Original Article

Impact of a Cost Visibility Tool in the Electronic Medical Record on Antibiotic Prescribing in an Academic Medical Center

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ABSTRACT

Background: Studies evaluating the impact of passive cost visibility tools on antibiotic prescribing are lacking.

Objective: The objective of this study was to evaluate whether the implementation of a passive antibiotic cost visibility tool would impact antibiotic prescribing and decrease antibiotic spending.

Methods: An efficiency and effectiveness initiative (EEI) was implemented in October 2012. To support the EEI, an antibiotic cost visibility tool was created in June 2013 displaying the relative cost of antibiotics. Using an observational study of interrupted time series design, 3 time frames were studied: pre EEI, post EEI, and post cost visibility tool implementation. The primary outcome was antibiotic cost per 1,000 patient days. Secondary outcomes included case mix index (CMI)–adjusted antibiotic cost per 1,000 patient days and utilization of the cost visibility tool.

Results: Initiation of the EEI was associated with a \$4,675 decrease in antibiotic cost per 1,000 patient days ($P = .003$), and costs continued to decrease in the months following EEI ($P = .009$). After implementation of the cost visibility tool, costs remained stable ($P = .844$). Despite CMI increasing over time, adjustment for CMI had no impact on the directionality or statistical significance of the results.

Conclusion: Our study demonstrated a significant and sustained decrease in antibiotic cost per 1,000 patient days when focused medication cost reduction efforts were implemented, but passive cost visibility tool implementation was not associated with additional cost reduction. Antibiotic cost visibility tools may be of most benefit when prior medication cost reduction efforts are lacking or when an active intervention is incorporated.

Key Words—antibiotic, antibiotic cost, cost reduction, cost visibility

Hosp Pharm 2015;50: 496–504

In an era of decreasing health care reimbursement, health systems face significant financial obstacles.¹ Many pharmacy practice models are adapting to the times by becoming stewards of drug cost while striving to maintain quality of clinical care.

Expensive drug products, including antibiotics, are often the focus of cost containment strategies as they have a significant impact on inpatient pharmacy budgets. Ansari et al² found that 22% to 65% of antibiotic prescriptions are either inappropriate or

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incorrect, which could contribute to increased cost and potential clinical harm. Additional studies have shown that antibiotics are prescribed incorrectly with regard to indication, choice of agent, or duration of therapy up to 50% of the time.³ According to the 2013 Centers for Disease Control and Prevention (CDC) threat report, approximately 2 million people annually in the United States will develop an infection with bacteria that is resistant to one or more antibiotics, which could be due in part to overuse of antibiotics.⁴ Antibiotic resistance contributes to increased risk of mortality as well as increased treatment duration and cost, length of hospital stay, doctor visits, and disability. It is estimated that resistant infections result in an additional \$20 billion in national health care spending annually.⁴ For these reasons, prescriber education to enhance awareness of appropriate antibiotic use and selection is imperative.

An antibiotic cost visibility tool may be valuable in this setting; however, the tool design and the presence of an accompanying active intervention may be critical in predicting the success of the tool. To date, passive and active cost visibility interventions have been reported in the literature with variable success, but reports of passive cost visibility tools specific to antibiotics are lacking. The objective of our study was to evaluate whether the implementation of an antibiotic cost visibility tool would have an impact on antibiotic prescribing and in turn decrease antibiotic spending.

METHODS

The Ohio State University Wexner Medical Center (OSUWMC) implemented an efficiency and effectiveness initiative (EEI) in October 2012 in an effort to become a more efficient, value-driven academic medical center.⁵ This initiative consists of 6 pillars that include digital, organizational, educational, clinical,

research, and financial innovation. It challenged the department of pharmacy to decrease its drug expense by \$8 million over 18 months.

