CONCISE COMMUNICATION

# Implementation of a Clinical Decision Support System for Antimicrobial Stewardship

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Clinical decision support systems (CDSSs) for antimicrobial stewardship require considerable human resources and financial investments. This pre-/postimplementation study evaluated the effect of a CDSS on performance of prospective audit with intervention and feedback and demonstrated an increase in interventions and recommendation acceptance countered by a substantial number of nonactionable alerts.

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Antimicrobial use drives antimicrobial resistance, and approximately 50% of antimicrobial use is inappropriate.[1,2] The Society for Healthcare Epidemiology of America and the Infectious Diseases Society of America published guidelines for developing antimicrobial stewardship programs (ASPs) to limit inappropriate antimicrobial use and the unintended consequences of such use, including the emergence of resistance, adverse events, and excess cost.[3] Prospective audit of antimicrobial use with direct interaction and feedback to prescribers is recommended as a core ASP strategy. Furthermore, clinical decision support systems (CDSSs) may improve antimicrobial decision making through availability of a combination of patient-specific data and costs.

Several studies have documented benefits associated with use of CDSSs, including decreased adverse events, shortened length of stay, decreased costs, and more appropriate antimicrobial use.[4-10] However, adoption of CDSSs is hampered by the time required by ASP and information technology personnel for implementation and maintenance and the cost of such systems.[11,12] Moreover, a key requirement for an effective CDSS is integration into clinical workflow.[13] This study evaluated the effect of the implementation of a CDSS on performance of prospective audit with intervention and feedback for the ASP at the Nebraska Medical Center, a 624-acute-care-bed academic medical center.

## METHODS

Institutional review board approval was obtained for this quasi-experimental pre-/postintervention study, hereafter referred to as pre-/postimplementation, since the intervention was implementation of a CDSS, TheraDoc (Hospira). During the preimplementation period (September 2007–February 2008), no reliable method existed for identification of patients for potential ASP intervention, and no systematic prospective audit with intervention and feedback occurred. Prospective audit with intervention and feedback by the ASP began following implementation of TheraDoc in October 2008. The postimplementation period included inpatients from September 2009–February 2010. Patients were identified for inclusion in the preimplementation period using an electronic database of patient data maintained by TheraDoc. More specifically, the same criteria used to trigger prospective alerts were applied, via an electronic query, to historical patient data to generate alerts retrospectively. Patients were identified for inclusion in the postimplementation period by prospective generation of 8 types of alerts within TheraDoc. The alerts evaluated and personnel responsible for them are described in Table 1.

For each alert type, the total number of actionable alerts (ie, an intervention was or could have been attempted) was collected. Reasons for alert dismissal were determined for alerts not considered actionable during the postimplementation period. Of the actionable alerts, the proportion for which an intervention was attempted was documented, as was the proportion of recommendations accepted.

Fisher exact tests and $\chi^2$ tests were utilized to assess categorical variables, while a $t$ test was used to compare continuous variables. SAS software (ver. 9.2; SAS Institute) was used.

## RESULTS

A total of 10,545 alerts were issued during the study: 1,974 during the preimplementation period and 8,571 during the postimplementation period. Alerts occurred among 607 and 791 patients in the pre- and postimplementation periods, respectively. Patient characteristics were similar except for a higher intensive care unit admission rate (33.5% vs 28.1%; $P = .03$) during the postimplementation period versus the preimplementation period. The mean age ($\pm$SD) of the patients in the pre- and postimplementation periods was 64 $\pm$ 19 and 63 $\pm$ 19 years, respectively ($P = .33$). Approximately half of the population was female (49% preimplementation and 51% postimplementation; $P = .48$), and the majority were Caucasian (86% preimplementation and 82% postimplementation; $P = .06$).

