Surveillance Software and Prospective Audit and Feedback Rounds Advance Antimicrobial Stewardship at an Acute Care Community Hospital

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Abstract

Antimicrobial stewardship is a key strategy to facilitate judicious antimicrobial use. Software that can amalgamate prescribing and microbiology information in near real-time reporting and track antimicrobial resistance patterns aids timely interventions. This article examines the impact of a clinical surveillance software used to identify patients for prospective audit and feedback rounds by an antimicrobial stewardship team on antibiotic utilization, patient outcomes and workload efficiencies at an acute care community hospital. Results from a general internal medicine unit show statistically significant reductions in the use of broad-spectrum antibiotics and antibiotic expenditures, with no untoward changes in key clinical and patient safety outcomes.

Background

Many existing antibiotics are fast becoming less effective or ineffective, and there is a striking lack of development of new drugs active against multi-drug-resistant bacteria (Boucher et al. 2013). This poses a challenge in the era of rising rates of infections caused by difficult-to-treat organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA) and extended spectrum beta-lactamase (ESBL) bacteria. The development of antimicrobial resistance has been shown to be associated with significant patient morbidity, mortality and increased cost of care. MRSA alone kills more people in the US (approximately 19,000) every year than other well-recognized diseases such as emphysema, Parkinson's disease and HIV/AIDS combined (Spellberg et al. 2011). Studies have shown that patients with MRSA infections have a significantly longer length of stay and account for substantially higher cost of care compared to patients with methicillin-susceptible *S. aureus* infections (Engemann et al. 2003; Lodise and McKinnon 2005). Similarly, another study revealed that a significantly higher proportion of patients (60.8%) died following a bacteraemic infection caused by ESBL-producing *Escherichia coli* compared to non-ESBL producing *E. coli* (23.7%) (Melzer and Petersen 2007). Delays in initiating appropriate antibiotic therapy was also found to be significantly associated with mortality.

The misuse of antibiotics plays a significant role in antibiotic resistance and other unintended consequences of antibiotic use. Often, antibiotics are mismatched to the causative pathogen or used in cases where they are not warranted at all. It is estimated as high as 50% of antimicrobial use in the inpatient setting is either unnecessary or suboptimal (Dellit et al. 2007). Antibiotics can alter normal bacterial flora by indiscriminately attacking both the pathological and naturally occurring, beneficial bacteria found in the intestines, lungs and bladder, leading to potentially life-threatening secondary infections, such as *Clostridium difficile* infections.

To optimize antibiotic use and to mitigate the unintended consequences of antibiotic therapy, there is a critical need for antimicrobial stewardship programs (ASPs). The Infectious Diseases Society of America defines antimicrobial stewardship as "coordinated interventions designed to improve and measure the appropriate use of antimicrobials by promoting the selection of the optimal antimicrobial drug regimen, dose, duration of therapy, and route of administration. Antimicrobial stewards seek to achieve optimal clinical outcomes related to antimicrobial use, minimize toxicity and other adverse events, reduce the costs of healthcare for infections, and limit the selection for antimicrobial resistant strains" (Infectious Diseases Society of America 2017)

Health Canada has made antimicrobial stewardship a national healthcare priority, through a federal framework for action and a subsequent action plan (Public Health Agency of Canada 2014, 2015). In 2012, antimicrobial stewardship was added to Accreditation Canada's Required Organizational Practices (ROPs) – each accredited acute care institution must have a program for antimicrobial stewardship to optimize antimicrobial use. The ROP states "the program must be inter-disciplinary, involving pharmacists, infectious diseases physicians, infection control specialists, physicians, microbiology staff, nursing staff, hospital administrators and information system specialists, as available and appropriate. Recommended interventions include audit and feedback rounds, a formulary of targeted antimicrobials and approved indications, education, antimicrobial order forms, guidelines and clinical pathways for antimicrobial utilization, strategies for streamlining or de-escalation of therapy, dose optimization, and parenteral to oral conversion of antimicrobials (where appropriate)" (Accreditation Canada 2017).

