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Article

Optimizing Provider Test Ordering and Patient Outcomes Through Best Practice Alerts and Doctorate in Clinical Laboratory Sciences (DCLS) Consultation for Urine Cultures

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Abstract: Recent initiatives have discouraged the treatment of asymptomatic bacteriuria in specific patient populations due to its lack of clinical benefit, no improvement in morbidity or mortality, and its contribution to antibiotic overuse. This study aimed to evaluate whether an intervention at order entry, combined with DCLS laboratory consultation for urine cultures and urinalyses, could reduce unnecessary lab tests and inappropriate antibiotic use, thereby improving patient outcomes. Our research design was a quasi-experimental study with a retrospective and prospective chart review on non-pregnant adult patients 18 years of age and older from July 2021 to September 2022. Data collected for both reviews included patient demographics, provider demographics, patient signs and symptoms, laboratory test results, test order type, test order utilization and antibiotic prescriptions. Our study included 6372 patients, with 3408 in the retrospective review and 2964 in the prospective review. Before the intervention, 60% (n = 2053) of test orders were inappropriate, which decreased to 20% (n = 591) post-intervention. In asymptomatic patients, reflexed urine cultures decreased from 51% to 13% post-intervention. Lastly, in asymptomatic patients, antibiotic therapy at discharge dropped from 54% to 25% after the intervention. Post-intervention ordering practices improved, decreasing the number of inappropriate orders across all patient and provider types. Overall, this initiative showed a significant reduction in the treatment of asymptomatic bacteriuria, which has been linked to the overuse of antibiotic therapy.

Keywords: asymptomatic bacteriuria; urine culture; best practice alerts; laboratory test utilization; DCLS; antibiotic therapy

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1. Introduction

Concerns regarding the emergence of antibiotic-resistant organisms remain at the forefront of the healthcare industry. The Centers for Disease Control and Prevention (CDC) has labeled it as a global threat, stating that more than 2.8 million antibiotic-resistant infections occur in the US each year, and more than 35,000 people die as a result [1]. Hospitals have been encouraged to implement robust antimicrobial stewardship committees to help mitigate the overuse of antibiotics, thereby reducing the emergence of multi-drug-resistant organisms. These factors not only lead to increased lengths of stay in the hospital but also increase morbidity and mortality. When antibiotic use is inappropriate, the patient is exposed to unnecessary risk and the risk/benefit algorithm is unjustified.

For several years, programs such as the Choosing Wisely Campaign and guidelines from the American Society for Microbiology (ASM), Infectious Disease Society of American (IDSA) and the Society for Healthcare Epidemiology of America (SHEA) have promoted the importance of antimicrobial stewardship for improved patient outcomes. These programs are designed to improve patient outcomes, reduce adverse events such as *C. difficile* infection (CDI), and reduce antimicrobial resistance, especially to targeted antibiotics [2–4]. Antibiotic resistance is a serious and increasing worldwide threat to global public health, and prolonged exposure to antibiotics decreases the normal gut microbiota and increases susceptibility to gastrointestinal pathogens; even though they play a critical role in fighting infections, their long-term or overuse can cause patient harm [5,6].

The isolation of bacteria in culture is often used to diagnose infections and provide a basis for prescribing antimicrobial therapy. In clinical practice, however, it is common to isolate bacteria that may be colonizing or not causing an infection. This is one reason laboratories are encouraged to have well-defined specimen collection protocols in place. For example, blood culture collection recommendations include very strict cleansing techniques to remove the colonizing bacteria present on the skin prior to collection. For urine cultures, suprapubic aspiration, straight catheter, or mid-stream collections are used to help improve diagnostic accuracy [7]. Even when stringent collection techniques are employed, bacteria may still be isolated in culture, which leads to diagnostic uncertainty. The definition of asymptomatic bacteriuria (ASB) has evolved over time, and clinical practice guidelines from IDSA currently define asymptomatic bacteriuria as the quantitative isolation of $\geq$100,000 colony-forming units (CFU) per milliliter of bacteria in a urine specimen appropriately collected from a patient without urinary tract infection signs or symptoms [8]. The Infectious Disease Society of America (IDSA) and the Society for Healthcare Epidemiology of American (SHEA) discourage the treatment of asymptomatic bacteriuria (ASB) in certain patient populations, stating that treatment has no clinical benefit, does not improve morbidity or mortality, and contributes to antibiotic overuse.

