

## A quality improvement project to reduce overutilization of blood tests in a teaching hospital

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### ABSTRACT

**Objective:** In hospitals, physicians-in-training are major contributors to the burden of tests ordered, increasing cost and resource utilization. We implemented an intervention to discourage overutilization of the complete blood count (CBC) and the basic metabolic panel (BMP).

**Methods:** An intervention was designed, comprising education on high-value care and burden of over-testing, encouragement of competition, and use of positive reinforcement. The intervention was monitored by a test index determined by dividing the total number of a specific laboratory test ordered for a patient by the total number of hospital days.

**Results:** Following a 6-month intervention, the mean CBC index decreased from  $1.56 \pm 0.02$  to  $1.45 \pm 0.03$  ( $p < 0.001$ ), and the BMP index, from  $1.35 \pm 0.02$  to  $1.14 \pm 0.03$  ( $p < 0.001$ ). There was significant interaction between the intervention and the slope of the BMP index trend ( $p = 0.03$ ), but not the CBC index trend. The intervention had no impact on hospital length of stay and mortality.

**Conclusion:** This quality improvement intervention is an effective approach to reducing overutilization of laboratory tests.

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### KEYWORDS

Laboratory investigations; quality improvement; health quality; patient care

## 1. Introduction

In the current era of value-based care, healthcare organizations are under increasing pressure to reduce costs while maintaining quality. Unnecessary tests are often targeted to control healthcare expenditures, yet their use continues to rise, contributing to higher costs and resource utilization, iatrogenic complications, patient discomfort, and the reflexive performance of additional tests and invasive procedures. Physicians-in-training are important contributors to the burden of tests ordered, and it is acknowledged that this stems from a variety of factors, including a focus on reaching a definitive diagnosis regardless of care value, the practice of defensive medicine, which deviates from recommended medical practice to protect from litigations, and ignorance of the financial costs associated with testing [1]. As such, an effective intervention to address the problem at any teaching institution must include the physician-in-training at its core. Previous interventions that included the display of informative flyers and alterations to electronic health record ordering platforms were deemed to be effective [2].

In this quality improvement report, we measured the extent of overutilization of laboratory tests in adult patients hospitalized on the general medicine service at

a community-based teaching hospital and implemented a simple intervention that involved medical resident education and raising level of awareness, and positive reinforcement for improvements in utilization behavior, which resulted in a decrease in unnecessary employment of laboratory testing.

## 2. Methods

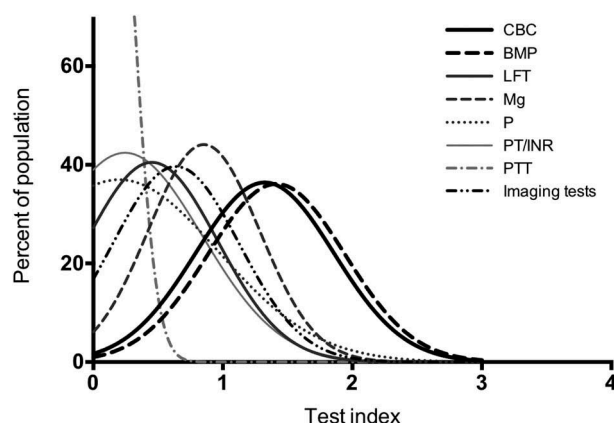
### 2.1. Identifying overutilized tests

The quality improvement project was initiated in November of 2016. The initial phase consisted of collecting a sample of laboratory tests ordered on patients hospitalized under the general medicine service over a one-month period at a teaching hospital (St. Elizabeth's Medical Center, Boston, MA). De-identified data collected were the hospital length of stay, the number of laboratory tests ordered, including complete blood count (CBC), basic metabolic panel (BMP), liver function tests (LFT), serum magnesium (Mg), serum phosphorus (P), prothrombin time (PT)/international normalized ratio (INR), and partial thromboplastin time (PTT); as well as the number of imaging tests, including radiographs, computed tomography scans, magnetic resonance imaging scans, and

ultrasonograms. Using a previously published method [2], we created a 'test index', which was determined by dividing the total number of a specific test obtained during the course of a hospitalization for a given patient by the length of hospital stay measured in days. The results of the test indices were interpreted on a regression frequency curve, assuming a normal distribution. As shown in Figure 1, the most frequently ordered daily tests were the CBC and BMP, based on the highest index values. As a result, these two laboratory tests were selected and targeted for our intervention.

