

Use of Computer Decision Support in an Antimicrobial Stewardship Program (ASP)

R.S. Evans^{1,2}; J.A. Olson³; E. Stenehjem⁴; W.R. Buckel⁵; E.A. Thorell⁶; S. Howe¹; X. Wu¹; P.S. Jones⁴; J.F. Lloyd¹

¹Medical Informatics, Intermountain Healthcare; ²Biomedical Informatics, University of Utah; ³Pharmacy, Primary Children's Medical Center; ⁴Clinical Epidemiology and Infectious Diseases, Intermountain Medical Center; ⁵Pharmacy, Intermountain Medical Center; ⁶Pediatric Infectious Diseases, University of Utah, Salt Lake City, Utah

Keywords

Clinical decision support, antimicrobial stewardship, antibiotic resistance, patient specific alerts, antimicrobial stewardship program, ASP, medical informatics, computer decision support

Summary

Objective: Document information needs, gaps within the current electronic applications and reports, and workflow interruptions requiring manual information searches that decreased the ability of our antimicrobial stewardship program (ASP) at Intermountain Healthcare (IH) to prospectively audit and provide feedback to clinicians to improve antimicrobial use.

Methods: A framework was used to provide access to patient information contained in the electronic medical record, the enterprise-wide data warehouse, the data-driven alert file and the enterprise-wide encounter file to generate alerts and reports via pagers, emails and through the Centers for Diseases and Control's National Healthcare Surveillance Network.

Results: Four new applications were developed and used by ASPs at Intermountain Medical Center (IMC) and Primary Children's Hospital (PCH) based on the design and input from the pharmacists and infectious diseases physicians and the new Center for Diseases Control and Prevention/ National Healthcare Safety Network (NHSN) antibiotic utilization specifications. Data from IMC and PCH now show a general decrease in the use of drugs initially targeted by the ASP at both facilities.

Conclusions: To be effective, ASPs need an enormous amount of "timely" information. Members of the ASP at IH report these new applications help them improve antibiotic use by allowing efficient, timely review and effective prioritization of patients receiving antimicrobials in order to optimize patient care.

Correspondence to:

R. Scott Evans, MS, PhD, FACMI
Department of Medical Informatics, LDS Hospital
8th Avenue & C Street
Salt Lake City, Utah 84143
Phone: 801 408-3029
Email: rscott.evans@imail.org

Appl Clin Inform 2015; 6: 120-135

<http://dx.doi.org/10.4338/ACI-2014-11-RA-0102>

received: November 4, 2014

accepted: January 20, 2015

published: March 3, 2015

Citation: Evans RS, Olson JA, Stenehjem E, Buckel WR, Thorell EA, Howe S, Wu X, Jones PS, Lloyd JF. Use of computer decision support in an antimicrobial stewardship program (ASP). *Appl Clin Inf* 2015; 6: 120-135
<http://dx.doi.org/10.4338/ACI-2014-11-RA-0102>

1. Introduction

The use of antimicrobial agents to treat infections creates selective pressure, allowing for increased spread of resistant bacteria. It is apparent that our ability to stay ahead of resistance by creating new antimicrobial agents is losing ground. Pharmaceutical companies have less incentive to create new antimicrobials given the short length of treatment and falling profits. Current regulatory mechanisms further impede this process with long delays in approval of new agents. These factors combined with the marked inappropriate use of antibiotics have led to an alarming situation where some infections have no cure [1, 2]. Moreover, previous reports indicate that inappropriate use of current antimicrobials results in higher mortality rates, longer lengths of stay, and increased medical costs [3].

In 2007, the Infectious Disease Society of America and the Society for Healthcare Epidemiology of America published guidelines for the development and enhancement of antimicrobial stewardship programs (ASPs) for adult and pediatric patients [4]. The main objective of antimicrobial stewardship is to improve clinical outcomes and minimize unintended consequences of antimicrobial use, including toxicity and selection of resistant pathogens. ASPs should include infectious diseases physicians, clinical pharmacists with infectious diseases training, a clinical microbiologist, and a hospital epidemiologist. Since these programs require a large amount of information, the guidelines state that information system specialists also need to be part of ASPs.

ASPs have been developed in urban and rural hospitals throughout the world and many report reductions in both inappropriate antimicrobial use and total antimicrobial use, decreased antimicrobial resistance, reductions in *Clostridium difficile* rates, and improved patient care and outcomes [3, 5–12]. Some also report improved documentation of antimicrobial use in the medical record [13]. One study showed their ASPs reduced antimicrobial expenditures an average of \$920,070 to \$2,064,441 per year [14] while another study reported that after their longstanding ASP was terminated, antimicrobial costs increased 32.3% within 2 years, at a cost of \$2 million for the medical center [15]. However, not all ASP studies show a positive impact on antimicrobial use [16, 17] and the misuse of antibiotics more often results from inadequate information rather than inappropriate behavior [18]. We found the amount of information required for ASPs to be effective is enormous. Thus, the inability of some ASPs to show a positive impact may have been due to limited medical informatics resources which resulted in a lack of timely information and the inability to monitor appropriate antimicrobial use and provide educational follow up. This paper describes four new computer applications we developed which are currently used by ASPs at Intermountain Healthcare to provide efficient, timely review and effective prioritization of patients receiving antimicrobials hospital-wide.

