (Table 4). No relevant adverse events were reported to the internal patient safety event system or ICU leadership during the study.

DISCUSSION

Interventions to improve resource utilization are essential as variable costs (e.g. laboratory tests, pharmaceuticals, blood products) are important contributors to rising healthcare costs.^{23–25} ABGs, CXRs, and RBCs are commonly utilized resources across multiple ICUs with evidence that utilization can be safely reduced. We present a multifaceted quality improvement intervention built around financial incentives that significantly reduced utilization rates of these resources across seven ICUs. The intervention achieved significantly lower utilization of all three target resources during the intervention period and a one-year follow-up period. We estimate that this reduction yielded approximately \$1.5M in direct net cost savings over 2 years and was associated with an improvement in ICU and hospital mortality. Our findings provide further evidence related to the safety, effectiveness,

and sustainability of incentive-based quality improvement interventions as well as insights into how incentive-based interventions affect providers' decision-making processes.

Financial incentives have been a contentious strategy for improving clinical practice in medicine.²⁶ This debate has escalated in recent years in response to greater attention to rising health care costs and health policy reform.^{27–30} The incentive included several design features to avoid provider conflicts of interest.^{31,32} First, we based the incentive on established evidence-based best practices. Second, the size of the incentive was designed to capture attention, but not unduly influence. Third, unit-level incentives encouraged providers to examine their overall practice rather than their decisions on the individual patient level. Finally, the audit and feedback served to both improve the understanding of providers regarding their actual clinical practice and to facilitate monitoring of unit-level patient outcomes.

Our findings are consistent with prior research suggesting that financial incentive-based interventions tend to see greater success if targets are clearly defined with room to improve and interventions are developed with provider collaboration.³³ Additionally, interventions that have seen the most success tend to target discrete health care processes^{34–38} whereas interventions targeting more complex problem solving behaviors or broad patient outcomes have reported much more modest effects.^{39–41} These trends are not surprising. Providers tend to have greater control over health care processes than they do over patient outcomes, which can be influenced by a variety of uncontrollable factors.⁴²

While we observed a sustained effect of our intervention on resource utilization during our one-year follow-up period, the sustainability of quality improvement interventions, particularly those involving incentives is a common concern.⁴³ For example, improvements in ambulatory hypertension management care reported by Petersen and colleagues were not sustained during a 12 month follow up period, yet Pronovost and colleagues reported sustained improvement in CLABSI rates 18 months after completion of a formal quality improvement intervention.^{44,45} The mechanisms underlying this varied sustainability are unclear but likely relate to changing provider and organizational normative behaviors.⁴⁶

Individuals are often limited in their capacity to weigh the full costs and benefits of every care decision, instead defaulting to traditional patterns of care established by the local provider community.^{7,47,48} An intervention's ability to affect local provider culture and practice patterns can subsequently influence the sustainability of resulting changes. By linking incentives to unit-level performance may have helped shift ICU culture and clinician behavior towards an increased awareness of resource utilization and overall ICU performance.⁴⁶ As such, the improved mortality observed in our study over time may be related more to changes in ICU team functioning than specific changes in ABG, CXR, and RBC orders. Future research is necessary to determine the approaches (e.g. target behavior identification, provider education, work flow re-design, intervention duration) and mechanisms that underlie effective and sustainable organizational change.^{31,49,50}

In addition to demonstrating the effectiveness of incentive-based interventions, our analysis suggests that this strategy changes decision-making on two levels, that is, determining which

patients will receive any orders and subsequently the quantity to be given to those patients. Observing changes within this two-step framework allows for a more detailed evaluation and helps to identify potential processes to target in future quality improvement efforts. For example, reductions in both the likelihood of any utilization and the quantity of utilization for ABGs and CXRs suggests that providers re-evaluated practice norms for which patients required these tests in initial ICU assessments as well as for which patients required repeat testing. Furthermore, the reduction in the likelihood of any RBC transfusion but increase in number of RBC orders among those transfused may reflect that providers were less likely to transfuse patients with mild anemia, which unmasked transfusions for patients with more severe anemia requiring multiple RBC units. While additional work remains, this analysis provides a multidimensional perspective of the complex effect that quality improvement interventions may have on provider and organization behavioral norms.