Additionally, culturing urine on asymptomatic patients may lead to the inappropriate reporting of catheter-associated urinary tract infections (CAUTIs) [9]. CAUTI is considered a preventable disease and hospital-acquired condition, and is a required disease reportable to Center for Medicare and Medicaid Services (CMS), which may ultimately be tied back to compensation for acute care hospitals [10].

Test selection and interpretation play a huge role in preventing diagnostic error. According to Laposata and Dighe, improved result interpretation leads to quicker and more accurate diagnosis [11]. When clinicians order laboratory tests such as urinalysis and urine cultures inappropriately, a pre-pre analytical error, the information provided by the results can lead to the inappropriate use of antibiotics and the emergence of resistant pathogens when ASB is present. Therefore, urine cultures and urinalyses that reflex a urine culture should not be ordered for certain patient populations when urinary symptoms, such as urgency, frequency, retention, dysuria, suprapubic pain, flank pain, pelvic discomfort, or acute hematuria, are absent. This identifies a gap in the ordering practices of providers, which was addressed in this project using an LIS intervention at order entry and a follow-up DCLS consultation for over- and under-utilization.

The purpose of this study was to determine if an intervention at order entry coupled with a DCLS laboratory consultation for the over- or under-utilization of urine cultures and urinalyses would reduce unnecessary laboratory testing. By determining over-utilization, the DCLS-led intervention could prevent the inappropriate use of antibiotics for ASB and, therefore, reduce the adverse effects of antibiotic therapy. Likewise, the DCLS-led intervention for under-utilization could alert clinicians to a potential need for urine cultures and antibiotic therapy when symptomatic cases are overlooked, improving patient outcomes.

Additionally, highlighting inappropriate ordering practices could educate clinicians and modify their ordering behavior for future patients. The overall aim of the project is to reduce inappropriate urine culture orders, which could indirectly reduce the inappropriate use of antibiotics and improve patient outcomes.

2. Materials and Methods

This study is a quasi-experimental quantitative analysis that involved both retrospective and prospective chart reviews of patients with urinalysis and/or urine culture orders at a community hospital. The hospital, a 293-bed, level II trauma and primary stroke center in North Central Texas, serves a nine-county area. The study included non-pregnant adult patients (18 years or older) with urinalysis and/or urine culture orders from July 2021 to September 2022. Patients excluded from the study include pregnant females, patients undergoing urologic procedures, ICU admissions, dialysis patients, cancer patients, patients with foley catheters, and those with symptoms that could not be assessed at order entry. The timeline was July 2021 to September 2022, with samples from 12 July 2021 to 30 September 2021 as the retrospective group and samples from 12 July 2022 to 30 September 2022 as the prospective or post-intervention group.

The intervention in this study was a Best Practice Advisory (BPA) alert integrated into the EPIC electronic health record (EHR). This alert notified providers via a pop-up message of the possibility of an inappropriate order. At this study's facility, urine culture reflexes occur automatically in the LIS when the urinalysis meets one of the following criteria: urine dipstick positive for leukocyte esterase or nitrates, or the presence of greater than five white blood cells on the microscopic review. Our study considered appropriate testing as when an assessment was made when urinary symptoms were present, with an order for urine culture or urinalysis that can reflex to urine culture, or when urinary symptoms were absent with an order for only urinalysis. Urinary symptoms were defined as the presence of one or more of the following: urgency, frequency, retention, dysuria, suprapubic pain, flank pain, pelvic discomfort and/or acute hematuria [12].

