

Effects of Process Improvement on Guideline-Concordant Cardiac Enzyme Testing

LT Gregory Condos, MD, MC, USN; Yohannes B. Tesema, MS, MPH; LT Megha Joshi, MD, MC, USN; CDR Andrew Lin, MD, MC, USN; and CAPT (Ret) Paul D. Rockswold, MD, MPH, MC, USN

Easily implemented ordering practices in the electronic health record increased the rate of guideline-concordant testing, decreased cost, and furthered the goal of high-value medical care.

Gregory Condos is a Cardiology Fellow at Naval Medical Center San Diego in California. **Yohannes Tesema** is a Statistician at the Veterans Health Administration in Denver, Colorado. **Megha Joshi** is a Nephrologist at Walter Reed National Military Medical Center in Bethesda, Maryland. **Andrew Lin** is a Cardiologist at the Naval Medical Center Portsmouth in Virginia. **Paul Rockswold** is Director of Epidemiology and Public Health at Co-gency Medical in Baltimore, Maryland. Gregory Condos and Megha Joshi are Assistant Professors, Andrew Lin is an Associate Professor, and Paul Rockswold is an Adjunct Associate Professor, all at the Uniformed Services University of the Health Sciences in Bethesda.

Correspondence:
Greg Condos
(greg.condos@gmail.com)

In recent years, driven by accelerating health care costs and desire for improved health care value, major specialty group guidelines have incorporated resource utilization and value calculations into their recommendations. High-value care has the characteristics of enhancing outcomes, safety, and patient satisfaction at a reasonable cost. As one example, the American College of Cardiology (ACC) recently published a consensus statement on its clinical practice guidelines with a specific focus on cost and value.¹ This guideline acknowledges the difficulty in incorporating value into clinical decision making but stresses a need for increased transparency and consistency to boost value in everyday practice.

Chest pain and related symptoms were listed as the second leading principle reasons for emergency department visits in the US in 2011 with 14% of patients undergoing cardiac enzyme testing.² The ACC guidelines advocate use of troponin as the preferred laboratory test for the initial evaluation of acute coronary syndrome (ACS). Fractionated creatine kinase (CK-MB) is an acceptable alternative only when a cardiac troponin test is not available.³ Furthermore, troponins should be obtained no more than 3 times for the initial evaluation of a single event, and further trending provides no additional benefit or prognostic information.

A recent study from an academic hospital showed that process improvement interventions focused on eliminating unnecessary cardiac enzyme testing led to a 1-year cost savings of \$1.25 million while increasing the rate of ACS diagnosis.⁴ Com-

mon clinical practice at Naval Medical Center Portsmouth (NMCP) in Virginia still routinely includes both troponin as well as a CK panel comprised of CK, CK-MB, and a calculated CK-MB/CK index. Our study focuses on the implementation of quality improvement efforts described by Larochelle and colleagues at NMCP.⁴ The study aimed to determine the impact of implementing interventions designed to improve the ordering practices and reduce the cost of cardiac enzyme testing.

METHODS

The primary focus of the intervention was on ordering practices of the emergency medicine department (EMD), internal medicine (IM) inpatient services, and cardiology inpatient services. Specific interventions were: (1) removal of the CK panel from the chest pain order set in the EMD electronic health record (EHR); (2) removal of the CK panel from the inpatient cardiology order set; (3) education of staff on the changes in CK panel utility via direct communication during IM academic seminars; (4) education of nursing staff ordering laboratory results on behalf of physicians on the cardiology service at the morning and evening huddles; and (5) addition of “max of 3 tests indicated” comment to the inpatient EHR ordering page of the troponin test. Acknowledging that the CK-MB has some utility to interventional cardiologists in the setting of confirmed ACS, the laboratory instituted an automated, reflexive order of the CK-MB panel only if the troponin tests were positive. This test was

