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Leveraging Information Technology to Hardwire Diagnostic Stewardship

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Abstract

Objective: This article reports the impact of an electronic educational tool embedded in the electronic medical record on diagnostic stewardship of procalcitonin (PCT)-a biomarker used to differentiate bacterial from viral infection. This tool specifically targets the preanalytic (ordering and collection) phase of the PCT test.

Methods: This retrospective study was conducted at a 401-bed academic medical center from February 2017-February 2018. The preintervention phase extended from February 2017-July 2017; intervention phase from August 2017- September 2017 and postintervention phase from October 2017-February 2018.

Results: A total of 567 PCT orders were evaluated. There was an overall reduction in total PCT orders and an improvement in appropriate PCT orders. Total PCT orders reduced by 54.4% (P<0.001). Appropriate ordering for PCT improved by 33.4% (P<0.001).

Conclusion: Our results further support the use of information technology to hardwire diagnostic stewardship, an important strategy to improve resource utilization and patient care.

Keywords: Diagnostic stewardship; Procalcitonin; Information technology; Electronic educational tool

Introduction

Diagnostic stewardship is defined as a systematic process that encourages optimal utilization of diagnostics. The primary goal of diagnostic stewardship is to facilitate clinical decisions to improve patient care. Principles of diagnostic stewardship are applicable to all three phases of laboratory procedures-preanalytic (ordering and collection), analytic (processing) and postanalytic (reporting) [1]. Under the Hospital Outpatient Quality Reporting Program, one-third of the measures monitor appropriate utilization of diagnostic tests. Performance on these measures directly influence financial reimbursement and the hospital star rating by Centre of Medicare and Medicaid services [2].

Diagnostic stewardship has immense potential to improve patient care. Overuse of tests will increase false positives that have a downstream domino effect on treatment decisions and can be associated with patient morbidity. Conversely, underuse of tests can adversely impact patient care by misdiagnosis or a delay in diagnosis.

The Institute of Medicine has emphasized a key role of computer systems to improve patient care. Computerized systems also play an important role in diagnostic pathology [3,4]. Accordingly, strategies deployed for diagnostic stewardship often rely on information technology (IT) for a broad impact. Computerized ordering is effective in reducing medication errors. Electronic order sets are useful in management of clinical conditions like bacteremia and in fostering antimicrobial stewardship [5-7]. Automated alerts have been used to encourage diagnostic stewardship for an accurate diagnosis of *Clostridium difficile infection* (CDI) [8].

We sought to study the impact of an electronic educational tool (EET) on the preanalytic phase of a biological marker-Procalcitonin (PCT). PCT is a biomarker that can help to differentiate bacterial from viral infections when used in conjunction with clinical judgement. PCT also correlates with resolution of bacterial infection [9-12]. PCT level rises within six hours of onset of a bacterial infection and declines with the control of infection [13].

Evidence from studies conducted in controlled settings has shown PCT to be useful in early discontinuation of antimicrobials without an increase in mortality [14]. In a controlled setting, a study protocol is followed that ensures optimal selection of subjects and appropriate serial monitoring of PCT. Of note, these studies have excluded subjects who received antimicrobials for prolonged periods and immunosuppressed hosts [15,16]. Certain inflammatory conditions like post-operative state, cardiogenic shock and trauma further limit the use of PCT. In these situations, specificity of PCT to identify bacterial infections is compromised.

In the 'real world' setting, where patients are not a part of a study protocol and patient selection and serial monitoring is done based on the ordering provider's judgement, the utility of PCT is equivocal. In a large study, conducted in intensive care units, PCT use was associated with an increase in antimicrobial use and an increase in CDI [17].

The Infectious Diseases Society of America and the Society of Healthcare Epidemiology of America offer a weak recommendation for PCT use. In addition, they recommend that each hospital assess if PCT use is appropriate for their patient population [18].

To encourage appropriate ordering of PCT, we implemented an EET in our electronic health record (EHR). This tool reinforces three cardinal rules of diagnostic stewardship, i.e., 'right test' on the 'right patient' and at the 'right time' [19].

Methods

Study setting and design

This is a retrospective, observational, quasi-experimental study evaluating the impact of IT (EET) on diagnostic stewardship of PCT.

The study was conducted at a 401-bed, tertiary, acute care academic facility. This is a referral hospital in Los Angeles County with a quarter of admissions directly from other facilities. Subjects included in the study were inpatients, 18 years of age and older with at least one serum PCT level. Both total and appropriate PCT orders were measured before and after implementation of EET. The preintervention phase (Pre-IP) extended from February 2017-July 2017. Intervention phase was August 2017-September 2017. Postintervention phase (Post-IP) extended from October 2017-February 2018. An approval from Institutional Review Board at University of Southern California was obtained for the study.

Intervention

An EET was implemented to optimize PCT ordering practices. The EET is a part of our EHR (Cerner). There was a 6-week trial period in August and September before the final launch of EET in late September 2017.