An interprofessional team, including a DCLS laboratory professional, a pathologist, an infectious disease practitioner, a physician champion, an application services coordinator, and an application services analyst, collaboratively designed the BPA using the Choosing Wisely Recommendations from ASM and IDSA guidelines. This study was developed as a quality improvement request from the Antimicrobial Stewardship Team and received approval from the hospital's Department of Compliance and the Project Governance Committee. It was also approved as an exempt study by the University of Texas Medical Branch Internal Review Board.

2.1. Data Collection

Retrospective data were manually collected and included patient demographics (age, race, sex, and ethnicity), provider types, patient location, antibiotic therapy at admission and discharge, test orders (urinalysis reflex to urine culture, urinalysis only and urine culture only), laboratory results for the urine culture when applicable, the patient's chief complaint and days since last admission (readmission is $\leq$30 days). For prospective review, data were extracted using a Business Intelligence SQL report available on the hospital server. This report included all variables from the retrospective review (patient demographics, provider types etc.) and added urinary symptoms, and BPA actions.

Providers for which the BPA was triggered at least five times were reviewed. For those providers who bypassed the BPA and continued with the original order more than 80% of the time, direct communication was attempted using both the Epic chat feature and email. Based on the BPA report, the DCLS provided consultations to practitioners when appropriate.

2.2. Data Analysis

Pre- and post-intervention practices were evaluated across several variables (over-/under-utilization, appropriate), the facility (provider type, patient location area, etc.), test order type (order, culture reflex) and symptom (symptomatic/asymptomatic). A chi-square statistical analysis was performed using SPSS software (version 28.0.1.0 (142)), with p values < 0.05 indicating statistical significance.

3. Results

In our study, we reviewed a total of 6372 patients, 3408 in the retrospective review group and 2964 in the prospective review group. Many of the patients were female, white, with a mean age of 50.6 years (range, 18–101 year) in the retrospective review and 53.5 years (range, 18–103 year) for the prospective review (Table 1).

Table 1. Demographic characteristics of study data.

Sample Characteristics	Retrospective [a]		Prospective [b]	
	n	%	n	%
Gender				
Female	2012	59.0	1848	62.3
Male	1396	41.0	1116	37.7
Ethnicity				
White	2395	70.3	2169	73.2
Hispanic or Latino	477	14.0	331	11.2
Black or African American	411	12.1	367	12.4
Other [c] or Unknown	125	3.7	97	3.3
Age (in Years)				
Mean (Range)	50.6 (18–101)		53.5 (18–103)	

[a] n = 3408. [b] n = 2964. [c] includes Asian, American Indian or Alaska Native, Middle Eastern Indian, or Native Hawaiian or Other Pacific Islander.

Regarding urinalyses test orders, our study identified that 60% (n = 2053) of the test orders were inappropriate; after BPA intervention, this was reduced to 20% (n = 591). The Chi-square test was statistically significant X^2 (1, N = 6372) 1060.609, $p < 0.001$, $\Phi = 0.408$, and indicated that the intervention had a moderate effect on urinalyses test orders. For inappropriate orders, overutilization accounted for 59% (n = 2021) of orders in the retrospective review and only 12% (n = 365) for the prospective review, while the rate of underutilization increased slightly from 1% (n = 32) to 8% (n = 226). Chi-square statistical analysis determined that there was a significant difference in inappropriate test orders (overutilization, underutilization vs. appropriate), with a moderate to large effect between the two reviews, X^2 (2, N = 6372) 1549.791, $p < 0.001$, $\Phi = 0.493$. Lastly, according to an analysis of data regarding the types of test orders, from the 3408 total test orders, 3078 (90.3%) were urinalyses reflex to urine culture, 204 (6.0%) were urinalyses only (no culture reflex), and 126 (3.7%) were urine culture only for the retrospective review. For the prospective review, from the 2964 total test orders, 2080 (70.2%) were urinalyses reflex to urine culture, 810 (27.3%) were urinalyses only (no culture reflex), and 74 (2.5%) urine were culture only.