TABLE 1 Characteristics of Study Participants by Intervention Period

Characteristics	Preintervention, No. (%)	Postintervention, No. (%)	Total, No. (%)
Total Individuals for Study Period	2,541 (40.5)	3,740 (59.5)	6,281
Age, y			
18-25	205 (8.1)	298 (8.0)	503 (8.0)
26-35	279 (11.0)	468 (12.5)	747 (11.9)
36-45	445 (17.5)	636 (17.0)	1,081 (17.2)
46-55	661 (26.0)	891 (23.8)	1,552 (24.7)
56-65	488 (19.2)	807 (21.6)	1,295 (20.6)
> 65	463 (18.2)	640 (17.1)	1,103 (17.6)
Sex			
Male	1,337 (52.6)	1,955 (52.3)	3,292 (52.4)
Female	1,204 (47.4)	1,785 (47.7)	2,989 (47.6)
Beneficiary category			
Retired	881 (34.7)	1,238 (33.1)	2,119 (33.7)
All others	778 (30.6)	1,180 (31.6)	1,958 (31.2)
Active duty (AD) or Reserve on AD (RAD)	568 (22.4)	845 (22.6)	1,413 (22.5)
Dependent of AD or RAD	314 (12.4)	477 (12.8)	791 (12.6)
Sponsor service			
Army	233 (9.2)	334 (8.9)	567 (9.0)
Air Force	98 (3.9)	153 (4.1)	251 (4.0)
Marine	82 (3.2)	123 (3.3)	205 (3.3)
Coast Guard	76 (3.0)	148 (4.0)	224 (3.6)
Other	77 (3.0)	137 (3.7)	214 (3.4)
Clinical setting			
Emergency medicine department	2,443 (96.1)	3,633 (97.1)	6,076 (96.7)
Cardiology clinic	34 (1.3)	36 (1.0)	70 (1.1)
Inpatient internal medicine	33 (1.3)	38 (1.0)	71 (1.1)
Inpatient cardiology	31 (1.2)	33 (0.9)	64 (1.0)
Mean age (SD), y	51 (16.7)	49.2 (16.4)	—

automatically run on the same vial originally sent to the lab to mitigate any additional delay in determining results.

Data Source

The process improvement interventions were considered exempt from institutional review board (IRB) approval; however, we obtained expedited IRB approval with waiver of consent for the research aspect of the project. We obtained clinical administrative data from the Military Health System Data Repository (MDR). We identified all adult patients aged ≥ 18 years who had a troponin test, CK-MB, or both drawn at NMCP on the following services: the EMD, IM, and cardiology. A troponin or CK-MB test was defined using Current Procedural Terminology (CPT) codes and unique Logical Observation Identifiers Names and Codes (LOINC).

Measures

The study was divided into 3 periods: the preintervention period from August 1, 2013 to July 31, 2014; the intervention period from August 1, 2014 to January 31, 2015; and the postintervention period February 1, 2015 to January 31, 2016.

The primary outcomes measured were the frequency of guideline concordance and total costs for tests ordered per month using the Centers for Medicare and Medicaid Services (CMS) clinical laboratory fee schedule of \$13.40 for troponin and \$16.17 for CK-MB.⁵ *Concordance* was defined as ≤ 3 troponin tests and no CK-MB tests ordered during 1 encounter for a patient without an ACS diagnosis in the preceding 7 days. Due to faster cellular release kinetics of CK-MB compared with that of troponin, this test has utility in evaluating new or worsening chest pain in

Table 2 Comparison of Endpoints Between Preintervention and Postintervention Periods