When an ordering provider attempts to order PCT, the EET is launched. This tool consists of two steps. In the first step, an educational alert outlines limitations of PCT. This alert gives the end user an option to proceed or cancel the order. If end user decides to proceed with the order, a second educational alert prompts the user to complete an electronic form. This form inquires about clinical conditions where utility of PCT is limited. The second step also gives the option to proceed or cancel the order. A PCT test can be ordered only if the electronic form is completed. If the order assessment form is completed, it is a part of the EHR. The steps involved in ordering PCT are displayed in Figure 1.

Education on PCT was ongoing through the calendar year of 2017, i.e., through both Pre-IP and Post-IP. Information about PCT was disseminated among physicians, trainees and pharmacists in the form of educational memorandums. Appropriateness of PCT ordering was also discussed in multidisciplinary rounds when pharmacists or infection preventionists were rounding with clinical teams.

Outcome definitions

Primary outcome is the proportion of appropriate PCT orders in Pre-IP and Post-IP. A PCT order was considered inappropriate if obtained in the setting of acute kidney injury (AKI), cardiogenic shock, if the patient was receiving antimicrobials for more than 72 hours, had undergone surgery in the last 72 hours or was receiving some form of dialysis. These clinical scenarios limit applicability of PCT [20-24].

A PCT order can either be a single order or a sequential order. A single order is placed only once during a clinical episode. Sequential order is defined as serial PCTs obtained for a clinical episode to assess improvement.

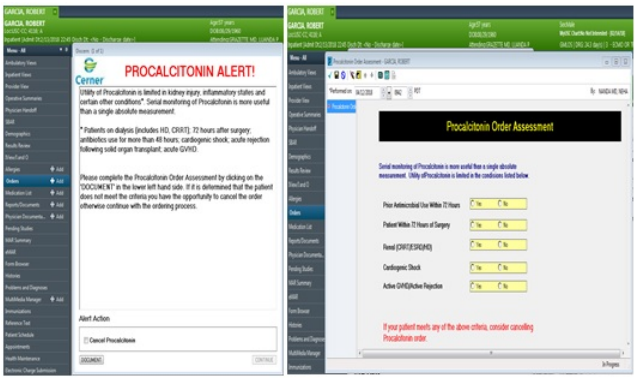

Figure 1: Electronic alert (Displaying Screen 1 and Screen 2).

Statistical analysis

To examine the trend in PCT orders over time, time-series graphs were generated for the total number of orders and number of appropriate orders. The Chi-square test of association was used to determine whether the intervention (EET) was related to the number of orders, single orders, and sequential orders. The Chi-square test of homogeneity was used to determine whether there was a difference between the appropriate orders for Pre-IP and Post-IP. A P-value of 0.05 or less was considered statistically significant. The graphs and analyses were conducted using Stata 15.0 (College Station, TX).

Results

Patient characteristics

In Pre-IP, PCT was ordered in 186 subjects and in Post-IP in 139 subjects. The average age of subjects was 60 years in both groups. Most common comorbid conditions in both groups were subarachnoid hemorrhage and sepsis. In Pre-IP, 127 subjects fell into the category of inappropriate patient selection. In this group, 75% of the subjects were considered inappropriate candidates for PCT, by virtue of duration of antibiotics. The remaining 15% had one of the following diagnosis i.e., AKI, cardiogenic shock and on dialysis. In Post-IP, 38 subjects fell into the inappropriate category with 68% of these subjects, on prolonged duration of antibiotics. In the remaining 32%, there was inappropriate patient selection because of AKI and/or dialysis.

Total PCT orders

A total of 567 PCT orders were evaluated for this study. Time-series graphs were generated for total and appropriate PCT orders. After EET was launched, there was an overall reduction in PCT orders and an increase in proportion of appropriate PCT orders (Figure 2). Monthly average for total PCT orders was 68 and 31 in Pre-IP and Post-IP, respectively ($P < 0.001$). The difference was statistically significant between Pre-IP and Post-IP, for both single and sequential total orders Table 1.

Appropriate PCT orders

In Pre-IP, there were a total of 409 orders and 42.54% (174 out of 409) were appropriate. In Post-IP, there were a total of 158 orders and 75.95% (120 out of 158) were appropriate (Figure 3). Monthly average for appropriate PCT orders was 29 and 24 in Pre-IP and Post-IP, respectively. EET resulted in a statistically significant improvement in ordering of appropriate PCT orders (P<0.001). Appropriate ordering improved for both single and sequential orders, when Pre-IP and Post-IP were compared (P<0.001) (Table 1).

Parameters	Pre-IP (Total)	Post-IP (Total)	P-value
Total Orders	68	31	<0.001
Single Orders	25	23	0.009
Sequential	13	4	<0.001
Parameters	**Pre-IP Appropriate**	**Post-IP Appropriate**	**p-value**
Total Orders	29	24	<0.001
Single Orders	13	18	<0.001
Sequential	5	2	<0.001

Table 1: Chi-square tests show a statistically significant difference between preintervention and postintervention phases for the total number of orders, single orders, and sequential orders.

