Executive Summary
In 2008, The Ohio State University’s Wexner Medical Center (OSUWMC) developed an antimicrobial stewardship program to monitor potential overuse, under use and misuse of antimicrobial agents. To gather information, OSUWMC built a data mart in 2013 that extracted data from its electronic medical record system. The program has resulted in clinical initiatives leading to decreased use of particular antimicrobial agents and an estimated $7.7 million in savings.
Background Knowledge
Antimicrobial resistance that renders previously treatable infections unresponsive to most antimicrobial agents is a significant clinical problem and a major public health concern. The Department of Health and Human Services (DHHS) has recognized this threat which has led to the development of a national action plan for the prevention of healthcare-associated infections (http://www.cdc.gov/drugresistance/actionplan/taskforce.html). The Centers for Disease Control and Prevention (CDC) is participating in this endeavor and has developed an Antibiotic Use and Resistance (AUR) module as part of a national program to monitor antimicrobial use and resistance (http://www.cdc.gov/nhsn/PDFs/pscManual/11pscAURcurrent.pdf).

Local Problem and Intended Improvement
National infectious disease professional organizations have published guidelines promoting implementation of antimicrobial stewardship programs (ASP) in hospitals 1. We have implemented a formal ASP at the Ohio State University Wexner Medical Center (OSUMWC) since 2008. The mission of the program is to minimize unintended consequences of antimicrobial use, including toxicity, the selection of pathogenic organisms with high morbidity and mortality, the emergence of resistant organisms and extended costly hospital stay. The overarching goal of ASP is to optimize clinical outcomes by ensuring the right antimicrobial therapy is given to the right patient at the right time avoiding the overuse, under use, or misuse of antimicrobial agents. It became apparent that one critical metric required for successful evaluation of the impact of ASP interventions was antimicrobial use. Knowing the quantity of targeted drugs being used over time was deemed necessary to understand resistance patterns, prescribing patterns, and antimicrobial cost burden.

Design and Implementation
With funding from the CDC Prevention Epi-Center program, investigators within ASP developed a preliminary antimicrobial data mart to monitor antimicrobial use in the intensive care units. The ASP investigators approached the Information Warehouse staff to assist with the development of a data mart to monitor antimicrobial use. Jointly, they outlined the desired metrics based on the goals and needs of ASP. This preliminary data mart was developed using antimicrobial charges and provided the foundation for the current data mart described here. Some details of this initial data mart have been published as part of a paper outlining methods for deriving antimicrobial use from computerized pharmacy data 2. In this paper, which examines data from five academic medical centers, “antimicrobial-days” were determined to be the best metric of individual drug use. This is defined as the sum of calendar days on which each antimicrobial drug was administered. The denominator was ICU patient –days and rates of antimicrobial use were calculated. This study critically examined some of the errors encountered during validation of antimicrobial utilization rates which provided further input as the current data mart was created 2.
**How Health IT Utilized**

The implementation of Epic electronic health record at OSUWMC provided the opportunity to upgrade the antimicrobial data mart to measure and display the actual drug administered based on electronic medical administration records (eMAR). In May 2013, the ASP and the IT Information Warehouse team (IW) met and jointly developed a plan to upgrade the data mart using Epic data. The goal was to allow ASP members to directly access and query the data from Epic’s Clarity database and generate custom reports within OSUWMC’s custom enterprise data warehouse. The goal was that data could be stratified by antimicrobial agent, time periods (typically by month), clinical service and/or unit, and prescribing clinician. The outlined goals of the new data mart were for ASP to utilize the information to monitor antimicrobial use in order to understand resistance patterns, prescribing patterns and antimicrobial cost burden. These data were deemed also to be invaluable in monitoring the impact of ASP interventions that effect targeted antimicrobial use. With access to these data, ASP can communicate the information to appropriate OSUWMC medical staff through email or other means. In addition, the information will be utilized to justify antimicrobial additions/deletion, susceptibility data and additional positions.

The data mart itself does not change physician’s behavior but it reflects the impact of ASP interventions which are designed to change physician behavior. For example, if an antibiotic becomes restricted, the prescribing clinician must page a member of the ASP team for approval. If the drug use is approved, then the clinician is provided a code that needs to be entered into Epic at the time of ordering. If the approval code is not entered, the pharmacist cannot process the order. The change in drug volume before and after restriction can be determined from the data mart and can be reported back to prescribers.