Periods	Concordant Testing, % (95% CI)	Monthly Laboratory Costs, \$ (95% CI)	CK-MB Tests/ Episode, No. (95% CI)	Troponin Tests/ Episode, No. (95% CI)	ACS Prevalence Visits, % (95% CI)
Preintervention, start	5.7 (1.7-9.8)	8,900 (7,600-10,200)	1.30 (1.21-1.39)	1.32 (1.18-1.46)	0.65 (0.52-0.77)
Preintervention, end	14.5 (10.4-18.6)	9,900 (8,500-11,200)	1.12 (1.03-1.21)	1.44 (1.30-1.58)	0.47 (0.34-0.60)
Preintervention, mean	10.1 (7.4-12.9)	9,400 (8,700-10,100)	1.21 (1.15-1.27)	1.38 (1.31-1.45)	0.56 (0.48-0.63)
Postintervention, start	74.0	5,100	0.28	1.14	0.60
Postintervention, mean	81.2 (77.5-84.8)	5,000 (4,600-5,300)	0.20 (0.16-0.25)	1.21 (1.17-1.25)	0.62 (0.54-0.65)
Mean change	71.1 (66.7-75.4)	-4,400 (-3,700- -5,100)	1.01 (0.94-1.08)	0.17 (0.09-0.24)	0.06 (-0.04-0.18)
Change (preintervention end to postintervention start)	59.5	-4,800	-0.84	-0.30	0.13

Abbreviations: ACS, acute coronary syndrome; CK-MB, fractionated creatine kinase.

the setting of a recent myocardial infarction (MI). Therefore, we excluded any patient who had a MI within the preceding 7 days of an order for either CK-MB or troponin tests. Additionally, the number of tests, both CK-MB and troponin, ordered per patient encounter (hereafter referred to as an episode) were measured. Finally, we measured the monthly prevalence of ACS diagnosis and percentage of visits having that diagnosis.

Data Analysis

Descriptive statistics were used to calculate population demographics of age group, sex, beneficiary category, sponsor service, and clinical setting. Monthly data were grouped into the preintervention and postintervention periods. The analysis was performed using *t* tests to compare mean values and CIs before and after the intervention. Simple linear regression with attention to correlation was used to create best fit lines with confidence bands before and after the intervention. Interrupted time series (ITS) regression was used to describe all data points throughout the study. Consistency between these various methods was verified. Mean values and CIs were reported from the *t* tests. Statistical significance was reported when appropriate. Equations and confidence predictions on the simple linear regressions were produced and reported. These were used to identify values at the start, midpoint, and end of the pre- and postintervention periods.

RESULTS

There were a total of 6,281 patients in the study population. More patients were seen during the postintervention period than in the preintervention period. The mean age of patients was slightly higher during the preintervention period (Table 1).

Guideline Concordance

To determine whether ordering practices for cardiac enzyme testing improved, we assessed the changes in the frequency of guideline concordance during the pre- and postintervention period. On average during the preintervention year, the percentage of tests ordered that met guideline concordance was 10.1% (95% CI, 7.4%-12.9%), increasing by 0.80% (95% CI, 0.17%-1.42%) each month. This percentage increased 59.5% from its immediate preintervention estimate of 14.5% to the immediate postintervention estimate of 74.0% (Table 2, Figure 1). On average during the postintervention year, the percentage of tests ordered that met guideline concordance was 81.2% (95% CI, 77.5%-84.8%), continuing to increase by 1.3% (95% CI, 0.7%-2.05%) each month. This rate of continuing increase was not statistically different from the preintervention period.

Costs

We assessed changes in total dollars spent on cardiac enzyme testing during the pre- and postintervention periods.

During the preintervention year, \$9,400 (95% CI, \$8,700-\$10,100) was spent on average each month, which did not change significantly throughout the period. During the postintervention year, the cost was stable at \$5,000 (95% CI, \$4,600-\$5,300) on average each month, a reduction of \$4,400 (95% CI, \$3,700-\$5,100) (Figure 2).