1.2 Program logistics, gap analysis, and improvement processes

In 2010, Primary Children's Hospital (PCH) hired a pharmacist and physician to create a comprehensive and prospective ASP. Their initial task was to document information needs, gaps within the current electronic applications and reports, and workflow interruptions requiring manual information searches that decreased their ability to prospectively audit and provide feedback to clinicians on antimicrobial use. In 2012, Intermountain Medical Center (IMC) hired an infectious diseases physician and a pharmacist specializing in infectious diseases to oversee the development of their ASP providing a new and different view for the need of additional information and workflow improvement. Over the past 5 years, numerous formal and ad hoc meetings were used to document which reports were useful, what time-sensitive data elements were necessary, frequency of report generation (e.g. every 5 minutes or once daily), and optimize the alerting methods (email, pager/cell phone, web/mobile device, etc). These meetings removed some of the information gaps and improved the ASP workflow. Although these new applications are being implemented at other IH hospitals, this paper only includes data from PCH and IMC. PCH is a 289 bed pediatric hospital and IMC is primarily an adult academic medical center with 477 beds. Both hospitals are teaching facilities for the University of Utah School of Medicine.

2. Methods

2.1 Setting

Intermountain Healthcare (IH) is a non-profit healthcare system that operates 22 hospitals and over 200 clinics, urgent care centers, and physician offices and home healthcare in Utah and Idaho. For over 30 years, the Departments of Infectious Diseases at LDS Hospital (LDSH) and Primary Children's Hospital (PCH) at IH have been developing, implementing and evaluating computerized tools to improve the use of empiric, prophylactic and targeted antimicrobial agents for pediatric and adult patients at both urban and rural hospitals [18–27]. Those previous computerized tools were designed to help physicians select appropriate antimicrobials (including dosage and route), shorten the duration of these drugs, improve the timing of administration (eg. pre-operative prophylaxis), and reduce antimicrobial resistance. In 2007, IH opened their new Level I trauma center, IMC. To date, IH does not have computerized provider order entry (CPOE) available at any of its hospitals. With the increase in antibiotic resistance and few new antibiotics being developed during the past eight years, it became apparent new and intensive antibiotic surveillance and control measures would be needed.

2.3 Intervention

Based on the information gaps identified by the ASPs at PCH and IMC (lack of a sortable list of all current antimicrobials, timely identification of serious infections, need for antimicrobial “time out” identification and better antimicrobial usage data) we determined that four new applications would need to be developed. To develop the four new applications for antimicrobial stewardship, we expanded the framework we initially developed in 2003 to monitor patients with multi-drug resistant organisms (MDRO) as they moved throughout IH [28]. This framework uses all clinical and financial information within the IH network including data from hospitals, clinics, urgent care centers, home health, ancillary echocardiogram and ECG databases and the insurance plan (► Figure 1). Clinical data from the electronic medical record (EMR) is stored in the enterprise-wide data warehouse (EDW) each night. After the EDW data is stored, the time-driver activates numerous SQL queries that scan the EDW, electrocardiogram, echocardiogram and insurance plan data for pertinent data that can be used to improve care and prevent possible harm whenever patients are readmitted to any facility. That pertinent data is stored as data-marts in the online staging server. Since the EDW is a huge archive database, data access time is not always acceptable for clinical care and it is off-line for a few hours once a month for updates and maintenance. In contrast, the staging server provides quick access and is always available.

All patient encounters are scheduled in the enterprise encounter table. When any data is stored in the EMR, the data-driver can automatically activate specific decision support applications and store that information in the Alert file. The time-driver can also activate decision support applications from once a day to every minute. Thus, the logic in the decision support applications has access to any data in the EMR, the EDW, the staging server, ECGs, echocardiograms, the insurance database, the enterprise encounter table and the data-driven alert file. This framework is then able to send alerts based on the programmed logic via email, pagers/cell phones, the provider message log, the web, smart phones, the Utah and Idaho departments of health and the Center for Diseases Control and Prevention (CDC) via the National Healthcare Surveillance Network (NHSN).

Changes in the administration of targeted antimicrobials reported in this paper were collected by the new NHSN application methods described below. This quality improvement study was approved by the Intermountain Office of Research for Publication.

3. Results

Four new applications are now used by ASPs at IMC and PCH based on the design and input from the pharmacists and infectious diseases physicians and the new Center for Diseases Control and Prevention/National Healthcare Safety Network (NHSN) antibiotic utilization specifications.

Members of the ASP report these applications help organize data more efficiently and in alignment with CDC recommendations and require data from the encounter table, EMR, EDW, staging server, data-driven alert file and were developed using java, SQL, XML, Tandem Application Language, an IH developed data-driven query language, and Excel®.