ASPs require resources to be truly effective in achieving their goals. The fiscal reality of the Canadian healthcare system makes the most important resource in an ASP – the staff time of infectious disease physicians, infection control practitioners and clinical pharmacists – increasingly scarce.

In recent years, a variety of software systems, both commercial and independently designed systems, have been developed to automate data collection and reporting to prioritize patient cases needing attention and enable the ASP team to expand its reach with a relatively modest allocation of staff resources. These systems integrate portions of the electronic medical record with laboratory, admission/discharge/transfer and medication information.

Interventions that facilitate initiating appropriate therapy in a timely manner improve patient care. Automated, computer-based surveillance facilitates more efficient targeting of antimicrobial interventions, tracking of antimicrobial resistance patterns and identification of nosocomial infections and adverse drug events (Dellit et al. 2007; Evans et al. 2009). Such programs that use surveillance technology have been shown to be cost-effective (Green et al. 2009).

Implementation/methodology

In March 2012, an antimicrobial stewardship program was introduced at The Scarborough Hospital (TSH), an acute care community hospital in Toronto, Ontario. TSH has two sites, the General site and the Birchmount site, with a total of 552 beds. (In December 2016, the Scarborough Hospital integrated with the Centenary site of Rouge Valley Health System to become one hospital corporation named Scarborough and Rouge Hospital.) The program consists of a full-time ASP pharmacist and two infectious disease physicians, who dedicate a total of two days to the program each week. The team uses a collaborative and evidence-based approach to optimize antimicrobial use. Prospective audit and feedback (PAF) rounds have been carried out on specific units since the beginning of the program. PAF is a patient-specific review of individual cases and recommendations to the most responsible physicians to promote the appropriate use of antimicrobials and to educate against misuse or overuse of antibiotics.

In June 2014, the ASP team started to conduct twice weekly PAF rounds on a general medical unit that was identified as a location of high antibiotic use. To facilitate identification of patients for PAF, an information technology solution was included as part of the program budget to facilitate workflow because of the limited availability of human resources. Any software solution employed had to be compatible with the TSH electronic medical record system (MEDITECH). ICNet Pharmacy, a clinical surveillance software system, was introduced at TSH's two sites in October 2013. The software links and integrates medication data, laboratory data, patient location data and selected clinical data in a single record to facilitate antimicrobial stewardship activities and drug utilization analysis.

Elements of the software include:

- Automatically generated alerts sent via email to ASP team members regarding microbiology and/or medication related elements for patients (e.g., pathogen/drug mismatches and bloodstream infections caused by selected organisms).
- Reports with medication and microbiology information for patients requiring surveillance to facilitate prioritization of interventions. Reports also cover cumulative antimicrobial susceptibility.
- Calculating and reporting of antimicrobial consumption by prescriber or unit-specific information, using defined daily doses (DDD) and days of therapy (DOT),
- A repository for documenting investigations and interventions. Notes are held in chronological order while highlighting different categories, encouraging communication and collaboration among users.
- Intervention reports summarizing documented ASP interventions and outcomes, allowing for future analysis of these records.

While there is no single best metric by which to evaluate the impact of ASPs, TSH chose DDD per 1,000 patient days, antibiotic costs, mortality rates, hospital length of stay, hospital readmission within 30 days from discharge from the general medical unit for evaluation purposes because they provide measures of antimicrobial consumption and patient outcomes that could be tracked and compared over time. The World Health Organization defines DDD as "the assumed average maintenance dose per day for a drug used for its main indication in adults" (2016).

The total number of ASP interventions and the types of interventions were also measured to evaluate the impact of the ASP team through PAF rounds.