The IW team chose a dimensional approach to store the data with OSUWMC’s enterprise data warehouse. The dimensional approach supports the goal of presenting data aggregated and normalized across the patient population and also allows for drilling into the details by agent, clinical service, patient location and prescribing clinician. Data is loaded monthly into the antimicrobial data mart. The diagram below shows the flow of information from Epic (branded as “IHIS” at OSUWMC) to the Information Warehouse data mart.
Value Derived/Outcomes

The new antimicrobial data mart went live in fall 2013. Since that time, it has specifically been utilized to monitor the impact of targeted interventions on the use of specific antimicrobial drugs. For example, in September 2012 a new ASP policy was implemented to remove ciprofloxacin as a second empiric drug for serious Gram negative bacterial infections. This decision was based on review of antibiotic susceptibility data demonstrating that this drug was not as effective as tobramycin; thus, tobramycin replaced ciprofloxacin as the empiric drug choice. Additionally, ciprofloxacin was also highly associated with the development of Clostridium difficile infections in hospitalized patients. This is an infection that can cause severe diarrhea. Reduction of C. difficile infections is an ongoing performance improvement initiative. As noted in the graph below, the antimicrobial utilization made available by the new data mart clearly demonstrated a significant decline (about 50-60%) in IV ciprofloxacin use as a result of this policy change. Furthermore, we noted a corresponding reduction and leveling of C. difficile infection rates.
Another ASP initiative looked at optimizing the use of some high use and expensive agents. A variety of interventions were implemented including developing utilization criteria, requiring prior authorization for some drugs, and feedback auditing on the appropriateness of use on other drugs. As outlined below, data derived from the antimicrobial data mart demonstrated reductions in use for daptomycin, linezolid, and ertapenem, three of the targeted drugs. The solid bar indicates the date of the implementation of interventions with a comparison of use before and after the start of the interventions. There had been some preliminary efforts to optimize daptomycin before the start of the major campaign which likely accounts for the pre-intervention downward trend.
These graphs above demonstrated how the data mart has been invaluable in assessing the impact of ASP interventions.

After initial decrease in use of linezolid through September 2013, there was a notable upswing in linezolid use, as illustrated in the first graph below. Based on this increase in use, the decision was made by ASP to restrict this medication. This restriction took effect in May 2015. As illustrated in the second graph, there was an almost immediate and noticeable decrease in linezolid use due to the ASP. This is an example of how the evaluation of the data mart actually prompted an ASP intervention that was highly successful.
The development of the antimicrobial data mart has been critical to the successful monitoring of ASP activities and will be invaluable in the future. The collaboration between the IW and ASP has been very productive over the past several years with the development of the preliminary data mart followed by the current version. The ease of data query and acquisition of reports has made this resource invaluable for daily functioning of our program. We have been able to access these data for most of ASP projects with only a few examples shared here. It would be very
difficult for us to demonstrate the impact of our programmatic interventions without the availability of antimicrobial use data that this data mart provides.

**Lessons Learned**

The major challenges in implementing the antimicrobial data mart were:

- Accounting for the patient’s location
- Identifying the anti-microbial drugs prior to the implementation of RxNorm, the National Institutes of Health’s medication naming and terminology system

Regarding the patients location, patients move around throughout the day. To create an “anti-microbial day” measure broken down by location, we had to decide which of these many locations to use. In the end, we decided to use the patient’s location at midnight. This allowed us to analyze the “anti-microbial days” in conjunction with the midnight census.

Identifying the anti-microbial drugs prior to the implementation of RxNorm proved difficult due to some drugs having multiple classifications and uses. In the end, a manual accounting of all drugs was done to identify which should be included as anti-microbial drugs. Because of antimicrobial labeling limitations in RxNorm, further analysis of RxNorm in 2015 has shown that OSUWMC will need to continue its manual identification of antimicrobial drugs for the foreseeable future.

Finally, another major lesson learned for IT was the value of deep collaboration with the clinical department. For this particular project, IT engaged the ASP early and often, rather than simply delivering exactly what was asked for. By questioning the ASP regarding their intent and their goals, IT was able to collaborate with the ASP to design a functional solution that got to the root of their request.

**Financial Considerations**

Although not directly responsible for changes in antimicrobial use and cost savings, the antimicrobial data mart was instrumental in measuring the impact of Pharmacy and ASP interventions on reduction in drug use and associated cost savings. As outlined, Pharmacy and ASP began a campaign in Fall 2012 to target optimizing use of more expensive agents. There was significant reduction in daptomycin, linezolid, piperacillin-tazobactam and ertapenem, as illustrated in the above figures.

The figure below demonstrates that the aggregated antimicrobial expenditures per patient days decreased significantly over time after September 2012 as a result of these and other initiatives.
The estimated cost savings just from the restriction of linezolid over 5 months (May 2015 to September 2015) was $315,560 when compared to the drug costs during the preceding months (July 2014 to April 2015) when the use of linezolid was increasing. Furthermore, based on the above graph the estimated total cost savings from the highest use (November 2011 to September 2012) to the lowest use (June 2013 to September 2015) was $7,463,204.

In terms of staffing expenses for implementation, five IW staff spent 913 hours planning, designing, building and configuring the data mart. At an average staff cost of $62.50 per hour, the total resource cost for this project was estimated to be $57,062.50 (913 hours*$62.5).

References