3.1 Daily Antimicrobial use email spreadsheet

A central part of the daily ASP workflow is the prospective audit of current antimicrobial use and feedback to clinicians on appropriateness and potential areas for prescribing improvement. Each morning at 6:30am, the ASP leadership at each hospital receives an email containing an Excel® spreadsheet listing every antimicrobial administered to inpatients during the past 24 hours along with 20 data elements that provide additional relevant clinical information (► Table 1). Due to the high volume of patients seen at both hospitals, a tool to identify patients on antimicrobials was found to be essential. During one year, PCH dispensed 75,200 doses of antimicrobials to 7,764 different patients while IMC dispensed 104,617 doses of antimicrobials to 23,505 different patients. However, simply identifying patients on antimicrobials is not enough. In larger hospitals, the number of patients on antimicrobials each day is too large to review all patients on any antimicrobial. Therefore, a sortable list of patients on antimicrobials was found to be paramount to assist ASP clinicians in identifying patients on antimicrobials of high stewardship importance (eg. carbapenems) and identify patients located on floors targeted for enhanced stewardship activities (eg. intensive care unit (ICU)). The spreadsheet solution provides the ASP a tool to prioritize their surveillance and sort data by a number of factors, including drug name, service, duration of therapy, renal dysfunction, or dose, etc. The variety of sortable fields provides the ASP the flexibility needed to identify targets of intervention. The additional data elements provide useful patient-specific references when making interventions to teams – including age, gender, weight, serum creatinine and antimicrobial allergies. The Excel® spreadsheet was found to be an ideal format since many members on the ASP had previous experience with the program. The ASP report the ability to use the sorting functions provided by the spreadsheet has allowed them to become more efficient by significantly reducing analysis time, streamlining documentation via follow-up notes for each antimicrobial in the “ASP Rounds” column, and facilitates sharing between ASP members by providing the ability to copy certain data to the secure ASP “TeamSpace” (a secure intranet area for sharing information). After implementation of the sortable spreadsheet, daily analysis time was significantly reduced (personal communication, ES, WRB, JAO). This information also helps the ASP organize information for interactions with providers on the floor during antibiotic stewardship rounds, leave more detailed and informative notes in the patient’s chart, and send text messages via the Short Message Service (SMS) or pager. The notes they enter in the spreadsheet also reminds them to follow up on certain patients and see if the recommendations they made were accepted and/or completed.

3.2 Spreadsheet data elements

Patient demographics provide multiple ways to find patients in the EMR and provide information for the ASP to more intelligently discuss patients with the provider. Weight, serum creatinine and creatinine clearance are needed to assess the appropriate dose in adult patients and height, BSA and mg/kg/day are needed to assess the dosage for pediatric patients. Antibiotic allergies are needed to prevent the ASP from recommending drugs to which the patient is allergic. The antibiotic dose, route and frequency and number of days on therapy are essential for identification of potential renal and hepatic issues that could result in adverse drug events or antimicrobials that may be amenable to de-escalation or discontinuation. Since antimicrobial start times change with each change in dose, route or interval, the program calculates continuous use based on the same code in the data dictionary of the same antimicrobial. Clinical service helps identify whom to contact regarding needed patient interventions. Admission date and antimicrobial start time provides a quick way to determine the length of hospitalization and antimicrobial administration during the current encounter, as well as the times for each antimicrobial administration. Antimicrobial order number provides a quick method to see where that drug fits within the total number of received medications.

This report also helps the ASPs identify patients on antimicrobials that have narrow therapeutic ranges (eg. aminoglycosides), are particularly prone to drug-drug interactions (eg. Rifampin), and are of high cost to the system (eg. daptomycin). This report allows study investigators to monitor the use of restricted antimicrobials used without prior authorization which allows the investigators to make contact with the prescribing provider to verify the drug's appropriateness.

3.3 Antibiotic time out

The CDC and The Joint Commission encourage clinicians to review antibiotic courses after 72 hours of treatment. Antibiotics are generally started empirically before a patient's full clinical picture is known. After 24-72 hours, it is time to review new microbiology, radiology, and clinical information and encourage clinicians to take a "time out." A "time out" is an opportunity to evaluate if the antibiotic is still warranted or, more importantly, if the prescribed antimicrobial is effective against the identified organism(s). Prompting clinicians with an electronically generated reminder when their patients have been on antibiotics for >48 hours serves as a gentle reminder to review the clinical context in which the antibiotic is being used. The local pharmacists receive these emails, print them out and place them in the medical record. These reminders do not offer clinical recommendations but rather serve as a prompt to review the antimicrobial treatment course.

The time-driver activates the antibiotic time-out application at 7:00am each day. That application uses the encounter table to identify each patient currently receiving any of 18 targeted antimicrobials and uses the days on therapy logic to determine if that patient has been on that drug for over 48 hours. The application then formats the email in ► Figure 2 based on the number of targeted antimicrobials each patient is receiving for longer than 48 hours.