Overall, 3,153 alerts (30%) were actionable. The proportion of actionable alerts was low for redundant anaerobic coverage, drug-bug mismatch, vancomycin for coagulase-negative staphylococci (CoNS), and vancomycin for methicillin-susceptible *Staphylococcus aureus* (Table 2). Of 6,517 nonactionable alerts during the postimplementation period, the reasons were no need for an intervention/therapy deemed appropriate ($n = 4,260$; 65%), previously dismissed alert

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TABLE 1. Alert Description and Personnel

| Alert | Description | Personnel responsible |
|---|---|---|
| Influenza vaccination | Eligible to receive influenza vaccine | NA[a] |
| Pneumococcal vaccination | Eligible to receive pneumococcal vaccine | NA[a] |
| Polyantibacterials | Receiving 3 or more antibacterials | ASP |
| Redundant anaerobic coverage | Receiving 2 or more agents with antianaerobic activity | ASP |
| Drug-bug mismatch | Agents not active against pathogens isolated | ASP |
| Vancomycin for CoNS | Receiving vancomycin and blood culture positive for CoNS | ASP |
| Vancomycin for MSSA | Receiving vancomycin and any culture positive for MSSA | ASP |
| No positive cultures | Receiving antibiotic therapy with no positive cultures in the prior 7 d | Decentralized pharmacists |

NOTE. ASP, antimicrobial stewardship program; CoNS, coagulase-negative staphylococci; MSSA, methicillin-susceptible *Staphylococcus aureus*; NA, not applicable.

[a] No interventions were made regarding influenza/pneumococcal vaccination because of the institutional policy for automatic screening and administration by nursing staff beginning in July 2007.

($n$ = 1,064; 16%), alert based on old data ($n$ = 838; 13%), duplicate alert ($n$ = 344; 5%), and other unspecified reasons ($n$ = 11; 0.2%).

Implementation of the CDSS led to statistically significant increases in intervention attempts, with 284 interventions made during the postimplementation period. Interventions were made by ASP personnel on 75%–92% of the actionable alerts. Interventions for no positive cultures, which were the responsibility of decentralized pharmacists, were made on 12% of the actionable alerts. Interventions were accepted in 88% of cases, with acceptance rates greater than 90% for drug-bug mismatch and 100% for vancomycin use for CoNS (Table 2).

## DISCUSSION

To our knowledge, this is the first published study evaluating the effect of CDSS implementation on performance of prospective audit with intervention and feedback for an ASP. The introduction of a CDSS allowed systematic performance of prospective audit with intervention and feedback, which previously was not possible at our institution. The results of this study demonstrate a statistically significant increase in interventions in patient care and a high rate of subsequent acceptance of those recommendations. Unfortunately, the increase in interventions in this study was countered by a substantial number of nonactionable alerts and significant time spent reviewing these alerts (approximately 2–3 hours/day, with an additional 1–2 hours for interventions on actionable alerts and documentation). Nonactionable alerts often occurred multiple times for the same patient, as evidenced by approximately 30% of nonactionable alerts being previously dismissed or duplicates and an average of about 11 alerts per patient during the postimplementation period. However, the most common reason that alerts were considered nonactionable was that an intervention was not deemed necessary by ASP personnel despite meeting criteria to trigger the alerts, indicating that electronic logic cannot replace clinical judgment of a pharmacist or physician. Feedback on the nonactionable alerts was provided to TheraDoc in the form of enhancement requests. TheraDoc reports making several enhancements to the CDSS in an effort to decrease the number of nonactionable alerts; however, we have not yet systematically evaluated the effect of the newly enhanced alerts on the number of nonactionable alerts.

This study noted higher intervention rates for alerts for which ASP personnel were responsible (average of 81%) as compared with the alert for which decentralized pharmacists were responsible (no positive cultures; intervention rate of 12%). This may be related to the fact that the ASP personnel had time dedicated to stewardship activities, while decentralized pharmacists had multiple competing initiatives to integrate into their daily workflow. Additionally, the low number of actionable alerts for no positive cultures (374/1,096, 34%; Table 2) likely contributed to alert fatigue, emphasizing the importance of working with the CDSS vendor to reduce the number of nonactionable alerts through system/alert enhancements. Importantly, acceptance rates were similar regardless of whether interventions were made by ASP personnel or decentralized pharmacists (Table 2), suggesting that decentralized pharmacists can play an important supportive role for ASPs.