CK-MB and Troponin Tests per Patient

To further assess ordering practices for cardiac enzyme testing, we compared the changes in the monthly number of tests and the average number of CK-MB and troponin tests ordered per episode pre- and postintervention. On average during the preintervention year, 297 tests (95% CI, 278-315) were run per month, with an average of 1.21 CK tests (95% CI, 1.15-1.27) per episode (Table 2, Figure 3). During the preintervention year, the total number of CK tests remained steady, but tests ordered per episode slowly decreased by 0.017 (95% CI, -0.030 to -0.003) per month. During the postintervention year, there were 52 tests (95% CI, 40-63) each month on average, a decrease of 246 (95% CI, 225-266). The number of CK tests per episode decreased by 1.01 (95% CI, 0.94-1.08) to an average of 0.20 (95% CI, 0.16-0.25) and continued to slowly decrease by 1.4% (95% CI, 0.3%-2.4%) each month. This slow decrease postintervention was not statistically different from that of the preintervention year.

The changes in troponin testing were not as dramatic. The counts of tests each month remained similar, with a preintervention year average of 341 (95% CI, 306-377) and postintervention year average of 310 (95% CI, 287-332), which were not statistically different. However, there was a statistically significant decrease in the number of tests per episode. During the preintervention year, 1.38 troponin tests (95% CI, 1.31-1.45) were ordered per patient on average. This dropped by 0.17 (95% CI, 0.09-0.24) to the postintervention average of 1.21 (95% CI, 1.17-1.25) (Table 2, Figure 4). Although there was no monthly change (0.011 [95% CI, -0.011-0.032]) in the preintervention year; in the postintervention year, it continued to slowly decrease by 0.013 (95% CI, -0.005- -0.021) monthly.

FIGURE 1 Guideline Concordant Testing

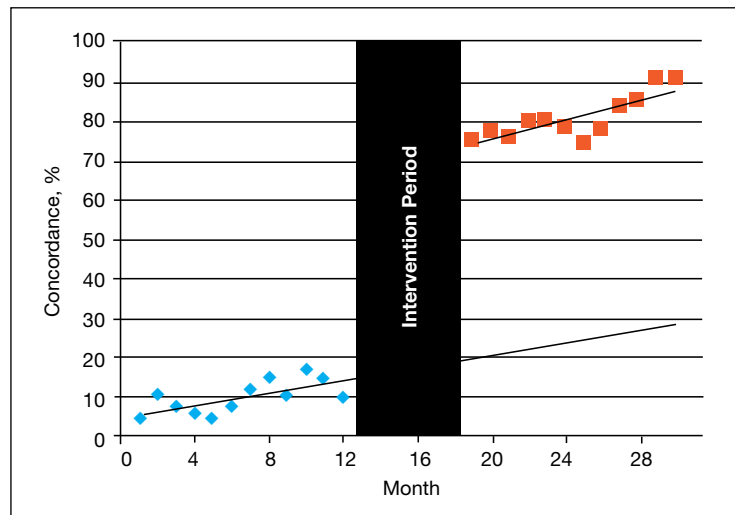
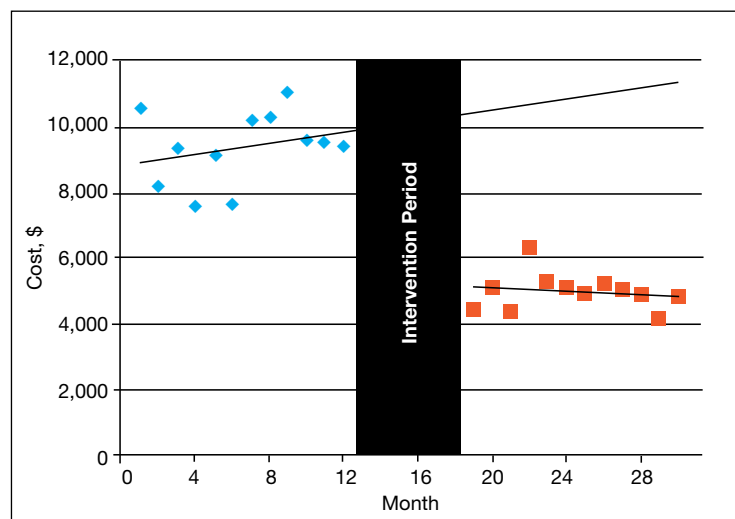