3.4 Positive blood or CSF culture pages and emails

Positive blood and cerebrospinal fluid (CSF) cultures represent critical microbiology results that often necessitate urgent action. Time to appropriate antimicrobial therapy in these critically ill patients has been directly correlated with mortality (i.e. longer time to effective therapy leads to higher mortality). Reviewing these cultures with the clinician in a timely manner is critical and a high priority for ASPs. Designated members of the ASP receive real time alerts of positive blood and CSF cultures via page and/or email within five minutes of the microbiology technician entering the data. The page and associated email contain the date and time of the culture collection, the encounter number and room number. This information allows the ASP staff to quickly identify the patient and access the detailed information contained in the culture result in the EMR. The ASP often receives feedback from providers that they are impressed by how quickly they are aware of positive cultures and are able to provide timely assistance usually before the attending physicians are aware of the results. Receiving this culture information via a secure "ASP email address" is an ideal method for work flow because it allows multiple people on the ASP team to simultaneously get the alerts and manage them effectively. The patient name, date, and time of the culture in the secure email help identify repeat positive blood cultures and indicates how fast the blood culture grew. Additional information such as the microbiologic results of the blood culture and current antimicrobial therapy would be very useful; however, that information is quickly accessible in the information system and too hard to read as a text page due to the length. During one year, September, 2013 through August, 2014, 2,125 pager alerts were generated at PCH and 4,446 alerts were generated at IMC compared to requiring the ASP to manually look through microbiology test results.

The positive blood and CSF pages/emails application depends on the data-driver to activate the logic that identifies the culture and rapid diagnostic test results as soon as they are entered in the microbiology laboratory and stored in the EMR. When found, those alerts are stored in the alert file. The time-driver then activates an application that checks the alert file every 5 minutes for any new positive blood and CSF alerts. That application then creates a text message that is sent to pagers of members of the ASP along with an email containing additional information.

3.5 NHSN monthly report of antimicrobial use by hospital and unit

One of the important tasks of an ASP includes monitoring the use and any changes in antimicrobial prescribing habits over time. Usage reports must be stratified by antimicrobial agent, route of administration, and hospital unit in order for ASPs to accurately assess stewardship initiatives. In addition, antimicrobial usage data must be normalized by hospital and unit volume to adequately compare usage across units and to compare hospital usage rates (typically expressed in days of therapy / 1000 patients days present). These data allow ASPs to assess the effectiveness of new antimicrobial restriction/preauthorization policies, identify inadvertent increases in alternative antimicrobials (squeezing the balloon [18]), monitoring increases in oral antimicrobial usage with the initiation of an IV to PO protocol, and determine cost savings over time.

The antimicrobial usage report can be generated manually or by the time-driver around or on the 5th day of subsequent months. The application pulls the needed data directly from the EDW for each antimicrobial in the NHSN list that was administered during the previous month. The report generates unit and hospital antimicrobial usage rates expressed as days of therapy per 1000 patient days present and is stratified by antimicrobial agent and route of administration. The data is population based only (no patient identification) and stored in a relational database. Another program converts that data to the NHSN AUR CDA structure as an XML document and compresses (“zips”) the data and attaches it to an email to the ASP. To date, the NHSN data cannot be automatically sent to the CDC. As such, a member of the ASP manually logs on to the NHSN web site and attaches the XML document to their respective hospital. The data returned from the CDC is currently used to track antibiotic use across IH hospitals to create visual reports (i.e. antibiotic usage dashboard) of antibiotic use for each hospital (►Figure 3). These reports are sent to hospital leadership as decision-making tools every month. To date, the number of hospitals submitting antimicrobial use reports to NHSN is too small to publicly share data and prevent hospital identification. As that number increases, we will then be able to compare our data nationally with similar size hospitals and similar types of nursing units.

Accurate, timely, and user-friendly antimicrobial usage reports for healthcare systems have been difficult to establish. New members of the ASP report that IH is fortunate to have an electronic bar-coded medication administration system and the informatics support and expertise to develop the data extraction tools from that system. A previous paper has shown the benefit and accuracy of having bedside, bar-coded nurse medication administration documentation [29]. Members of the ASP also feel that the information they receive using these data helps them to improve patient health and provider satisfaction through reduced or more appropriate drug use hospital-wide, heighten awareness of prescribing patterns, and reduce healthcare costs. Using the information generated with these new ASP applications in conjunction with hospital acquired infection rates and an enterprise-wide antibiogram, physicians are more likely to de-escalate from broad-spectrum antimicrobials.

3.6 Impact on antimicrobial use

PCH's stewardship program started in 2010 while IMC's program started in 2012. Antimicrobial use data has been collected at PCH since 2009 and antimicrobial use data have been collected and sent to the CDC via the NHSN database from both hospitals since January of 2011. The reports generated for PCH and IMC show a general decrease in the drugs initially targeted by the ASP at both facilities (►Figure 4a, ►Figure 4b). Without these new applications described in this paper, the ASPs at these hospitals would not have had the information to monitor daily antimicrobial use, identify patients with severe invasive infections, identify potential problem areas based on prescribing patterns, or know the effect their stewardship interventions have on total antimicrobial use. These data are also essential to report the value of the ASP to administrative sponsors and ensure the continuation of the ASPs. Eventually, data like these will be useful to prioritize new initiatives, as well as benchmarking.