When analyzing urinalyses reflex to urine culture for test order appropriateness, there was a significant difference between the two reviews, with a moderate effect size, X^2 (1, N = 5158) 1019.458, $p < 0.001$, $\Phi = 0.445$. Neither group had test orders that demonstrated underutilization; however, overutilization accounted for 62% (n = 1913) of the retrospective review and intervention then dropped to 17% (n = 357) in the prospective review. Regarding urinalysis-only test orders, there was a significant difference between the two reviews, with a small to medium effect size, X^2 (2, N = 1014) 61.744, $p < 0.001$, Φ = 0.247. However, post hoc tests demonstrated that there was only a small to no effect when comparing appropriate test orders and underutilization, which accounted for most of the data in this test group, X^2 (1, N = 1001) 9.843, $p < 0.005$, Φ = 0.099. The statistical differences occurred when including overutilization (assessment variable), which was only present in the retrospective data (n = 13). Of note, there were four times as many test orders for urinalysis in the prospective data when compared to the retrospective data. For urine cultures ordered alone, there was a significant difference in the appropriate test orders between the two reviews, demonstrating a large effect size, X^2 (1, N = 200) 74.686, $p < 0.001$, Φ = 0.611. After intervention, appropriate ordering practices increased from 25% (n = 31) to 88% (n = 65) (Table 2).

Table 2. Assessment of urinalyses test orders.

Test Orders	Retrospective [a]		Prospective [b]	
	n	%	n	%
All Urinalyses Test Orders				
Appropriate	1355	40.0	2373	80.0
Inappropriate	2053	60.0	591	20.0
Overutilization	2021	59.0	365	12.0
Underutilization	32	1.0	226	8.0
Assessment of Types of Urinalyses				
Urinalysis reflex to urine culture	3078		2080	
Overutilization	1913	62.0	357	17.0
Underutilization	0	0	0	0
Appropriate	1165	38.0	1723	83.0
Urinalysis only	204		810	
Overutilization	13	6.0	0	0
Underutilization	32	16.0	225	28.0
Appropriate	159	78.0	585	72.0
Urine culture only	126		74	
Overutilization	95	75.0	9	12.0
Underutilization	0	0	0	0
Appropriate	31	25.0	65	88.0

[a] n = 3408. [b] n = 2964.

Furthermore, data regarding the appropriateness of test orders in asymptomatic patients were assessed based on the presentation of clinical symptoms. When comparing appropriate test orders (overutilization vs. appropriate; no underutilization for this test group) for asymptomatic patients, a significant difference was present, with a large effect size, X^2 (1, N = 3129) 1079.144, $p < 0.001$, Φ = 0.588. Our study identified inappropriate ordering practices, which were all categorized as overutilization; this accounted for 93% (n = 2021) of the retrospective data, dropping to 38% (n = 366) after the intervention. For urinalyses that reflex to a urine culture by symptoms, there was a significant difference between the two reviews, which demonstrated a moderate effect, X^2 (1, N = 1964) 318.554, $p < 0.001$, Φ = 0.403. In asymptomatic patients, urinalyses that reflex to urine culture decreased from 51% (n = 501) in the retrospective review (n = 990) to 13% (n = 127) after intervention.

Finally, for asymptomatic patients, the presence of antibiotic therapy at discharge dropped from 54% (n = 509) to 25% (n = 219) after intervention. A statistical analysis of the two review groups showed a significant difference in antibiotic therapy for asymptomatic patients at discharge, with a moderate effect size, X^2 (1, N = 1841) 171.377, $p < 0.001$, $\Phi = 0.305$ (Table 3).

Table 3. Appropriateness for asymptomatic patients.