To enhance prescriber awareness of antibiotic cost and, in turn, decrease antibiotic spending in support of EEI efforts, an antibiotic cost visibility tool was implemented in June 2013. This medication class was selected to pilot the cost visibility concept, because there are multiple appropriate antibiotics for most infections and this increases the likelihood that a more cost-effective agent could be prescribed. The passive tool displays relative cost of antibiotics in the electronic medical record at the time of physician order entry and includes a link to the antibiotic cost visibility Web site located on the institutional intranet (Figure 1). A key was created using cent and dollar signs to designate the relative cost of one antibiotic day for each antibiotic, with the average daily dose being based on normal renal function and a patient weight of 80 kg for weight-based antibiotics. Each symbol in the key represents a range of costs such that multiple agents fall within each category (Table 1). The ranges were selected in an effort to separate drugs with similar spectrums of activity such that the most cost-effective option for a particular organism would be apparent. For example, an agent with 5 dollar signs costs significantly more per day than an agent with 2 cent signs. Relative costs were determined based on the institution's acquisition costs. The tool contains all formulary antibiotics sorted by drug class along with the spectrum of activity and cost of the agent relative to other formulary antibiotics (select examples illustrated in Table 2). An e-mail was sent to all medical staff prior to implementation to alert them to the availability of this tool. The tool is updated bi-annually or sooner if major (>10%) price changes occur.

Medications (2 Orders)

2 of 2 selected

Remove Group

☒ nafcillin (NAFCIL) 2 g in sodium chloride 0.9%, with overfill 120 mL (total volume) IVPB

2 g. Intravenous, at 120 mL/hr, for 1 Hours, ONCE, 1 dose Today at 1630

Administer bolus over 60-120 minutes followed by continuous infusion.

Order Inst: Nafcillin does not require adjustment for renal failure alone. However, if patient has both renal and hepatic failure: r

Reference Links:

1. Central Line Conc. Dependent

2. OSU Relative Cost \$\$\$\$

Dose: 2 g

Figure 1. Example of antibiotic cost displayed in the electronic medical record at the time of physician order entry. © 2014 Epic Systems Corporation. Used with permission.

Table 1. Antibiotic cost visibility tool key

Cost per day range	Symbol
<\$1	¢
\$1-2.49	¢¢
\$2.50-4.99	¢¢¢
\$5-9.99	¢¢¢¢
\$10-29.99	\$
\$30-59.99	\$§
\$60-99.99	\$\$\$
\$100-149.99	\$\$\$§
\$150-199.99	\$\$\$§§
\$200-399.99	\$\$\$§§§
>\$400	\$\$\$§§§§

This was an observational study using interrupted time series design and segmented regression analysis. The primary outcome was antibiotic cost per 1,000 patient days. Secondary outcomes included case mix index (CMI)–adjusted antibiotic cost per 1,000 patient days and number of views of the passive cost visibility tool. Three time frames were used since the

EEI began prior to implementation of the cost visibility tool and could have had a significant impact on the primary outcome: pre EEI (November 2011 to October 2012), post EEI (November 2012 to May 2013), and post implementation of the cost visibility tool (June 2013 to May 2014). The metric used to assess cost was antibiotic cost per 1,000 patient days before and after adjustment for CMI, which is a sum of weighted diagnosis-related groups (DRGs). Adjustment for CMI was done to account for variances in acuity of illness from month to month. All costs were based on doses dispensed and were adjusted to 2014 dollars using the consumer price index (CPI) (<http://www.bls.gov/>). Inpatient and outpatient administrations of formulary antibiotics during the study time frame were included. Antifungals, antivirals, and antiretrovirals were excluded from this analysis, as they were not included in the cost visibility tool. Cef-taroline was also excluded due to formulary addition during the study time frame. Utilization of the cost visibility tool Web site was also evaluated using the number of times the Web site was accessed (“hits”) and the amount of time viewers spent on the Web site.

Data collection included overall number of patient days per month; cost of antibiotic dispenses and returns per month; CPI for 2011, 2012, and 2013; aggregated hospital CMI per month; number of cost visibility tool Web site hits; and time spent on