4. Discussion

Surveillance and feedback of antimicrobial use are essential for ASPs to be effective. This paper demonstrates how informatics can support a multidisciplinary ASP team to improve their design and workflow. Members of the ASP report the applications at IH help them improve antibiotic use by allowing efficient, timely review and effective prioritization of patients receiving antimicrobials. Priorities vary by institution and the development of flexible applications that identify potential patients for intervention based on patient locations, microbiology (i.e. positive blood cultures), and prescribed antimicrobial characteristics (ex. spectrum, number of antimicrobials prescribed, cost of therapy, and duration) helps to advance ASPs at all stages of development.

Our daily antimicrobial usage report allows the ASPs to provide a timely and accurate prospective audit of antimicrobial use with intervention and feedback to prescribers, one of the two pillars of antimicrobial stewardship according to national guidelines. New Centers for Medicare and Medicaid Services draft guidelines for surveying healthcare facilities have 5 new items regarding antimicrobial stewardship. These draft guidelines include “a mechanism in place to prompt clinicians to review antibiotic courses of therapy after 72 hours of treatment”. ASPs prospective audit and feedback and the antibiotic time-out report are two methods in which IH is meeting these guidelines and is highly dependent on quality informatics support. Many ASPs are unable to review the appropriateness of antimicrobials for every patient every day, either due to high patient volumes or limited resources. The Excel® spreadsheet format we developed enables easy and efficient data analysis while the other pages, emails and monthly NHSN reports provide timely supporting information. Priority can be given to specific patient locations, number of antimicrobials prescribed, high-cost antimicrobials, and certain durations of therapy (such as 72 hours).

Prevention of healthcare-associated infections and the control of multidrug-resistant organisms are important clinical outcome measures for ASPs. Information technology is expected to provide an area for growth and innovation in antimicrobial stewardship [30]. Moreover, computer-assisted decision support, based on epidemiology principles and flexible and dynamic medical informatics, can be used to inform and improve antibiotic decisions rather than enforce them [18]. However, only one quarter of hospitals with ASPs report they can monitor clinical outcomes and one reason is the low utilization of automated electronic surveillance system tools and computerized physician order entry [31]. Lack of funding remains a key barrier for many ASPs and administrators need additional cost savings data in order to support ASPs. Interestingly, while guidelines and editorials regard compensated participation by an infectious diseases physician in these programs as essential, more than half report no direct compensation for ASP activities [32]. The state of California now has legislation requiring hospitals to develop processes to evaluate the judicious use of antimicrobials, which appears to have played a role in initiating many ASPs in community hospitals [33].

4.1 Previous use of electronic methods for ASP

A number of previous papers also report a variety of electronic methods aimed at improving ASP workflow. Alerts based on order sets and customized templates developed within CPOE have been used by multiple institutions to catch potential antimicrobial incidents of overuse or concern [34, 35]. A mandatory field for antimicrobial-use indications was included in CPOE and an automated report of antimicrobials prescribed along with doses, patient demographics, and microbiology results was developed. Review of prescribed antimicrobials by an infectious-disease physician and pharmacist providing physician feedback was reported to have a significant impact on reducing the 16 targeted and also non-targeted-antimicrobials which was associated with improving quality of care in a pediatric hospital [11].

One report found that a high proportion of calls to ASPs requesting prior approval of restricted antimicrobials included patient data inaccuracies which could have led to inappropriate recommendations [36]. The World Wide Web has been used to implement antimicrobial restriction applications with automated clinical decision support to replace previous applications [37, 38]. Those applications were found to facilitate approval and enhance communication among prescribers and pharmacists and reduce the number of restricted antimicrobials. Some web based applications have been developed to enhance surveillance for resistance [39, 40] while others interface to a database to

provide assessment of antimicrobial therapy and was used to reduce antimicrobial therapy and *C. difficile* infection in the ICU [41].

Data-mining software has also been used to build a report based on prospective identification of inpatients receiving antimicrobials along with microbiology and other laboratory results, allergies, medical history and demographics [42]. The ASP pharmacists use the report to identify potential cases, which are then reviewed by ID physicians who provide written recommendations to improve the antimicrobial therapy. The authors report a significant decrease in antimicrobial use, associated costs and a decrease in certain hospital-acquired infections during four years after implementation. Moreover, the study found that 80% of the recommendations were accepted within 48 hours and no negative impact was found in patient survival after antimicrobial de-escalation.

Lastly, a causal probabilistic network was used to significantly improve empiric antimicrobial treatment by using less broad-spectrum antibiotics at half the cost [43]. Thus, there are a number of different electronic tools and methods that can be used and a recent review of computerized tools to facilitate the correct use of antimicrobials demonstrates the international focus on inappropriate and overuse of these drugs [44].

