Use of a Clinical Decision Support System (CDSS) to improve antimicrobial stewardship efforts at a single academic medical center

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Antimicrobial resistance remains one of the greatest global health threats. According to the Centers for Disease Control and Prevention (CDC), an estimated two million people are infected with resistant organisms in the US, and this has resulted in an annual mortality of approximately 23,000 cases.[1] This has largely stemmed from the misuse or overuse of antibiotics. Up to 50% of antibiotic prescriptions have been found to be inappropriate.[2] Thus, improving appropriate utilization of antibiotics has now become a national priority leading to The Joint Commission (TJC) developing antimicrobial stewardship standards for hospitals, critical access hospitals, and nursing care centers that became effective on January 1, 2017.[3]

Loyola University Medical Center (LUMC) is a quaternary academic center with 547 licensed beds. There has been an established Antimicrobial Stewardship Program (ASP) for over 20 years which has expanded over time. The current ASP is led by Infectious Disease (ID) physicians and ID clinical pharmacy specialists, and includes multi-disciplinary members from infection prevention, microbiology, hospital medicine, and nursing. The program primarily utilizes formulary restriction and preauthorization as methods to ensure the appropriate use of antimicrobials. Additionally, several facility treatment guidelines have been developed and implemented to optimize antibiotic selection and duration, as well as pharmacy-driven programs such as intravenous to oral conversion of selected antimicrobials, renal dosing, and pharmacy-to-dose vancomycin protocol.

With the adoption of electronic health records – meaningful use (EHR-MU) over the past 10 years, the volume of digital health data available to clinicians has increased dramatically. With changes to reimbursement and a shift in focus to quality, healthcare organizations must allocate resources appropriately to drive value. Clinical Decision Support Systems (CDSS) receive data feeds, such as pharmacy orders, vitals, general laboratory orders and microbiology cultures from the EHR, and aggregate the data to identify at risk patients. This data aggregation is presented to clinicians in the form of electronic notifications or alerts to help direct the clinician to patients who require the most attention. CDSSs have had mixed results in the literature depending on the type of system used, although most studies have shown a decrease in the use of broad spectrum antibiotics.[4] CDSSs can provide clinicians a more effective and efficient way of reviewing pharmacy and microbiology data, overall furthering the efforts of ASPs when the program is incorporated into the clinician's workflow. This practice is supported by the 2016 Infectious Disease Society of America and Society for Healthcare Epidemiology of America guidelines for implementing an ASP.[5] Moreover, CDSSs can easily be customized to fit the needs of specific hospitals and health-systems, depending on the number of ASP personnel, the size of the institution, and the goals of the ASP.

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Beginning July 2017, LUMC began utilizing a CDSS to aid in antimicrobial stewardship. Through the CDSS, the LUMC ASP implemented customizable real-time alerts as tools for ASP staff to optimize antimicrobial usage. One of the alerts that the program uses is antimicrobial susceptibility mismatch. This alert has been utilized by the ASP staff to identify instances where the pathogen being treated is not susceptible to the current antimicrobial regimen chosen for a patient. After reviewing the patient's chart, the ASP staff then recommends appropriate antimicrobial changes to the patient's primary care team. These recommendations may be to change therapy, continue therapy (in case the alert was deemed invalid, e.g., alert for trimethoprim-sulfamethoxazole being utilized for *Pneumocystis* prophylaxis in a patient with a blood culture growing *P. aeruginosa*), or ID consultation. Commonly, patients are already being followed by the ID service, and in this instance, recommendations are deferred to the ID service. Another alert utilized by ASP identifies patients on unnecessary double anaerobic coverage. The results of implementation of these two alerts can be seen in Figures 1 and 2.

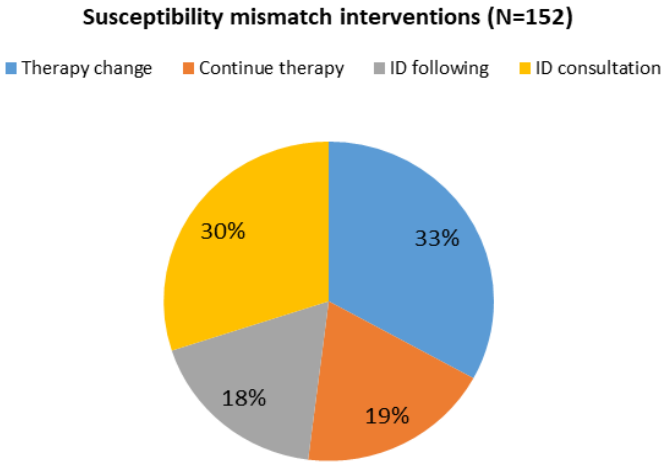


Figure 1. Graph showing the percentage of interventions for mismatch susceptibility alert for January 2018 through April 2019