## 2.2. Quality improvement plan and intervention

The second phase involved the planning and implementation of an intervention to discourage unnecessary over-utilization and promote conscientious usage of the two routine laboratory tests (CBC and BMP) via a multifaceted approach (Figure 2). The approach entailed education of medical residents through the distribution of flyers that outlined the inappropriate clinical indications for the use of specific laboratory tests and some general information regarding the costs and financial burden of over-testing on patients and the healthcare system. CBC testing was discouraged if the hemoglobin, white blood cell count, and platelet count were stable within 24 hours of the previous test and if there was no suspicion for bleeding or infection. BMP testing was discouraged if the serum creatinine was at baseline for the previous 24 hours, if there were no diuretic or nephrotoxic medications being used, and if there was low clinical suspicion for acute kidney injury (Supplemental Figure 1). Both tests were discouraged if



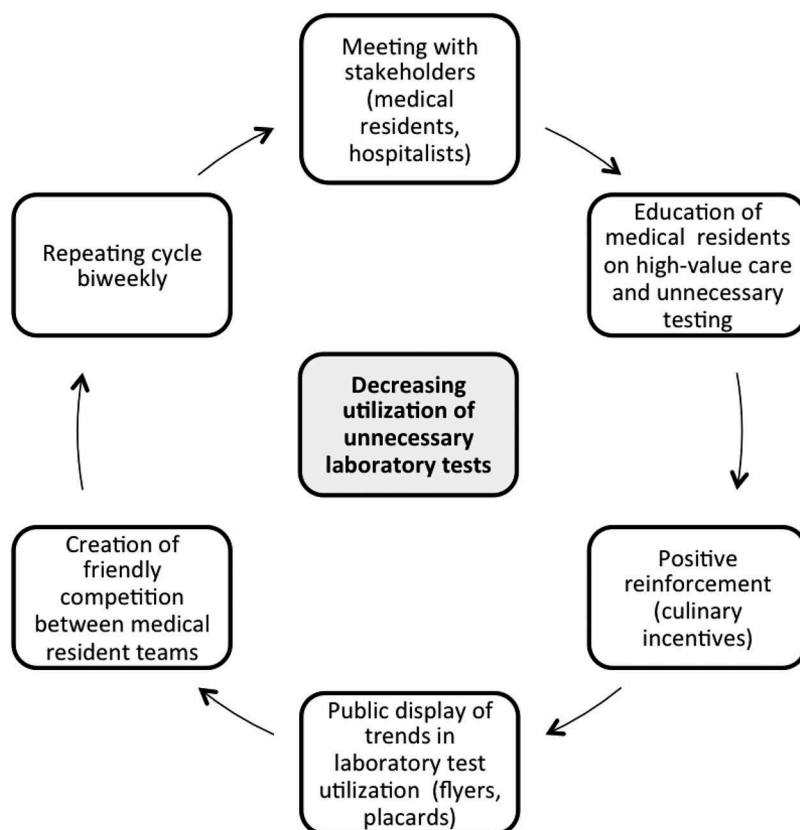
**Figure 1.** Frequency of commonly ordered tests among hospitalized patients on a general medical service. Each 'test index' was determined by dividing the number of a specific test obtained over the course of a hospitalization for a given patient divided by that patient's length of stay in total number of hospital days. CBC, complete blood count; BMP, basic metabolic panel; LFT, liver function tests; Mg, serum magnesium; P, serum phosphorus; PT/INR, prothrombin time/international normalized ratio; PTT, partial thromboplastin time.

the patient was awaiting hospital discharge to a short- or long-term care facility or if the results were not expected to change treatment plan. We targeted two general medicine teams that cared for randomly assigned hospitalized patients. Each team comprised two interns, one resident, and a hospitalist attending physician. Following the intervention, we prospectively monitored and compared the CBC and BMP indices among patients hospitalized on these two general medicine services.