FIGURE 2 Total Cost Per Month



ACS Prevalence

To determine whether there was an impact on ACS diagnoses, we looked at the numbers of ACS diagnoses and their prevalence among visits before and after the intervention. During the preintervention year, the average monthly number of diagnoses was 29.7 (95% CI, 26.1-33.2), and prevalence of ACS was 0.56% (95% CI, 0.48%-0.63%) of all episodes. Although the monthly rate was statistically decreasing by 0.022% (95% CI, 0.003-0.41), this has little meaning since the level of correlation ($r^2 = 0.2522$, not displayed) was poor due to the essentially nonexistent correlation in number of visits each month ($r^2 = 0.0112$, not displayed).

FIGURE 3 Fractionated Creatine Kinase Tests Per Episode

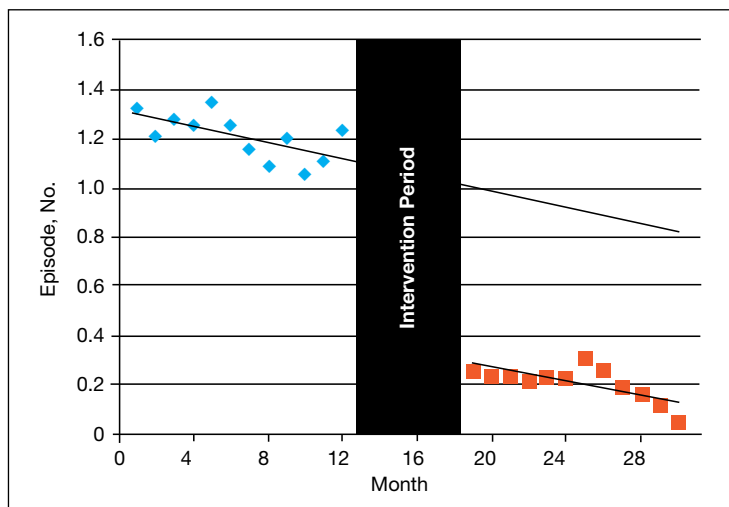
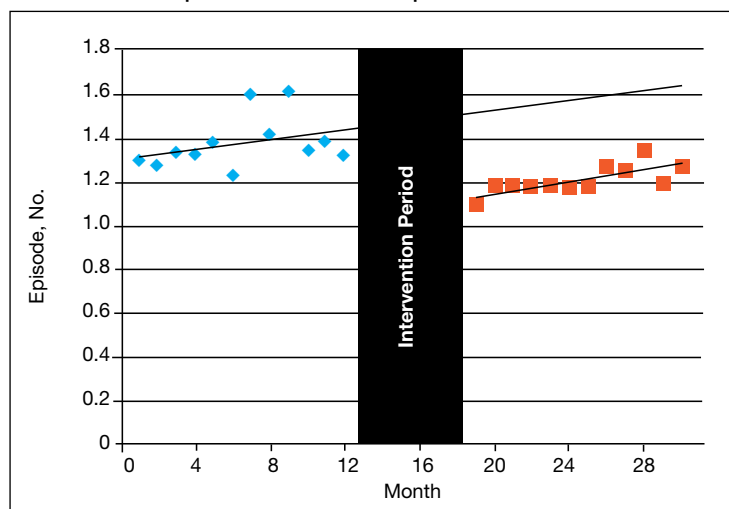


FIGURE 4 Troponin Tests Per Episode



During the postintervention year, the average number of diagnoses was 32.2 (95% CI, 27.9-36.6), and the prevalence of ACS was 0.62% (95% CI, 0.54-0.65). Neither of these values changed significantly between the pre- and postintervention period. All ICD-9 and ICD-10 diagnosis codes used for the analysis are available upon request from the authors.