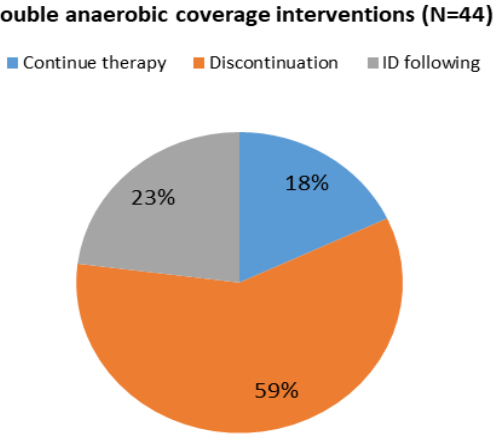


Figure 2. Graph showing the percentage of interventions for double anaerobic coverage alert for October 2018 through April 2019

Recently, the LUMC ASP implemented a policy that mandates an ID evaluation or consultation for patients with *Staphylococcus aureus* bacteremia, carbapenem-resistant Enterobacteriaceae (CRE) infections (except urinary isolates), *Candida auris* infections, fungemia, nocardiosis, mucormycosis, cryptococcosis, multidrug-resistant (MDR) bacteremia from any of the following pathogens: daptomycin and vancomycin-resistant enterococci, daptomycin-resistant *S. aureus*, or *Pseudomonas* spp. The program utilizes real-time alerts to identify these patients. The alerts are automatically directed to the e-mail of key ASP members who will then ensure that an ID consultation is obtained by notifying the primary medical team and documenting the appropriate response in the CDSS (i.e., recommend ID consult, ID already following, recommend change in therapy, etc.). The ability to document is available to all LUMC ASP users to ensure that efforts are not duplicated. Data from these stewardship efforts will be collected in order to determine the quantity of ID consultations that are obtained in response to direct ID intervention through the alerts. The protocol was implemented on February 1st, 2019 and the cases that generated the alerts are illustrated in Figure 3.

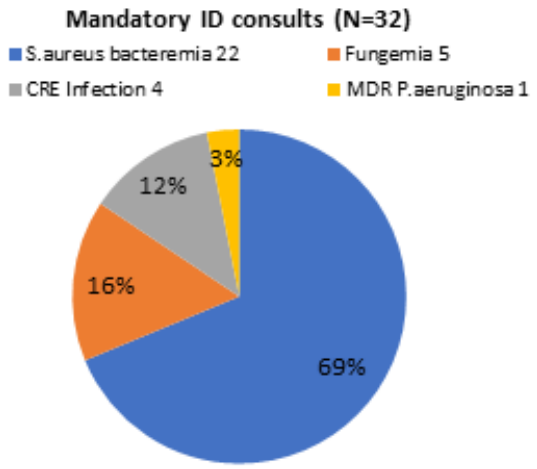


Figure 3. Graph showing the cases that mandated an infectious diseases consultation since implementation

The CDSS can also develop customizable facility and unit-based antibiograms. This enables the ASP to analyze resistance patterns and guide the program in developing facility based treatment guidelines. The antibiogram is created annually, however can be customized to run on an as-needed basis. Since LUMC's microbiology results are available in the CDSS, data can be accessed for the number of specific organisms that were isolated, as well as susceptibility to specific antimicrobials. In addition, location specific antibiograms can be created (i.e., intensive care unit, emergency department, etc.). CDSS also allows customized searches to obtain the desired data (e.g., methicillin-resistant *S. aureus* [MRSA] isolates in March 2019 and their susceptibilities).

We collaborate with our Infection Control team to monitor hospital-acquired infections secondary to *Clostridioides difficile*, MRSA, vancomycin-resistant *Enterococcus* (VRE), extended-spectrum beta-lactamase producing (ESBL) organisms, and CRE. The CDSS provides automated surveillance that has the ability to detect these pathogens at the unit level. In addition, through data mining surveillance, the CDSS is able to automatically identify specific opportunities for improvements and provides evidence-based recommendations on how to correct any trends that are identified through "patterns", a graphic representation of a change that has occurred in microbiology culture results and patient census information. The process monitors the entire hospital for early signs of any emerging issues, helping our staff to be more proactive with interventions and education by knowing when and where they can have the most impact.Finally, the system facilitates institution and unit-specific antimicrobial usage analysis. Opportunities are available for benchmarking among CDSS users nationally and through submission to the National Healthcare Safety Network (NHSN). Monitoring antibiotic prescribing or usage is an essential element in any ASP. LUMC ASP measures antibiotic usage by days of therapy (DOT) standardized to 1000 patient days at risk. The ASP tracks the facility's total antibiotic usage quarterly as well as the four most commonly used empiric antibiotics: vancomycin, cefepime, piperacillin-tazobactam and meropenem. The ASP also monitors the usage of these four antibiotics per specialized unit location. The results are reported to all medical staff, including attending physicians, house staff, advanced practice nurses and physician assistants, as well as registered nurses. Antibiotic usage can also be monitored at the service, unit or provider level, and can be run on-demand (Figures 4 and 5). LUMC's DOT are analyzed by the CDSS and compared to other facilities in the United States that utilize the same system. This benchmarking report is released quarterly, and facilities are compared to those with similar institutional size and teaching status.