We encouraged a friendly competition between the two medicine teams by measuring their specific test indices for a period of two weeks, during which time team membership and composition remained constant. The medical residents then received pocket cards that displayed the trends of the CBC and BMP indices for both teams, and an internal medicine residency program-wide email was then sent announcing which team 'won' as defined by a trend of less test utilization (Supplemental Figure 1). We incentivized the medical residents by rewarding donuts to the medical resident team that achieved the most optimal average CBC and BMP indices over the course of the previous two-week period.

The results included all CBC and BMP indices of patients discharged from the teaching medical service in the hospital between November 2016 and November 2017. Values obtained during the baseline period were compared using unpaired t-tests. We compared pre- and post-intervention test indices. We conducted interrupted time series analysis to compare the linear trend in values before and after the intervention. In brief, the CBC and BMP indices were fitted through a linear regression analysis with the month as the predictor interacting with the pre- and post-intervention period as a binary variable. Intercepts and slopes of pre- and post-intervention trends were compared. In addition, we compared the average values obtained during the 6-month baseline period and the 6-month intervention period using unpaired t-tests.

To explore the indirect impact of our intervention on outcomes of patients hospitalized on the general medical service, the following hospital-based measures were compared (by the Student's t-test) during the pre- and post-intervention period: hospital length of stay, length of stay index (defined as the observed over expected length of stay), crude hospital mortality rate, and hospital mortality index (defined as the observed over expected mortality rate). The case mix index is a relative value reflecting the diversity, clinical complexity and the needs for resources in hospitalized patients. To account for the complexity of cases, we also compared the case mix index on the general medical service between the two periods. The primary source for this analysis was the hospital discharge data warehouse for the period of November 2016 to November 2017, housed in the electronic health record (MEDITECH, Inc., Westwood, MA).



**Figure 2.** Key elements of the quality improvement program. The program started by meeting with the stakeholders (medical residents and hospitalists) to design the intervention, which entailed continued education, positive reinforcement, incentivization, and creation of a competitive environment to reduce overutilization of laboratory tests among hospitalized patients on medical services. This educational cycle was repeated biweekly with the new rotating medical team.

Continuous variables were described as mean  $\pm$  standard error and frequency plots, and categorical variables, as count and percentage. All analyses were performed using GraphPad Prism version 6.0c for OS X (GraphPad Software, La Jolla, California USA, [www.graphpad.com](http://www.graphpad.com)) and R: A language and environment for statistical computing. (R Foundation for Statistical Computing, Vienna, Austria, <https://www.R-project.org>).

The institutional review board (IRB) determined that this quality improvement project (IRB number QI023) is not considered human subjects research, and therefore does not require IRB approval or oversight.