Table 2. Select examples from the antibiotic cost visibility tool

AHFS class	Name	Dosage form	Route	Spectrum	Cost per day of therapy
Natural penicillins	Penicillin V potassium	Oral tablet	PO	Gram (+) (<i>Streptococcus</i>) and oral anaerobes	¢
	Penicillin G potassium	Powder for injection	IV-CI	Gram (+) (<i>Streptococcus</i>) and oral anaerobes	\$
Penicillinase-resistant penicillins	Dicloxacillin sodium	Oral capsule	PO	<i>Streptococcus</i> and <i>Staphylococcus</i> (no MRSA)	¢¢
	Nafcillin	Powder for injection	IV-CI	<i>Streptococcus</i> and <i>Staphylococcus</i> (not MRSA)	\$\$\$§
Aminopenicillins	Amoxicillin	Oral capsule	PO	PCN coverage plus some <i>Enterococcus</i> , <i>H. influenzae</i> and some <i>E. coli</i> , <i>Listeria</i> , some <i>Proteus</i>	¢
	Amoxicillin	Powder for oral suspension	PO	PCN coverage plus some <i>Enterococcus</i> , <i>H. influenzae</i> and some <i>E. coli</i> , <i>Listeria</i> , some <i>Proteus</i>	¢

Note: AHFS = American Hospital Formulary Service; CI = continuous infusion; *E. coli* = *Escherichia coli*; *H. influenzae* = *Haemophilus influenzae*; IV = intravenous; MRSA = methicillin-resistant *Staphylococcus aureus*; PCN = penicillin; PO = by mouth.

the Web site per month. Antibiotic dispensing costs were obtained from the institution's Information Warehouse. The total cost of returns was subtracted from the total cost of dispenses to obtain the net cost per month. All costs were summed for each month during the study time frame. Aggregate hospital CMI and patient days were obtained from the institution's department of finance. Cost visibility tool Web site utilization statistics were gathered using Google Analytics.

We used segmented linear regression to analyze the interrupted time series data, which allowed us to assess changes in the outcome of interest both over time (slope) and at the point of the intervention (level).⁶ Autocorrelation was determined based on the Durbin Watson *d* statistic and adjusted for via Prais-Winsten regression as necessary. Robust standard errors were calculated in the presence of heteroscedasticity. *P* values less than .05 were considered statistically significant. Statistical analysis was performed using STATA 11 (StatCorp LLC, College Station, TX). The protocol was approved for human subjects research by the institutional review board of the OSUWMC Office of Responsible Research Practices.

RESULTS

The results of the segmented regression analyses are shown numerically in Table 3 and graphically in Figure 2. Prior to implementation of EEI and the cost visibility tool, baseline antibiotic cost per 1,000 patient days was \$26,072 and was relatively stable (*P* = .844). Initiation of EEI was associated with a significant decrease in antibiotic cost per 1,000 patient days of \$4,675 (*P* = .003) at the time of intervention followed by a decreasing slope of \$906 per 1,000 patient days per month (*P* = .009). Initiation of the cost visibility tool was not associated with a change in level or slope of the main outcome (*P* = .508 and *P* = .844, respectively) (Table 3). Despite CMI increasing over the study time frame, adjustment for CMI had no impact on the directionality or statistical significance of the results (Table 3, Figure 3). Overall, with both of these interventions in place, this resulted in a 39% decrease in cost per 1,000 patient days (Figure 4).

When intravenous (IV) and oral (PO) antibiotics were evaluated separately, both were associated with significant decreases in cost immediately after the implementation of EEI (*P* = .008 and *P* = .001 respectively) (Table 3). After the implementation of EEI, only the cost of the IV antibiotics continued to decline at a significant rate (*P* = .004) (Table 3).

Table 3. Changes in selected antibiotic cost parameters pre and post implementation of an EEI and cost visibility tool