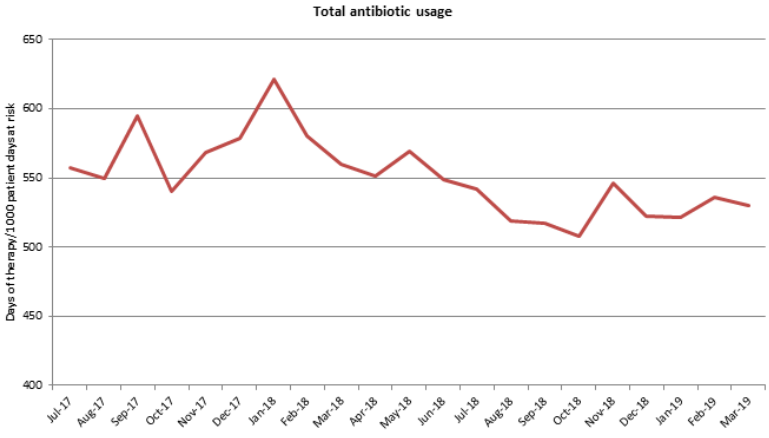


Figure 4. Graph showing LUMC's total antibiotic usage, as days of therapy (DOT) from July 2017 through March 2019

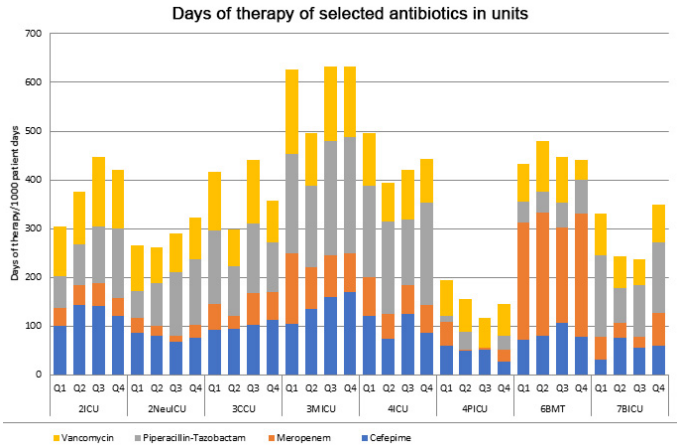


Figure 5. Graph showing days of therapy of selected antibiotics per unit in 2018

Q – quarter; **ICU** – intensive care unit; **NeuICU** – neurology intensive care unit; **CCU** – coronary care unit; **MICU** – medical intensive care unit; **PICU** – pediatric intensive care unit; **BMT** – bone marrow transplant unit; **BICU** – burn intensive care unit.

The CDSS has been a critical resource in monitoring and measuring stewardship activities at LUMC. However, some limitations to the CDSS exist, which include system cost, inaccessibility, and alert fatigue. Since the CDSS is a separate system that is not incorporated into our EHR, interruptions in workflow can occur. In addition, at times of high usage, the system may not be accessible due to the volume of users accessing the CDSS. Another challenge is the amount of time spent reviewing nonactionable alerts that are deemed unnecessary by ASP staff. This occurred in approximately 19% of susceptibility mismatch alerts (Figure 1) and 18% of double anaerobic coverage alerts (Figure 2). This is a well-known challenge in utilizing CDSSs that has been previously described in the literature.[4]

In conclusion, CDSSs are beneficial to ASP and Infection Control team members. CDSSs are able to provide a streamlined approach to determine high risk patients using real-time alerts for susceptibility mismatch, double anaerobic therapy, as well as culture alerts for targeted organisms and/or susceptibility patterns. Antibiogram development can be completed including customizability that allows susceptibility reports for specific key hospital locations (i.e., intensive care unit) and can be run on an as-needed basis. Hospital acquired infections can be monitored and tracked to the unit level, with the addition of pattern recognition for these infections. Importantly, the CDSS is able to report institution specific antimicrobial usage to the NHSN, which allows for benchmarking with nationally aggregated data.

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Conflicts of interest: NB reports being an employee of Becton, Dickinson and Company (BD). All other authors – none to declare.

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