### 3. Results

#### 3.1. Extent of laboratory tests overutilization during the baseline period

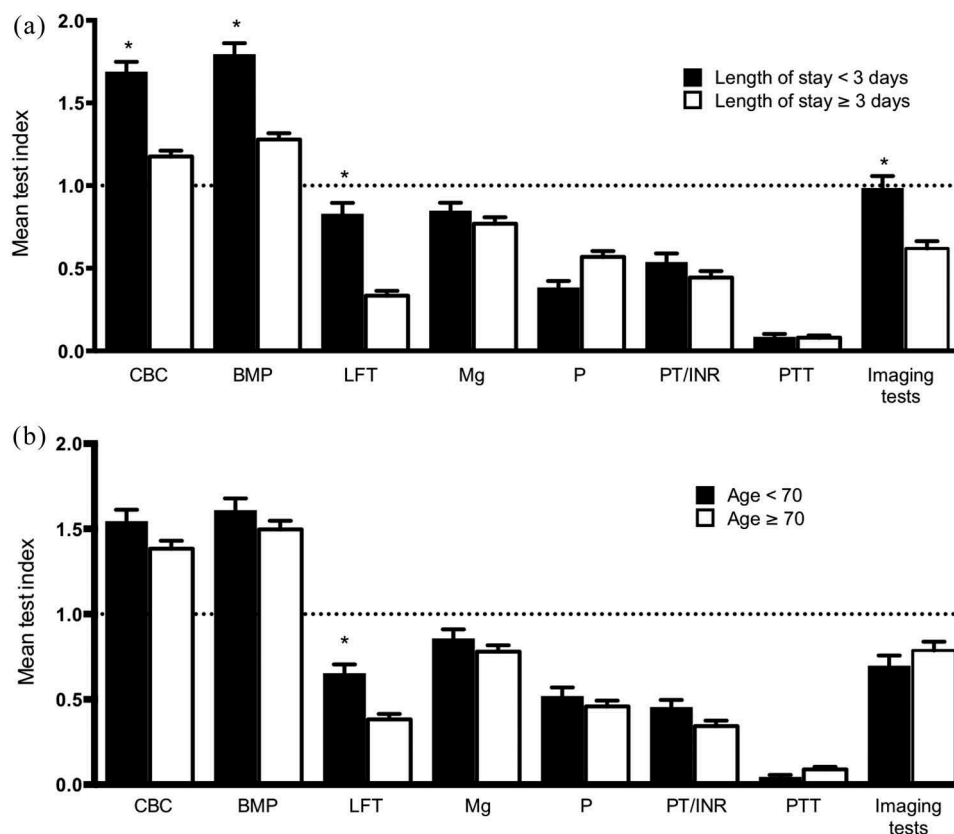
The results of the initial sample obtained during the baseline period were interpreted on a regression frequency curve assuming normal distribution. As shown in Figure 1, over a 1-month period, the highest observed laboratory test indices were the CBC and the BMP indices with a mean value of  $1.41 \pm 0.04$  and  $1.49 \pm 0.05$ , respectively. When stratified according to hospital length of stay ( $<$  vs.  $\geq 3$  days) and age ( $<$  vs.  $\geq 70$  years old, the median

age of the population studied), both the CBC and the BMP indices were significantly lower among patients with prolonged hospitalizations ( $1.72 \pm 0.07$  vs.  $1.17 \pm 0.03$ ,  $p < 0.001$ ; and  $1.85 \pm 0.08$  vs.  $1.29 \pm 0.04$ ,  $p < 0.001$ , respectively; Figure 3(a)). When stratified by age, no differences were observed in the CBC and BMP indices between the two age groups (Figure 3(b)); however, the LFT index was significantly higher among younger patients ( $0.65 \pm 0.05$  vs.  $0.38 \pm 0.03$ ,  $p < 0.001$ ).

#### 3.2. Impact of the intervention on utilization of laboratory tests

We next monitored the trend in the CBC and BMP indices during the intervention period. Figure 4 displays the CBC and BMP indices by month over time. Using interrupted time series analyses, pre- and post-intervention trends showed a decrease in the intercept for both the CBC and BMP indices ( $p < 0.001$ ). However, when we tested for an interaction between the intervention and the slope of the pre- and post-intervention trend in the laboratory test indices, there was a significant interaction between the intervention and the slope of the BMP index trend ( $p = 0.03$ ) but not the CBC index trend ( $p = 0.41$ ).

Comparing the combined baseline 6-month period to the combined post-intervention 6-month period,



**Figure 3.** Laboratory and imaging test indices stratified according to hospital length of stay (3A) and age (3B). \*  $P = 0.001$ . CBC, complete blood count; BMP, basic metabolic panel; LFT, liver function tests; Mg, serum magnesium; P, serum phosphorus; PT/INR, prothrombin time/international normalized ratio; PTT, partial thromboplastin time.

the mean CBC and BMP index decreased significantly from  $1.56 \pm 0.02$  and  $1.35 \pm 0.02$  to  $1.45 \pm 0.03$  and  $1.14 \pm 0.03$ , respectively ( $p < 0.001$  for both indices), representing an absolute reduction of 7% and 16% respectively.