DISCUSSION

Our data demonstrate the ability of simple process improvement interventions to decrease unnecessary testing in the workup of ACS, increasing the rate of guideline concordant testing by > 70% at a single military treatment facility (MTF). In particular, with

the now widespread use of EHR, the order set presents a high-yield target for process improvement in an easily implemented, durable fashion. We had expected to see some decrease in the efficacy of the intervention at a time of staff turnover in the summer of 2015 because ongoing dedicated teaching sessions were not performed. Despite that, the intervention remained effective without further dedicated teaching sessions. This outcome was certainly attributable to the hardwired interventions made (mainly via order sets), but possibly indicates an institutional memory that can take hold after an initial concerted effort is made.

We reduced the estimated preintervention annual cost of \$113,000 by \$53,000 (95% CI, \$42,000-\$64,000). Although on a much smaller scale than the study by Larochelle, our study represents a nearly 50% reduction in the total cost of initial testing for possible ACS and a > 80% reduction in unnecessary CK-MB testing.⁴ This result was achieved with no statistical change in the prevalence of ACS. The cost reduction does not account for the labor costs to clinically follow-up and address additional unnecessary lab results. The estimated cost of intervention was limited to the time required to educate residents, interns, and nursing staff as well as the implementation of the automated, reflexive laboratory results ordering process.

Unique to our study, we also demonstrated an intervention that satisfied all the major stakeholders in the ordering of these laboratory results. By instituting the reflexive ordering of CK-MB tests for positive troponins, we obtained the support of the facility's interventional cardiology department, which finds value in that data. Appreciating the time-sensitive nature of an ACS diagnosis, the reflexive ordering minimized the delay in receiving these data while still greatly reducing the number of tests performed. That being said, if the current trend away from CK-MB in favor of exclusively testing troponin continues, removing the reflexive ordering for positive laboratory results protocol would be an easy follow-on intervention.

Limitations

Our study presented several limitations. First, reporting errors due to improper or

insufficient medical coding as well as data entry errors may exist within the MDR; therefore, the results of this analysis may be over- or underestimated. Specifically, CPT codes for troponin and CK-MB were available only in 1 of the 2 data sets used for this study, which primarily contains outpatient patient encounters. For this reason, most of the laboratory testing comes from the EMD rather than from inpatient services. However, because we excluded all patients who eventually had an ACS diagnosis (patients who likely had more inpatient time and better indication for repeat troponin), we feel that our intervention was still thoroughly investigated. Second, the number of tests drawn per patient was significantly < 2 , the expected minimum number of tests to rule out ACS in patients with appropriate symptoms.

This study was not designed to answer the source of variation from guidelines. Many patients had only 1 test, which we feel represents an opportunity for future study to identify other ways cardiac enzyme testing is being used clinically. These tests might be used for patients without convincing symptoms and signs of coronary syndromes or for patients with other primary problems. Third, by using the ITS analysis, we assumed that the outcome during each intervention period follows a linear pattern. However, changes may follow a nonlinear pattern over a long period. Finally, our intervention was limited to only a single MTF, which may limit generalizability to other facilities across military medicine. However, we feel this study should serve as a guide for other MTFs as well as US Department of Veterans Affairs facilities that could institute similar process improvements.

CONCLUSION

We made easily implemented and durable process improvement interventions that changed institution-wide ordering practices. These changes dramatically increased the rate of guideline-concordant testing, decreasing cost and furthering the goal of high-value medical care.

Author disclosures

The authors report no actual or potential conflicts of interest with regard to this article.

Disclaimer

The opinions expressed herein are those of the authors and do not necessarily reflect those of *Federal Practitioner*, Frontline Medical Communications Inc., the US Government, or any of its agencies.

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