The ASP team considered three factors in evaluating the impact of using the surveillance software with the PAF rounds:

- The reduction in staff time spent in identifying patients for potential interventions and the ability to identify all patients who were receiving antibiotic treatment in the units in which PAF rounding is done.
- The types of interventions suggested and the percentage accepted by the most responsible physicians.
- The impact of intervention, as measured by DDD and antibiotic expenditures. The pre-intervention period (July 2013–June 2014) was compared against year 1 of PAF rounds/software implementation (July 2014–June 2015) and year 2 of PAF rounds/software implementation (July 2015–June 2016).

Statistical analyses were performed using SAS (Version 9.4, Cary, North Carolina).

Results

Prior to using ICNet Pharmacy, the ASP pharmacist would need to manually review each patient profile in the hospital electronic medical record system to identify all the patients who had an active antibiotic prescription on the day of PAF rounds. The average time spent by the ASP pharmacist on this task was 30 minutes. In contrast, the ICNet Pharmacy software was able to generate the pre-programmed report in 2–3 minutes.

The tables in this section compare the difference in antibiotic usage before and after implementation of the software and PAF rounding. Table 1 illustrates the recommendation acceptance rates. On the general medical unit, ASP recommendations were fully accepted by physicians more than 90% of the time. The top three types of ASP recommendations were antibiotic discontinuation, duration optimization and antibiotic de-escalation.

Table 2 details antibiotic utilization pre- and post-implementation on the general medical unit. A statistically significant reduction in broad-spectrum antibiotic utilization was observed, driven by a dramatic decrease in use of fluoroquinolones, piperacillin-tazobactam and vancomycin use. The reduction in broad-spectrum antibiotic utilization was especially notable, as it was accompanied by a statistically significant decrease in usage of azithromycin. There was also a trend towards decreased usage of other narrow-spectrum antibiotics, such as penicillins and metronidazole.

Consequent to the reduction in antibiotic utilization, antibiotic expenditure was reduced by a statistically significant amount (Table 3). While cost reduction was not the objective of instituting the program, it is a positive outcome. While the nosocomial *C. difficile* rate appeared to increase during the post-intervention period, the rate of 0 cases per 10,000 patient days during the 12 month pre-intervention period is atypical for the unit. A review of historic data found 2.24 and 4.40 *C. difficile* cases per 10,000 patient days in the two years prior to the pre-intervention period, that are comparable to year 1 and year 2 PAF rounds/software implementation, respectively.

TABLE 1.
Outcomes of antimicrobial stewardship program interventions

Intervention outcomes	Year 1 of PAF rounds/software, *n* (%)	Year 2 of PAF rounds/software, *n* (%)
Accepted	683 (94%)	671 (92%)
Partially accepted	12 (2%)	23 (3%)
Rejected	28 (4%)	39 (5%)
Total	723	733

PAF = prospective audit and feedback.

Discussion

The positive impact of PAF rounds validates earlier studies that show patient-specific review and recommendations to the prescriber, along with feedback of reliable institutional-specific reports for antimicrobial utilization and resistance to clinicians over time, optimize antibiotic use (Ansari et al. 2003; Fraser 1997; Solomon et al. 2001). PAF is greatly facilitated by timely data and analysis. Manual data extraction from the electronic health records is time-consuming and difficult. Data are raw and not in a format that can be easily analyzed. Understanding of and proficiency in software spreadsheet programs is required for data analysis. In contrast, the surveillance software used at TSH is user-friendly and facilitates workflow by minimizing the time required to identify patients for stewardship interventions. Productivity as a function of efficiency in performing tasks such as extracting patient lists, compiling reports and analyzing data were the main advantages of using the ICNet software.