This study has several considerable strengths. Few pay-for-performance studies have reported on financial incentives targeting resource utilization in the inpatient setting, at the unit level, and with explicitly defined rewards for individual providers.^{33,51} The resources targeted in this study are also commonly used across different types of ICUs. Additionally, the study design enabled us to evaluate the cost effectiveness of the intervention.⁵¹ Finally, this study evaluated the sustainability of the intervention over a one-year follow-up period, which is similar or longer than post-intervention observations in many other multifaceted critical care studies.^{34–36,40,52,53}

The study has potential limitations. First, there is a risk of non-equivalence of intervention and comparison groups, particularly with external changes over time in the fast-paced, complex hospital environment. Due to practical restrictions, we could not create a separate, equivalent cohort of unexposed ICU patients during the intervention period. Nevertheless, the design accounted for numerous potential confounding factors with a baseline group and regression model analysis.

Second, our study did not evaluate the marginal contribution of the financial incentive relative to other intervention components. Identifying the individual and interactive effects of multifaceted interventions is a common challenge as non-financial components (i.e. provider education, audit and feedback mechanisms) are often an inherent part of operationalizing financial incentive programs.⁴² Still, evaluating the relative effects of each intervention component has meaningful implications for those implementing similar programs.⁸ Future studies may attempt to capture these differences by including qualitative data from post-intervention questionnaires or sequentially implementing intervention components to evaluate the marginal contribution of each element.

Third, we were not able to evaluate changes at the individual provider level. Due to the multidisciplinary nature of critical care and the close collaboration between physicians and advanced practice providers in patient care, attributing distinct clinical decisions and changes in patient condition to specific clinicians can be challenging. Our study observes these effects at the unit level, which is the intervention level. Future studies may seek to characterize the effect of unit level interventions on variations in practice between providers within a unit.

Fourth, causality cannot be established between the intervention and observed mortality rate reductions as mortality encompasses the full spectrum of care received throughout the ICU and hospital stay, including unobserved factors not measured in this study. The goal was to evaluate the effectiveness of a financial incentive-based intervention on reducing resource use without adversely affecting mortality. The presence of significant improvements in mortality over the study may relate to changes in specific resource utilization, other indirect intervention effects, or unmeasured changes in ICU care unrelated to the intervention. Further studies should evaluate the effects of interventions targeting resource utilization on mortality and other patient outcomes.

Finally, this study was conducted in an academic health system with a unified critical care center, which may limit the generalizability of the study to other organizational models. Still, our findings offer valuable insight on strategies to align provider behaviors with evidence-based practices and highlight an important area to improve healthcare value. Future studies will need to examine whether strategies implemented in our intervention can be applied with similar success in other environments and clinical settings.

CONCLUSIONS

Healthcare is driving towards the triple aim of better health, better care, and lower cost. Our study builds upon existing evidence that multifaceted quality improvement interventions can improve the translation of research evidence into routine clinical practice, and supports the role of financial incentives in these efforts. Implementing similar programs may improve adherence to evidence based practices, resource utilization and patient outcomes in other health care systems.

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Figure 1.

Table 1

Patient characteristics of seven study ICUs during baseline, intervention, and follow-up years