There are several limitations to note when considering these results. First, during the preimplementation period, no mechanism for intervention documentation existed, so it is possible that interventions were made during the preimplementation period that are not accounted for in this study. Second, an institutional policy whereby nurses were responsible for screening and administering influenza and pneumococcal vaccines to eligible patients began in July 2007. Although this made review of interventions a moot point, influenza and pneumococcal alerts were tracked to document how many patients were eligible to receive the vaccine(s) and how many ultimately received the vaccine(s). Third, the number of alerts in the preimplementation period was lower than in the postimplementation period, which may be related to patients being identified through a retrospective query of an electronic database. This method of alert generation may have led to fewer alerts by eliminating many of the nonactionable

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TABLE 2. Alert Summary

| | Preimplementation ($n$ = 1,974) | Postimplementation ($n$ = 8,571) |
|---|---|---|
| Influenza vaccination | 477 | 1,030 |
| Actionable | 451 (95) | 852 (83) |
| Intervention made[a] | NA | NA |
| Intervention accepted | NA | NA |
| Pneumococcal vaccination | 256 | 713 |
| Actionable | 243 (95) | 495 (69) |
| Intervention made[a] | NA | NA |
| Intervention accepted | NA | NA |
| Polyantibacterials | 287 | 2,888 |
| Actionable | 153 (53) | 157 (5) |
| Intervention made[b] | 0 (0) | 118 (75) |
| Intervention accepted | NA | 102 (86) |
| Redundant anaerobic coverage | 96 | 758 |
| Actionable | 40 (42) | 68 (9) |
| Intervention made[b] | 0 (0) | 60 (88) |
| Intervention accepted | NA | 50 (83) |
| Drug-bug mismatch | 311 | 1,688 |
| Actionable | 67 (22) | 85 (5) |
| Intervention made[b] | 0 (0) | 70 (82) |
| Intervention accepted | NA | 66 (94) |
| Vancomycin for CoNS | 294 | 259 |
| Actionable | 14 (5) | 13 (5) |
| Intervention made[b] | 0 (0) | 12 (92) |
| Intervention accepted | NA | 12 (100) |
| Vancomycin for MSSA | 126 | 139 |
| Actionable | 27 (21) | 10 (7) |
| Intervention made[b] | 0 (0) | 9 (90) |
| Intervention accepted | NA | 8 (89) |
| No positive cultures | 127 | 1,096 |
| Actionable | 104 (82) | 374 (34) |
| Intervention made[b] | 0 (0) | 15 (12)[c] |
| Intervention accepted | NA | 12 (80) |
| Total | | |
| Actionable | 1,099 (56) | 2,054 (24) |
| Intervention made | 0 (0) | 284 (40)[d] |
| Intervention accepted | NA | 250 (88)[d] |

NOTE. Data are no. (%). CoNS, coagulase-negative staphylococci; MSSA, methicillin-susceptible *Staphylococcus aureus*; NA, not applicable.

[a] No interventions were made regarding influenza/pneumococcal vaccination because of the institutional policy for automatic screening and administration by nursing staff beginning in July 2007.

[b] $P < .01$ for pre- versus postimplementation periods.

[c] One hundred twenty-five were fully evaluated.

[d] Excludes influenza/pneumococcal vaccination alerts.

alerts, as suggested by higher rates of actionable items for all alert types except vancomycin use for CoNS (Table 2). Last, since the purpose of this study was to evaluate the effect of CDSS implementation on performance of prospective audit with intervention and feedback, comparisons related to clinical outcomes, costs, and time were not made. These factors are important to consider in the decision to purchase a CDSS for one's institution.

In conclusion, this study provides information suggesting that although the overall proportion of actionable alerts generated by a CDSS was low, implementation of a CDSS for an ASP significantly improved the ability to perform prospective

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audit with intervention and feedback, as evidenced by the statistically significant increase in intervention rates.

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*Potential conflicts of interest.* E.D.H. reports that she is currently an employee of Cubist Pharmaceuticals; is a shareholder in Cubist Pharmaceuticals; has been a consultant for Ortho-McNeil Pharmaceuticals, Cubist Pharmaceuticals, and Forest Laboratories; and has received research funding from Pfizer. M.E.R. reports that he has received research funding from Cubist Pharmaceuticals, Sanofi-Pasteur, Cardinal Health Foundation, 3M, and Molynlcke. T.C.V. reports that he has received research funding from Cubist Pharmaceuticals and ViroPharma. All other authors report no conflicts of interest relevant to this article. All authors submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and the conflicts that the editors consider relevant to this article are disclosed here.

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