Model	Baseline level	Baseline slope	Level change after EEI	Slope change after EEI	Level change after cost visibility	Slope change after cost visibility ^a
Antibiotic cost (\$)	26,072 (24,041, 28,103)	26 (-246, 298) <i>P</i> = .844	-4,675 (-7,641, -1,710) <i>P</i> = .003	-906 (-1,564, -249) <i>P</i> = .009	891 (-1,842, 3,624) <i>P</i> = .508	-20 (-239, 199) <i>P</i> = .844
CMI-adjusted antibiotic cost (\$)	15,597 (14,513, 16,682)	2 (-14, 148) <i>P</i> = .979	-3,084 (-4,765, -1,404) <i>P</i> = .001	-537 (-895, -179) <i>P</i> = .005	975 (-567, 2,518) <i>P</i> = .205	-66 (-197, 65) <i>P</i> = .287
IV antibiotic cost (\$)	23,047 (21,238, 24,857)	7 (-237, 251) <i>P</i> = .952	-3,890 (-6,673, -1,108) <i>P</i> = .008	-909 (-1,505, -313) <i>P</i> = .004	1,300 (-1,255, 3,855) <i>P</i> = .305	-78 (-291, 136) <i>P</i> = .440
PO antibiotic cost (\$)	2,946 (2,616, 3,275)	36 (-9, 80) <i>P</i> = .112	-1,026 (-1,563, -489) <i>P</i> = .001	-7 (-117, 104) <i>P</i> = .898	-245 (-735, 246) <i>P</i> = .315	58 (29, 87) <i>P</i> = .010

Note: Cells contain adjusted regression coefficient, 95% confidence interval, and *P* value unless otherwise noted. *P* values were determined by segmented linear regression. Level of significance = .05. CMI = case mix index; EEI = efficiency and effectiveness initiative; IV = intravenous; PO = by mouth.

^aUnadjusted model due to multicollinearity.

Figure 2. Change in antibiotic cost per 1,000 patient days pre and post implementation of an efficiency and effectiveness initiative (EEI) and cost visibility tool.

Figure 3. Change in case mix index (CMI)-adjusted antibiotic cost per 1,000 patient days pre and post implementation of an efficiency and effectiveness initiative (EEI) and cost visibility tool.

After cost visibility tool implementation, the cost of PO antibiotics increased at a significant rate ($P = .01$) (Table 3, Figure 5).

Figure 6 demonstrates the overall utilization of the cost visibility Web site as the number of Web site

views per month and time in minutes spent accessing the Web site per month. There was an average of 76 page views per month, which equates to approximately 2 Web site views per day. The average time that the cost visibility site was opened per view

Figure 4. Change in antibiotic cost per 1,000 patient days extrapolation post implementation of an efficiency and effectiveness initiative (EEI).

Figure 5. Changes in intravenous (IV) and oral (PO) antibiotic cost per 1,000 patient days pre and post implementation of an efficiency and effectiveness initiative (EEI) and cost visibility tool.

was approximately 4 minutes. Page views peaked around the time of cost visibility tool implementation then declined over the study time frame. The average amount of time the Web site was opened varied over the time frame.

DISCUSSION

Implementation of EEI resulted in a significant decrease in antibiotic cost per 1,000 patient days immediately after implementation and over time; perhaps because of this, implementation of our passive

Figure 6. Cost visibility tool utilization.

cost visibility tool was generally not found to be associated with any additional antibiotic cost reduction. A longer observation time after implementation of the cost visibility tool may have demonstrated a more significant impact. Antibiotics are necessary in the care of many hospitalized patients, so the cost of antibiotics will never reach zero. Our data suggest that a new baseline antibiotic cost may have been achieved at the time of the implementation of the cost visibility tool.

To further evaluate the effects of EEI as well as the cost visibility tool, IV and PO antibiotic data were evaluated separately. In general, IV therapy is more costly than PO; part of the EEI initiative was stricter enforcement of the IV to PO conversion policy. Immediately after the implementation of EEI, both IV and PO routes of administration were associated with decreased cost per 1,000 patient days, which was likely due to a general push for overall cost reduction. This decrease in the cost metric continued for IV and PO therapy over time throughout the EEI time period until PO costs increased after implementation of the cost visibility tool, suggesting that the cost visibility tool may have been a driver of increased IV to PO conversion. This may be due in part to the availability of spectrum of activity information in the cost visibility tool, which facilitates the selection of PO antibiotics in place of IV therapy.

A number of studies have demonstrated that active pharmacy interventions have the potential to

reduce cost in the hospital environment. Ansari et al² reported success when implementing an active pharmacy intervention aimed at changing prescribing patterns based on knowledge of antibiotic cost. Pharmacists were responsible for actively monitoring antibiotic use and its appropriateness. If an antibiotic was identified as inappropriate due to the availability of a lower cost option with similar efficacy, pharmacy staff intervened with the medical team. These active interventions reduced cost of overall antibiotic use over 2 years by \$213,274, which exceeded the overall \$32,213 cost of implementing the intervention.