While more research is needed, the current evidence suggests that antimicrobial stewardship activities in inpatient, outpatient and emergency room settings is associated with improved antimicrobial prescribing quality, reduction in antimicrobial resistance and adverse events without compromising patient care [45–49]. The increase in the use of EMRs in hospitals and ambulatory care over the past couple of years should facilitate the use and further development of the electronic tools needed by ASPs. To date, infection control and antimicrobial improvement needs have mainly been filled by third-party vendors with different abilities to store information into the EMRs, which are now mainly provided by a few large vendors. Recent publications are now reporting the development and benefits of some decision support tools used by ASPs within these large vendor EMRs [34, 50, 51].

4.2. Limitations

There are still gaps and limitations not met by the four new ASP applications presented in this paper. The daily antimicrobial list still requires ASP time to sort and remove certain low priority antibiotics and nursing units each day. Providing the name and telephone number of the prescribing physician would be ideal, but without CPOE, that information is usually not available or accurate in our current EMR. In an academic institution with interns, residents, and attending physicians, finding the correct person to speak with can be difficult and time intensive. Our applications don't address this and we currently do not have an "online schedule" of coverage. Also, while the ASP can enter notes on the antimicrobial spreadsheet, those reports and the positive blood and CSF pages are not interactive. Thus, patients will continue to be listed or alerted until they are discharged or are no longer on antibiotics or their cultures are finalized. That requires the ASP to manually keep track of who they have reviewed and who are already receiving infectious diseases consultation.

5. Conclusions

To be effective, ASPs need an enormous amount of "timely" information. Members of the ASP at IH report these new applications help them improve antibiotic use by allowing efficient, timely review and effective prioritization of patients receiving antimicrobials in order to optimize patient care. Priorities can be identified based on patient locations and antimicrobial spectrum, cost, duration of therapy, and number prescribed. These applications need to be designed and tested by members of the ASP and new applications and updates are needed as use and ASP experience increases.

Clinical relevance

As more hospitals create ASPs, the need for medical informatics participation and input will also increase. ASPs are dependent on an enormous amount of timely information to be effective. This paper provides some examples on how this information need can be filled by having medical informatics as an active participant in the ASP.

Conflicts of interest

The authors declare that they have no conflicts of interest in this research.

Protection of Human and Animal Subjects

This study was performed as a quality improvement project and performed in compliance with the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects and approved by the Intermountain Office of Research for Publication.

Acknowledgements

The development of the applications reported in this paper was supported as quality improvement initiatives by Intermountain Healthcare and the Center for Diseases Control/National Healthcare Safety Network through grant 740 399.

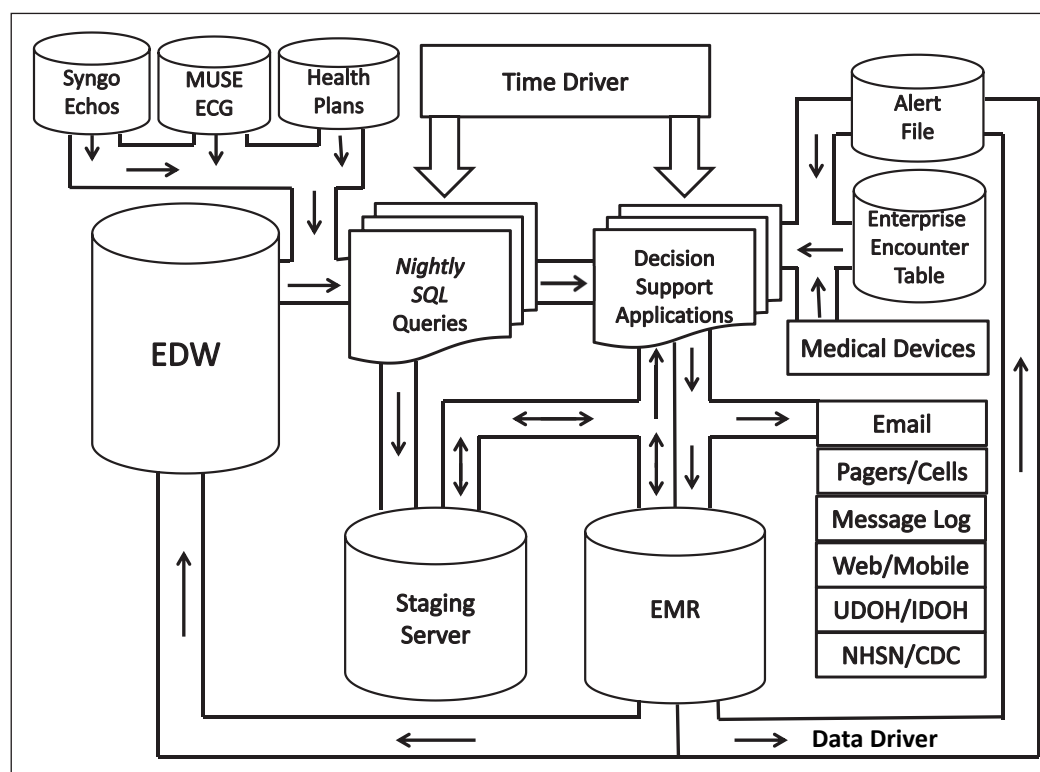


Fig. 1 Framework used to develop the new Antimicrobial Stewardship Program information needs.