TABLE 2.
Antibiotic utilization pre- and post-intervention, general medical unit and intensive care unit

Data in defined daily doses per 1,000 patient days					
Class or agent	**Pre-intervention**	**Year 1 of PAF/software**	***p*-value***	**Year 2 of PAF/software**	***p*-value***
Broader-spectrum antibiotics					
Fluoroquinolones§	112.9	47.7	0.001	43.9	0.0005
Piperacillin-tazobactam	43.1	32.0	0.62	21.3	0.03
Vancomycin	23.3	14.2	0.09	10.1	0.03
Carbapenems¶	17.0	18.6	0.73	11.5	0.09
Aminoglycosides†	5.9	0.4	0.02	2.4	0.31
Amoxicillin-clavulanic acid	75.6	78.8	0.62	66.5	0.38
Ceftriaxone	2.4	8.9	0.01	6.2	0.08
Ceftazidime	4.5	18.6	0.38	13.2	0.03
Narrow-spectrum antibiotics					
Penicillins‡	47.8	34.9	0.08	36.4	0.20
First-generation cephalosporins◊	30.9	39.0	0.27	31.3	0.91
Second-generation cephalosporins**	144.3	104.9	0.03	136.4	0.57
Azithromycin	74.1	55.3	0.13	54.8	0.03
Metronidazole	65.9	57.1	0.13	50.7	0.09

*Wilcoxon signed-rank test. §Ciprofloxacin, levofloxacin, moxifloxacin. ¶Ertapenem, imipenem, meropenem. †Gentamicin, tobramycin. ‡Ampicillin, amoxicillin, cloxacillin, penicillin. ◊Cefazolin, cephalexin. **Cefuroxime, cefprozil.

TABLE 3.
Secondary outcomes of software/PAF rounds

Outcome	**Pre-intervention**	**Year 1 of PAF/software**	***p*-value**	**Year 2 of PAF/software**	***p*-value**
Antibiotic expenditures					
Total antibiotic expenditure per patient day	$2.80	$2.34	0.03*	$1.83	0.007*
Total antibiotic expenditure	$30,806	$28,515	0.62*	$22,726	0.02*
Clinical outcomes					
Mean length of stay (days)	8.43	7.90	0.27§	8.59	0.55§
Mortality	6.30%	5.96%	0.71§	6.67%	0.86§
Mean 30-day readmissions	10.33	11.75	0.24§	10.92	0.44§
Microbiologic outcome					
Clostridium difficile cases per 10,000 patient days	0	3.28	0.04¶	1.61	0.34¶

PAF = prospective audit and feedback.*Wilcoxon signed-rank test. §Wilcoxon rank-sum test. ¶Student's *t*-test with Satterthwaite's correction.

The software is highly configurable in generating reports for internal and external purposes. Data can be run for any unit or any time frame specified by the user. Data analysis tools are built into the software to enable quick investigation into different data sets with means of presenting the data in a meaningful and timely way. These time savings and analytics free the ASP team to spend more time on patient care, providing more targeted clinical input and feedback directly to the most responsible physicians.

Better patient care is realized by optimizing antibiotic selection, dose and duration which in turn, minimizes the unintended consequences of antibiotic use. PAF was safe, as no significant changes in mortality, hospital length of stay, hospital readmission within 30 days from discharge were observed despite the reduction in antibiotic use.

Conclusion

Choosing between various strategies to optimize antibiotic use with limited resources is a common challenge faced by many hospitals. Prospective audit and feedback rounds, enhanced by automated surveillance software, is a promising solution that improves the productivity and efficiency of antimicrobial stewardship staff and enable more effective reports and analysis. In a general internal medicine unit of an acute care community hospital, this approach resulted in decreased overall antibiotic use and expenditures, driven by optimizing antibiotic duration of therapy and de-escalation from broad-spectrum to narrow-spectrum antibiotics where appropriate. Moreover, the software enabled the team to dedicate more time to the provision of direct patient care, provide timely targeted clinical input and feedback directly to clinicians and track metrics on the impact of the antimicrobial stewardship program. Although it was not a goal of the program, it also resulted in clear savings in drug acquisition costs.

Systematic reassessment of antibiotics, even when conducted on a twice-weekly basis, with case-by-case feedback to the prescribing physicians, appears to be a safe and effective means to improve antibiotic use. HQ

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