	Retrospective		Prospective	
	n	%	n	%
Test Orders for Asymptomatic Patients	2178		951	
Appropriate	157	7.0	585	62.0
Inappropriate	2021	93.0	366	38.0
Overutilization	2021	100.0	366	100.0
Underutilization	0	0	0	0
Reflexed Urine Cultures by Symptoms	990		974	
Symptoms Present	489	49.0	847	87.0
Symptoms Absent	501	51.0	127	13.0
Presence of Antibiotic Therapy at Discharge	940		901	
Symptomatic	431	46.0	628	76.0
Asymptomatic	509	54.0	219	24.0

Next, the data were assessed based on the provider type. Physicians included both MDs and DOs while advanced practice providers included physician assistants and nurse practitioners. Differences in pre- and post-intervention ordering practices were statistically significant for both provider types. For physicians, a medium to large effect size was calculated, X^2 (2, N = 5310) 1130.699, $p < 0.001$, $\Phi = 0.461$; appropriate orders accounted for 42% of the retrospective data and 80.5% of the prospective data (Table 4). The intervention demonstrated a large effect for advanced practice providers, X^2 (2, N = 1062) 1079.144, $p < 0.001$, $\Phi = 0.646$, who used appropriate orders only 27.6% of the time on the retrospective review, but 78.0% on the prospective review. Overutilization decreased for both provider types: physicians went from 57% overutilization down to 13%, while advanced practitioners went from 72% down to 9%. Unexpectedly, underutilization increased from 1% to 7% for physicians and 0 to 13% for advanced practitioners.

Table 4. Assessment by provider type.

Assessment	Retrospective [a]		Prospective [b]	
	n	%	n	%
Overutilization	2021	59.3	366	12.3
Physician	1633	80.8	317	13.0
Advanced Practitioner	388	19.2	49	9.4
Appropriate	1355	39.8	2373	80.1
Physician	1206	89.0	1965	82.8
Advanced Practitioner	149	11.0	408	17.2
Underutilization	32	0.9	225	7.6
Physician	30	93.8	159	70.7
Advanced Practitioner	2	6.2	66	29.3

[a] n = 3408. [b] n = 2964.

4. Discussion

The objective of this quality improvement project focused on the following question: Will an intervention at order entry coupled with a DCLS consultation for inappropriate orders of urinalyses and urine cultures reduce the unnecessary laboratory testing of asymptomatic patients? Our study established that the over and under-utilization of urinalyses and urine cultures occurred; after the intervention (BPA alerts and DCLS consults), we saw a reduction in inappropriate test orders from 60% (n = 2053) to 20% (n = 592). Similar results were seen in studies where they recommend interventions at order entry to prevent the overutilization of cultures and in studies that require symptom documentation, including sending inappropriate order alerts to providers in order to achieve improved provider practices and laboratory test utilization [9,13].

Regarding inappropriate urinalysis test orders, the most common overutilized test order was a urinalysis with culture reflex, which supports the findings of a similar study and the need for diagnostic stewardship [9]. The overutilization of this specific test accounted for 62% (n = 1913) within the retrospective review and, after intervention, reduced to 17% (n = 357). One reason for this test being ordered most often is that it automatically reflexes to urine culture when indicated, and that the indications are based on urinalysis results rather than the presence of urinary symptoms. Adding the BPA intervention highlighted the need to consider symptoms along with the urinalysis order, thereby reducing unnecessary urine culture [9,13].

For urinalysis only, the overutilization of urinalysis only tests reduced from 6% (n = 13) to 0% after the intervention, while underutilization increased from 16% (n = 32) to 28% (n = 225). Our study showed that the urinalysis-only test was affected least by the BPA. The appropriate order of urinalysis only was at 78% (n = 159) and decreased to 72% (n = 585) after the intervention, which was unexpected, but supported by Sullivan et al. [9]. This is likely because urinalyses that automatically reflex to urine culture were the predominant order used for physician order sets. When only urinalysis was ordered, the physicians were aware of the exact urinalysis ordered and likely did not want urine culture results. This would have been a conscious additional step and likely not part of the routine order set workflow for the retrospective study. For the prospective review, there was a four-fold increase in urinalysis-only orders, indicating an awareness of the need to reduce urinalysis with urine culture reflex orders on the asymptomatic population. For urine culture only, after intervention, the overutilization of this test type dropped to 12% (n = 9) from 75% (n = 95), with an increase in appropriate test orders from 25% (n = 31) to 88% (n = 65), highlighting the effectiveness of BPA and the DCLS consultation intervention. The reduction in inappropriate urine culture orders between the two review periods showed a large effect, highlighting ASB awareness.