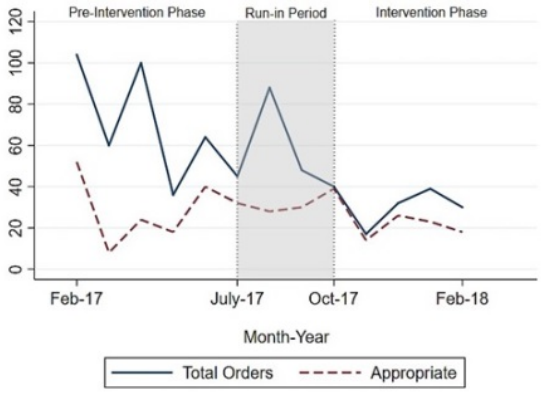

Figure 2: Time series graph showing total PCT orders and inappropriate PCT orders in preintervention and postintervention phases.

Economic impact

Direct cost savings were estimated by measuring the reduction in total PCT orders and a reduction in inappropriate PCT orders. In Pre-IP, there were 409 total orders and 235 orders were inappropriate. The cumulative cost of total orders was $10,225 and cost of inappropriate orders was $5,875. The cumulative cost in Post-IP for total orders (158 orders) was $3,950 and cost of inappropriate orders (38 orders) was $950. These calculations are done based on $25 (approximate) for each PCT order. EET resulted in reducing the direct costs by 61.36% ($6,275).

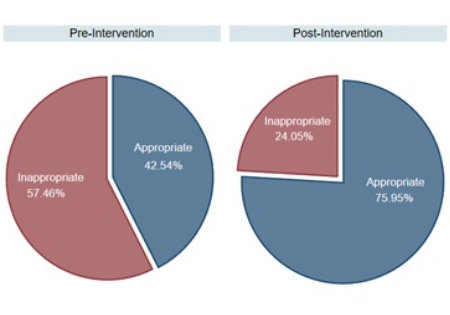

Figure 3: Breakdown of appropriate and inappropriate PCT orders in preintervention and postintervention phases.

Discussion

In this study, we demonstrate benefits of harnessing IT for diagnostic stewardship of PCT in the preanalytic phase. Appropriate ordering of PCT increased by 33.41% (42.54% in Pre-IP and 75.95% in Post-IP) after introduction of EET. Total orders reduced by 54.4% in Post-IP compared to Pre-IP. Impact of EET was noted on both single and sequential orders. Improvement in total orders and appropriate orders was statistically significant. This reflects improved patient selection and better understanding of this diagnostic marker by ordering providers.

Two attributes of EET were able to modify ordering provider's behaviour- a) availability at the point of ordering and b) reliance on active learning, i.e., ordering provider was required to complete an electronic form before proceeding to the next step. Availability of EET at the point of ordering gave the ordering provider easy access to educational information about PCT. In contrast, in-person educational efforts led by pharmacists and infection preventionists occurred after PCT results were available.

Similar interventions have been used to improve appropriate usage of select antimicrobials [25]. A systematic review showed an overall improvement in antimicrobial usage with the use of various clinical decision support systems like computerized provider order entry and computerized approval systems [26]. Such system-based stewardship interventions can be useful in saving personnel time and hardwiring evidence-based medicine in practice.

With increasing emphasis on 'Choosing Wisely' campaign, it is incumbent on healthcare professionals to practice evidence-based medicine [27]. Diagnostic stewardship is a critical component of this campaign. Typically, implementation strategies for diagnostic stewardship are either user-based or system-based. User-based approaches take the form of audit and feedback as commonly used in antimicrobial stewardship efforts. System-based efforts often rely on IT and include clinical decision support tools for optimization [28]. In our study, a system-based tool, i.e., EET, allowed us to socialize evidence-based use of PCT.

While this work demonstrated convincing results, there are some caveats that should be kept in mind while interpreting these results. It was a single-center experience and will need to be replicated at other centers to confirm its generalizability. We relied on capturing patient information from chart documentation which may have introduced human error. EET was not deployed in isolation. Educational efforts

were simultaneously ongoing and may have reinforced optimal use of PCT. It is therefore not possible to conclusively determine what portion of the behaviour change can be attributed to EET versus other interventions. However, it is important to note that other educational efforts were ongoing through both Pre-IP and Post-IP, so EET was the main variable between the two time periods. Finally, it is challenging to calculate the true economic impact of optimizing PCT orders. We have only estimated direct costs. Indirect cost benefits of PCT would include several data points, including antimicrobial use, additional testing and length of stay which were beyond the scope of this study.

In conclusion, a well-designed and a well-implemented EET has the potential to influence the preanalytic phase of laboratory procedures. To design and implement an effective diagnostic stewardship intervention, an ongoing dialogue between IT, diagnosticians and clinicians is imperative. An effective intervention should be accessible at the point of ordering to facilitate the three cardinal rules of diagnostic stewardship, i.e., the 'right' test, on the 'right' patient, and at the 'right' time. By harnessing IT, we can hardwire evidence-based medicine and optimize resource utilization in the current healthcare environment.

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