ANTIBIOTIC TIME-OUT

Patient Name

Room

The above patient has been on the following antibiotics for > 48 hours:

Vancomycin

Imipenem

Please take a moment and review your patient's available microbiology and clinical data to determine if antibiotics can be de-escalated or discontinued.

An ANTIBIOTIC TIME-OUT is considered to be an 'Antibiotic Best Practice' by the Centers for Disease Control and The Joint Commission.

Thank you.

Antibiotic Stewardship Team

Fig. 2 Example of the antibiotic time-out email alerts.

NHSN Output - Line Listing - Most Recent Month of AU Data by Location - Windows Internet Explorer

https://nhsn2.cdc.gov/nhsn/analysisrequest.do?method=runFromView&NHSNSessionID=8416

National Healthcare Safety Network
Line Listing - Most Recent Month of AU Data by Location
 As of: September 15, 2014 at 6:03 PM
 Date Range: All SUMMARYAU1MONTH

location=254

orgID	summaryYM	drugIngredientDesc	location	antimicrobialDays	numDaysPresent	IM_Count	IV_Count	digestive_Count	respiratory_Count
18618	2014M08	AMOX - Amoxicillin	254	5	818	0	0	5	0
18618	2014M08	AMOXWC - Amoxicillin with Clavulanate	254	1	818	0	0	1	0
18618	2014M08	AMP - Ampicillin	254	37	818	0	37	0	0
18618	2014M08	AZITH - Azithromycin	254	30	818	0	30	0	0
18618	2014M08	AZT - Aztreonam	254	8	818	0	8	0	0
18618	2014M08	CEFAZ - Cefazolin	254	52	818	0	52	0	0
18618	2014M08	CEFEP - Cefepime	254	13	818	0	13	0	0
18618	2014M08	CEFOT - Cefotaxime	254	2	818	0	2	0	0
18618	2014M08	CEFOX - Cefoxitin	254	2	818	0	2	0	0
18618	2014M08	CEFTRX - Ceftriaxone	254	83	818	0	83	0	0
18618	2014M08	CEFUR - Cefuroxime	254	26	818	0	26	0	0
18618	2014M08	CIPRO - Ciprofloxacin	254	6	818	0	3	3	0
18618	2014M08	CLARTH - Clarithromycin	254	5	818	0	0	5	0
18618	2014M08	CLIND - Clindamycin	254	32	818	0	30	2	0
18618	2014M08	DOXY - Doxycycline	254	6	818	0	2	4	0
18618	2014M08	ERTA - Ertapenem	254	7	818	0	7	0	0
18618	2014M08	ERYTH - Erythromycin	254	3	818	0	3	0	0
18618	2014M08	FLUCO - Fluconazole	254	85	818	0	69	16	0
18618	2014M08	GENTA - Gentamicin	254	5	818	0	5	0	0
18618	2014M08	IMIPWC - Imipenem with Cilastatin	254	28	818	0	28	0	0
18618	2014M08	LEVO - Levofloxacin	254	10	818	0	7	3	0
18618	2014M08	LNZ - Linezolid	254	24	818	0	24	0	0
18618	2014M08	MERO - Meropenem	254	77	818	0	77	0	0
18618	2014M08	METRO - Metronidazole	254	7	818	0	7	0	0
18618	2014M08	MICA - Micafungin	254	24	818	0	24	0	0
18618	2014M08	NAF - Nafcillin	254	2	818	0	2	0	0
18618	2014M08	PENG - Penicillin G	254	4	818	0	4	0	0
18618	2014M08	PIPERWT - Piperacillin with Tazobactam	254	156	818	0	156	0	0
18618	2014M08	RIF - Rifampin	254	3	818	0	3	0	0

Done

Internet | Protected Mode: On

Fig. 3 Example of antimicrobial use data returned from Centers for Disease Control and Prevention.