Additionally, Stuebing et al⁷ found similar results in a prospective observational study aimed at reducing the cost per patient day for routine laboratory testing. In the 4-month study, weekly announcements were made to surgical house staff and attending physicians during an educational conference. These announcements detailed the total cost of laboratory tests charged to non-intensive care unit patients during the previous week. Over the course of the study, cost savings amounted to \$54,967.

Literature surrounding the effect of passive pharmacy interventions has not shown such a benefit. Bates et al⁸ conducted 2 prospective controlled trials evaluating the impact of cost visibility at the time of order entry on the ordering of laboratory and radiological tests. The primary objective of both of these studies was to evaluate whether implementation of this tool reduced the total number of laboratory or radiological

tests per patient admission. Neither of the studies resulted in a significant change in this endpoint.⁸ These results are consistent with our findings; our passive tool did not appear to have a significant impact on antibiotic cost. Future studies at OSUWMC with a more active cost visibility intervention are anticipated.

Monthly aggregate CMI was factored into the metric because CMI is a measure of hospital resource utilization, so it was assumed to correlate with patient acuity and medication cost. Despite this, CMI increased while antibiotic cost decreased over time in our study, suggesting that either CMI is not well correlated with medication costs or that EEI combined with the cost visibility tool successfully minimized cost despite increasing patient acuity.

In our study, overall antibiotic cost per 1,000 patient days was substantially lower post EEI and implementation of the passive antibiotic cost visibility tool. Due to the fact that the effects of EEI and the cost visibility tool cannot be separated, we cannot conclude that the cost visibility tool alone would be successful. However we speculate that the effects may be more apparent at an institution that has not already undergone such a drastic cost reduction effort. An active intervention component may also enhance the impact of such a tool. Other analyses could include evaluating the impact of this tool on antibiotic prescribing in teaching versus nonteaching services or intensive care units versus non-intensive care units.

There were several limitations to our study. The data used to complete all analyses contained both inpatient and outpatient data; some patient care areas contain patients with both designations, and this could not be delineated for this project. There is currently no measure of patient acuity for outpatients, and therefore inpatient CMI was applied to all of the data in the CMI-adjusted analysis. Additionally, CMI determination methodology at OSUWMC changed during the study, which may have caused a change in CMI values without an associated change in patient acuity. Cost of antibiotics may fluctuate seasonally, but we could not account for seasonality in this study because there are less than 12 months in the EEI group. Due to the timing of the implementation of the cost visibility tool, it was not feasible to increase the number of months contained within the EEI-only timeframe. In addition, since the EEI and cost visibility time periods did have a significant amount of overlap, the impact of the cost visibility tool on antibiotic cost may have been masked by the success of EEI. EEI did not stop impacting antibiotic cost when the cost visibility tool

was implemented. The hits to the Web site decreased over time as expected due to suspected familiarity with the site content. Additionally, copies of the information located on the Web site could have easily been printed as a reference document. The time the Web site was opened may not reflect the amount of time the viewer was actively reviewing the information. Multicollinearity was present in the regression models; this is common with interrupted time series data. Multicollinearity causes imprecise and unreliable coefficients, increased standard errors, and wider confidence intervals. The unadjusted regression results of the slope after cost visibility tool implementation are reported as the adjusted magnitude and the direction of the coefficient of the slopes were inapt. Finally, we did not collect clinical outcomes data, therefore we cannot determine whether utilization of the tool had any impact on outcomes.

CONCLUSION

Our study demonstrated a significant and sustained decrease in antibiotic cost per 1,000 patient days when focused medication cost reduction efforts were implemented. An additional decline in the cost metric was not seen after the implementation of the cost visibility tool, which was likely due to the significant impact of EEI alone. Such a tool may be of more obvious benefit in institutions that have not implemented significant medication cost reduction strategies or where an active intervention could be paired with the cost visibility tool.

ACKNOWLEDGMENTS

The authors have no financial disclosures or conflicts of interest to report.

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