### 3.3. Impact of the intervention on hospital-based measures of throughput and mortality

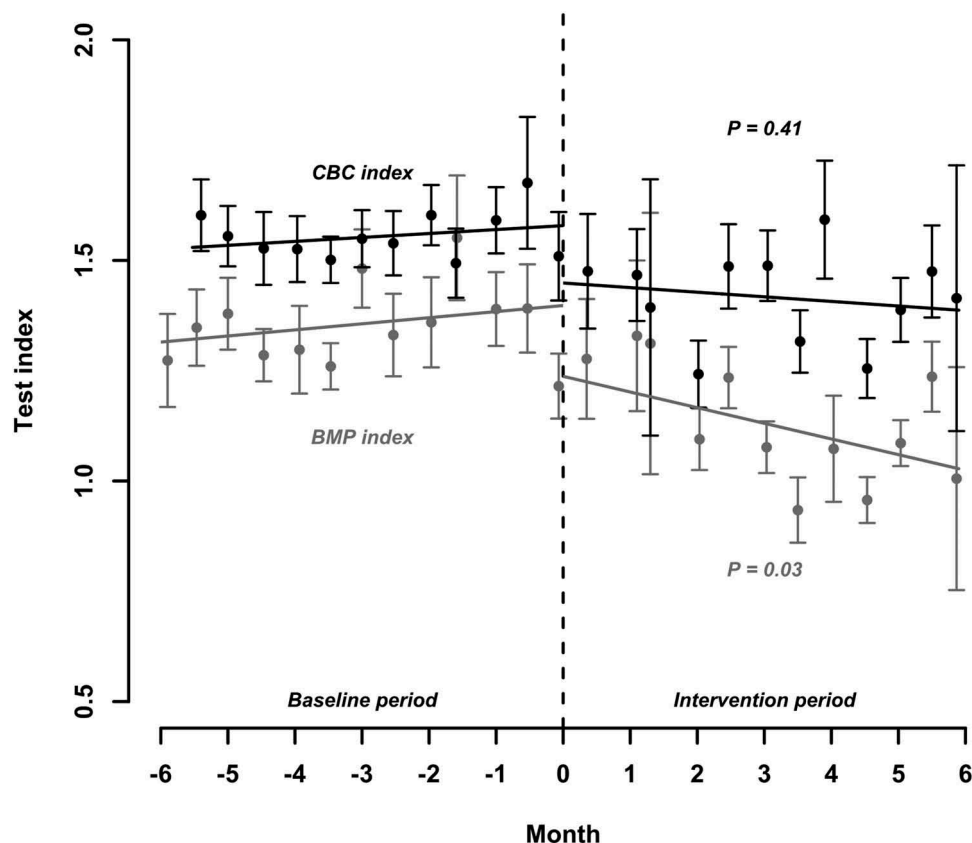
Our intervention had no meaningful impact on hospital measures of throughput and mortality. Indeed, as shown in Supplemental Figure 2, there was no statistically significant difference between the pre- and post-intervention period in terms of reduction in hospital length of stay, length of stay index, mortality rate, and mortality index. Based on the case mix index, there was also no significant change in the complexity of patients hospitalized on the general medical service between the pre- and post-intervention period ( $1.14 \pm 0.004$  vs.  $1.12 \pm 0.013$ ;  $P = 0.22$ ).

## 4. Discussion

Healthcare spending in the USA accounts for approximately 17% of gross domestic product [3]. The New England Health Institute has estimated that 30% of total healthcare spending goes towards unnecessary,

ineffective, overpriced and wasteful services, amounting to an estimated \$700 billion of wasteful spending [4]. Physicians are responsible for the bulk of such unnecessary spending, as the two major areas of highest expenditure include imaging and laboratory testing [3]. In 2012, the American Board of Internal Medicine Foundation launched the 'Choosing Wisely' campaign, aimed at challenging the medical community to identify tests, procedures, and therapies that are overused or inappropriately used and might potentially cause harm, thus increasing unnecessary health care spending [5]. Further, unnecessary testing can potentially induce harm, including phlebotomy-induced anemia. This in turn can make false positive results more likely, which can trigger further testing [6].