Next, we will discuss the effect of the BPA on the treatment of ASB, since recognizing test selection errors (pre-pre-and post-post-) and the need for test interpretations play a huge role in the prevention of diagnostic errors [11]. Pre-preanalytical errors occur when clinicians order inappropriate tests or fail to order appropriate tests; when applied to ordering practices for urine cultures and urinalyses in the hospital setting, this would include the ordering of urine cultures for non-pregnant adult patients who are asymptomatic. In our study, for the asymptomatic population, inappropriate test orders were found in 93% of the patients in the retrospective review; due to the intervention, this decreased to 38%, demonstrating a large effect and a reduction in diagnostic errors.

As discussed previously, the results from inappropriate urine cultures led to the treatment of ASB and the improper reporting of CAUTIs. To demonstrate this significant reduction, we compared the urine culture reflexes to the symptoms present, which confirmed that fewer culture results were reported for the asymptomatic population in the post-intervention data, dropping from 51% to only 13%. Furthermore, we compared the initiation of antibiotic therapy at discharge in the presence of symptoms, and a significant difference with a moderate effect size was identified. This validates the reduction in the treatment of ASB in the post-intervention population—reducing ASB treatment by more than 55%. Overall, this intervention led to a significant reduction in the treatment of ASB, which has been linked to the overuse of antibiotics leading to the development of antimicrobial resistance.

Additional studies are needed to assess whether a reduction in inappropriate test orders leads to a reduction in adverse events such *C. difficile* infection and readmissions. Our study documented the days since the patient's last admission but did not then determine if the patient had another admission in the next 30 days. This information would be useful to determine if readmission rates were affected by the reduction in inappropriate orders. Our study's findings highlight the importance of using technological developments to reduce errors and provide easy and rapid access to test interpretation [14]. The study further shows that improvements in test request appropriateness and the interpretation of results should occur due to initiatives that seek to improve knowledge about laboratory tests and the correct interpretation of test results. Therefore, reducing pre-preanalytical errors by improving knowledge at the point of care using technology presents a distinct and readily available opportunity for process improvement.

Lastly, all provider types showed a significant improvement in appropriate orders. For both provider types, the overutilization of lab tests dropped from 59.3% (n = 2021) to 12.3% (n = 366), while appropriate test orders increased from 39.8% (n = 1355) to 80.1% (n = 2373). One unexpected significant finding, although there was no effect size, was the increase in underutilization. A reason for this could be the lack of physicians' understanding of the BPA, as mentioned above. Specifically, one provider did not realize they should have been modifying the order rather than "accepting" or proceeding with the original order. A post-study follow-up of the specific provider's BPA information shows a decrease in BPA bypasses from the 100% BPA bypass rate during the last month of the study.

An interesting finding from the medical staff meeting, which supported findings from other studies, was that physicians were already aware that they should not treat ASB, and agreed they needed something to reinforce what they already knew [15,16]. The best practice alert provided this reassurance and corrected many of the inappropriate ordering practices. The treatment of ASB, therefore, was not due to a lack of education but due to providers having access to unnecessary culture information. When a provider was given unnecessary culture information, he or she tended to err on the side of caution and treat it [4]. By reducing the overutilization of the urine culture, practitioners withheld antibiotic treatment, as evidenced by the reduction in new antibiotic therapy at discharge in the asymptomatic population. Antimicrobial stewardship continues to play a huge role in the prevention of the development of multi-drug-resistant organisms and reductions in other adverse events. Ongoing studies are necessary to determine the best way to reduce antibiotic usage while also reducing patient harm and adverse events. Education alone is not always an appropriate tool. Practitioners must learn to rely on evidence-based practice and quit erring on the side of caution, especially when that caution leads to patient harm.

Further studies are needed to assess the differences in the ordering practices of physicians who received a consultation compared to those that did not. Finally, although it is extremely important to process improvement projects, practitioner feedback is severely lacking. Future studies are needed to determine the cause of this disconnect and to determine the best way to increase practitioner feedback.