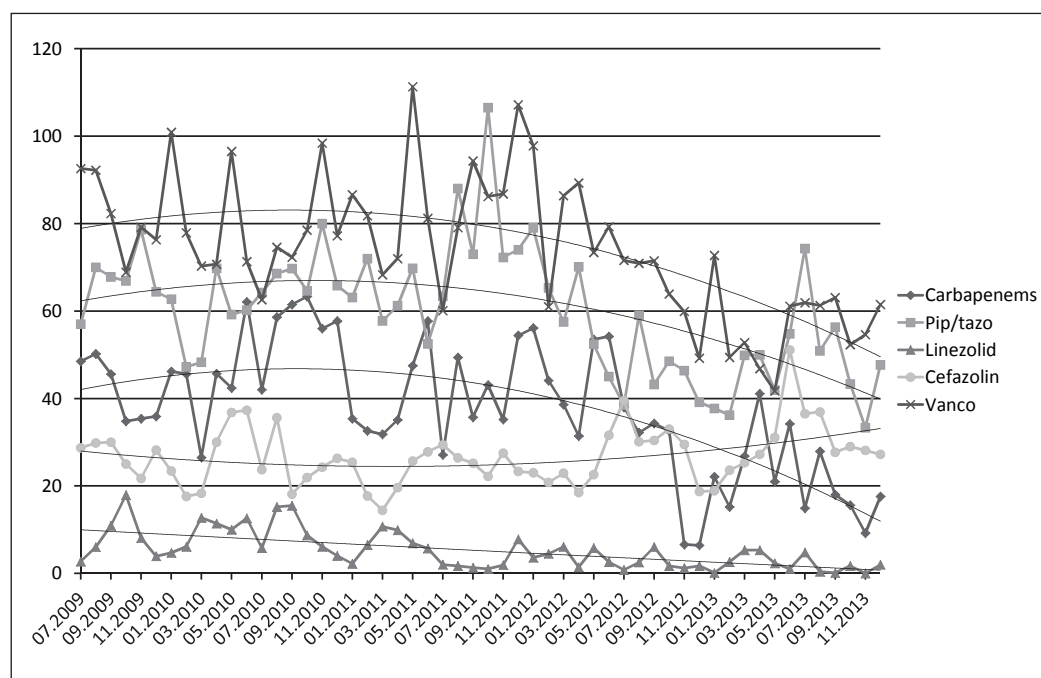


Fig. 4a Primary Children's Hospital (PCH) antimicrobial days of therapy per 1000 patient days for initial targeted antimicrobials since 2009. CH's ASP started in 2010.

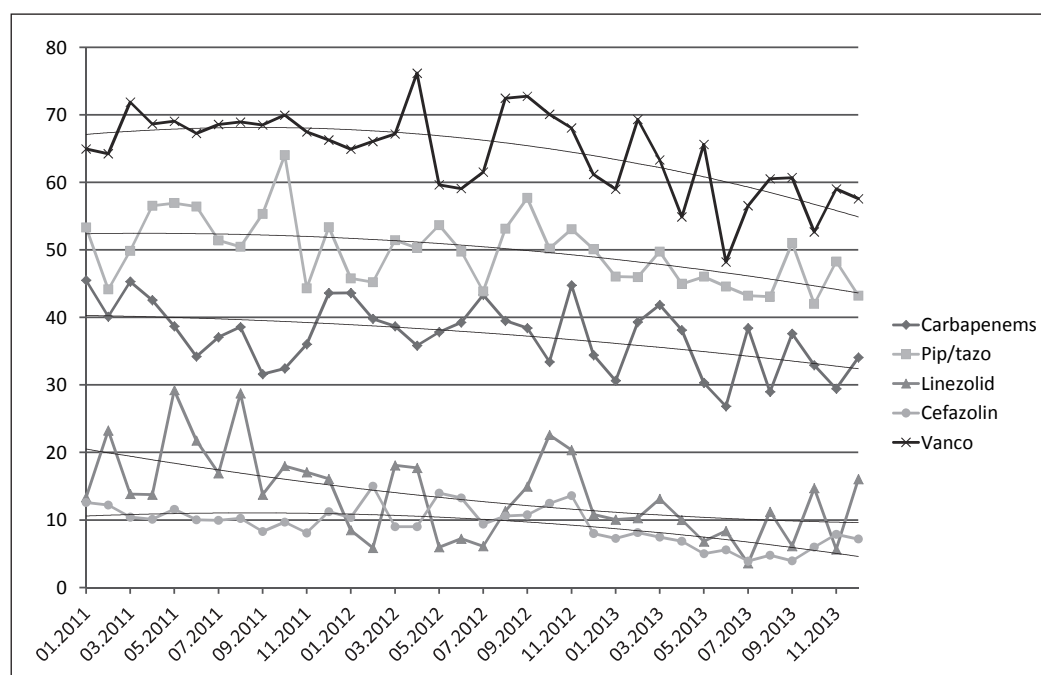


Fig. 4b Intermountain Medical Center (IMC) antimicrobial days of therapy per 1000 patient days for initial targeted antimicrobials since 2011. MC's ASP started in 2012.

Table 1 Information provided with the daily antimicrobial spreadsheet.

Patient Name	Medical Service
Room	Antimicrobial Allergies
Patient number	Antimicrobial
Age	Antimicrobial Dose
Sex	Antimicrobial Route
Admission Date	Antimicrobial Interval
Height (cm)	KGD ((24/interval) * dose) / weight
Weight (kg)	Number of days on antimicrobial
BSA	Medication Order number
Cr	Start Date/time
CrCl	ASP Rounds notes

BSA = body surface area. Cr = creatinine level. CrCl = creatinine clearance. KGD = kilograms per day

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