In one study, approximately 70% of medical residents self-reported ordering unnecessary daily laboratory tests [7]. Such observation supports the view that a new utilization balance can and must be struck with respect to laboratory investigations in healthcare. Multiple hypotheses have been proposed regarding why physicians order daily laboratory tests indiscriminately, including the ability to gather an overflow of information and trends that would eventually help make a diagnosis, lack of specific guidelines or consensus regarding testing indications, apprehension over potentially avoidable malpractice, and the ease of ordering through electronic medical record systems.



**Figure 4.** Temporal trend in laboratory test utilization (complete blood count [CBC] and basic metabolic panel [BMP] index) over the course of the quality improvement intervention. The pre- and post-intervention trend shows a decrease in the intercept for both the CBC and BMP index ( $p < 0.001$ ); there is a significant interaction between the intervention and the slope of the BMP index trend ( $p = 0.03$ ) but not the CBC index trend ( $p = 0.41$ ).

Physicians-in-training are particularly vulnerable to the practice of over-ordering tests, especially early in their training. Reasons include duplicating role-modeled behavior, the desire to be complete, pre-emptive ordering or rushing an evaluation, discomfort with diagnostic uncertainty, curiosity, unfamiliarity with associated costs and harms, defensive medicine, patient's request, faculty demand and culture of the training institution, lack of training to weigh benefit relative to cost and harm, and the ease of access to services in hospitalized patients [8–10].

Our quality improvement project aimed to tackle the problem of unnecessary laboratory testing in the hospital setting. Throughout the initial data collection period, we established that medical residents rotating on the inpatient general medicine service were over-utilizing laboratory investigations, especially CBC and BMP testing. We introduced a simple intervention that included spreading awareness and education amongst the medical residents, as well as introducing positive reinforcement during the entire 6-month period in the form of an intra-service competition and food incentive for appropriate laboratory test utilization. This proved effective in optimizing the CBC and BMP indices throughout a follow-up period of 6 months, although the intervention was more effective at impacting physician utilization behavior regarding the BMP. This also

reduced patient discomfort by limiting the number of phlebotomies they received during hospitalization. Despite this favorable cognitive effect on physician behavior, the intervention had no significant impact on hospital length of stay, a measure of hospital of patient throughput, and on overall mortality.

Other institutions have made structural organizational changes to establish guidelines and templates for their medical teams, with favorable outcomes after a 10-year follow-up period [11]. Other interventions have included modifying ordering methods and implementing guidelines for phlebotomists to honor physician orders [12]. Displaying the cost of tests in the electronic medical system has not been shown to improve trends of laboratory test ordering by physicians [13].

There are important limitations to our quality improvement project that should be acknowledged. While hospital length of stay, an identifiable confounder, was not factored into the analysis, we computed a 'test index', which accounts for the hospital length of stay by dividing the number of a specific test obtained over the course of a hospitalization for a given patient by the number of hospital days, and then stratified this data by short versus prolonged length of stay. We also did not include measurement indices of specific electrolytes, such as sodium and potassium, for which daily testing might be beneficial,



especially in the setting of clinical scenarios such as adrenal insufficiency or adverse medication effects. Furthermore, our intervention had no impact on patient outcomes, including hospital length of stay and mortality. These shortcomings limit the interpretation of our results.

In conclusion, in this proof-of-concept quality improvement project, our intervention, which was designed to promote judicious use of laboratory testing by medical residents, was effective and served to heighten awareness of unnecessary laboratory testing and promoting accountability.

## 5. Implications

This study serves to prove that interventions designed to improve awareness of unnecessary laboratory testing and periodic awareness and positive reinforcement measures can serve as effective and simple interventions to improve quality of care by minimizing patient discomfort through fewer unnecessary phlebotomies, and reducing health care costs. This can potentially be implemented on a large scale across hospitals to effectively optimize the quality of healthcare delivery.

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## Disclosure statement

No potential conflict of interest was reported by the authors.

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