Characteristic	Baseline (n=7,357)	Intervention (n=7,553)	Follow-up (n=7,657)
First ICU, n (%) [†]			
Cardiothoracic ICU 1	953 (13.0)	990 (13.1)	966 (12.6)
Cardiothoracic ICU 2	1,052 (14.3)	898 (11.9)	992 (13.0)
Neurologic ICU 1	1,328 (18.1)	1,327 (17.6)	1,345 (17.6)
Neurologic ICU 2	688 (9.4)	835 (11.1)	777 (10.2)
Medical ICU 1	941 (12.8)	950 (12.6)	988 (12.9)
Medical ICU 2	1,311 (17.8)	1,469 (19.5)	1,448 (18.9)
Surgical ICU	1,084 (14.7)	1,084 (14.4)	1,141 (14.9)
Demographics			
Age, mean (SD)	59.4 (16.5)	59.1 (16.5)	59.1 (16.5)
Male (vs. Female), n (%)	3,754 (51.0)	3,917 (51.9)	3,935 (51.4)
White (vs. non-White), n (%)	3,916 (53.2)	3,929 (52.0)	4,001 (52.3)
Severity of illness			
Charlson Comorbidity Index score, mean (SD)	3.1 (2.5)	3.1 (2.5)	3.1 (2.5)
SOFA on ICU admission, mean (SD)	3.7 (3.1) ^{†§}	5.3 (3.7) ^{†‡}	5.7 (3.6) ^{‡§}
ICU length of stay, mean (SD)	4.0 (6.0)	3.9 (5.6)	4.0 (5.5)

[†] p<0.05 between baseline and intervention year[‡] p<0.05 between intervention and follow up year[§] p<0.05 between baseline and follow up year

Table 2

Comparison of mean utilization per encounter and mortality across three study periods for seven intervention ICUs

	Baseline (n=7,357)	Intervention (n=7,553)	Follow-up (n=7,657)
Orders per encounter, mean (SD)			
Arterial Blood Gas Test (ABG)	3.9 (9.3) ^{†§}	2.3 (6.1) [†]	2.3 (5.8) [§]
Chest X-Ray (CXR)	3.5 (6.9) ^{†§}	2.6 (5.2) ^{†‡}	2.4 (4.8) ^{‡§}
Red Blood Cell Unit (RBC)	0.6 (1.2) ^{†§}	0.5 (1.2) ^{†‡}	0.5 (1.7) ^{‡§}
Mortality Rate, n (%)			
ICU	466 (6.3) ^{†§}	348 (4.6) [†]	393 (5.1) [§]
Hospital	517 (7.0) ^{†§}	395 (5.2) [†]	418 (5.5) [§]

[†] p<0.05 between baseline and intervention year

[‡] p<0.05 between intervention and follow up year

[§] p<0.05 between baseline and follow up year

Table 3

Comparison of adjusted intervention effect on utilization during and after the intervention period, using pre-post analysis^{*}

	Intervention vs. Baseline		Follow-up vs. Baseline	
	Marginal Change (% relative effect ^I)	p-value	Marginal Change (% relative effect ^I)	p-value
Arterial Blood Gas orders overall	-1.28 (-59)	<0.01	-1.44 (-66)	<0.01
Probability of any order	-0.22 (-34)	<0.01	-0.25 (-38)	<0.01
Number of orders if any order	-1.88 (-38)	<0.01	-2.06 (-41)	<0.01
Chest X-Ray orders overall	-0.73 (-35)	<0.01	-0.97 (-47)	<0.01
Probability of any orders	-0.14 (-19)	<0.01	-0.18 (-24)	<0.01
Number of orders given any use	-0.79 (-20)	<0.01	-1.09 (-28)	<0.01
Red Blood Cell orders overall	-0.16 (-37)	<0.01	-0.22 (-50)	<0.01
Probability of any units	-0.10 (-33)	<0.01	-0.20 (-65)	<0.01
Number of units given any use	-0.07 (-4)	0.02	0.84 (49)	<0.01

* Adjusted for CCI score, SOFA score at ICU admission, age, race, sex, and ICU length of stay

^I Compared to predicted baseline period mean

Table 4

Comparison of adjusted intervention effect on ICU and hospital mortality during and after the intervention period, using pre-post analysis*

	Intervention vs. Baseline		Follow-up vs. Baseline	
	Odds Ratio (95% CI)	p-value	Odds Ratio (95% CI)	p-value
ICU mortality	0.41 (0.35 – 0.48)	<0.01	0.44 (0.37 – 0.51)	<0.01
Hospital mortality	0.43 (0.37 – 0.51)	<0.01	0.42 (0.36 – 0.49)	<0.01

* Adjusted for CCI score, SOFA score at ICU admission, age, race, sex, and ICU length of stay