Grol and Grimshaw acknowledge the existence of a gap between evidence and practice, stating that educational materials alone, such as continuing medical education sessions, may not be effective in implementing practice changes [15]. The article highlights common barriers and strategies; one specific barrier being noted was that the clinical environment must be conducive to change. They concluded that change requires heavy preparation, which includes the involvement of appropriate people, evidence-based best practices, concrete descriptions of the desired performance, the definition of appropriate indicators of success, and thorough monitoring.

Clinical decision support (CDS) is a term used to describe a wide array of tools available in the electronic health record (EHR) to support clinicians by providing information such as evidence-based clinical guidelines at the point of care [17]. Largely due to the Affordable Care Act mandate, this technology has been incorporated into and is readily available in most EHRs. One CDS tool available is the BPA, which is a method of communication within the EHR that notifies the provider of specific information through messages, storyboard alerts, and/or interruptive or passive alerts when defined criteria are met [18]. While it has been shown that CDS tools like the BPA have a positive impact on patient care, many barriers exist across healthcare facilities, preventing their implementation. For CDS to be successful, one must transfer the right information to the right person in the right format through the right channel at the right point in the workflow; these are called the "5 rights". Along with the 5 rights BPA design, one must also have support from administration, clinicians, and information services and use reporting tools to enhance provider communication, evaluation, and follow-up [16]. Another study supported the need for CDS; however, it highlighted the existence of alert fatigue as a barrier, noting that alerts regarding inappropriate culture orders may be deemed a nuisance by some nurses [19]. Technology alone is not enough, and monitoring quality indicators does not necessarily achieve improvements [20].

There were several limitations to our study. Antimicrobial stewardship practices and ongoing provider education may have made physicians more aware of appropriate ordering practices and proper indications for antibiotic prescription, and could be responsible for skewing the data. Also, antibiotics may be initiated for non-urinary indications, which is not accounted for in this study. There was an instrumentation effect in this study. The determination of the presence of urinary symptoms in the prospective review was based on the provider-answered order entry question, while the retrospective review was based on the chief complaint and chart review. Additionally, this analysis assumes that the practitioner selected the appropriate answer to the order entry question and does not account for inappropriate or incorrect answers, both of which could lead to inconsistencies in symptom determination affecting the assessment of order appropriateness. Finally, our data were a convenience sample collected at one specific hospital and may not be reflective of the entire patient population.

5. Conclusions

Our study reinforces the value of direct interventions in guiding appropriate ordering behaviors in community hospital settings. It highlights the importance of providing direct feedback to end users to ensure their compliance with and understanding of the intervention. Educating providers about appropriate orders at the point of order entry proved effective, highlighting the need for diagnostic stewardship. Post-intervention ordering practices improved significantly, reducing the number of inappropriate orders across all patient and provider types. Overall, this initiative led to a significant reduction in the treatment of asymptomatic bacteriuria, which has been linked to the overuse of antibiotic therapy.

Author Contributions: A.F. designed the research study, performed the research, acquired/analyzed data and wrote the thesis paper. N.W.-B. aided in conceptualization and writing. P.R. aided in

conceptualization and writing. J.H.S. aided in analysis, visualization and writing. R.R. supervised the research, aided in research design, reviewed, and generated the first draft of the manuscript. C.C. aided in research design and data curation and analysis. All authors had final responsibility for the decision to submit for publication. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was developed as a quality improvement request from the Antimicrobial Stewardship Team and received approval from the hospital's Department of Compliance and the Project Governance Committee. It was also approved as an exempt study by the University of Texas Medical Branch Internal Review Board (IRB# 22-0075) on 31 May 2022.

Informed Consent Statement: Patient consent was waived due to the study primarily being retrospective in nature. The study collected and analyzed de-identified retrospective data from the electronic medical records, where contacting patients was unnecessary and impractical since the study posed minimum risk to the patients and all data pertaining to patients were protected via measures recommended by the University of Texas Medical Branch Internal Review Board.

Data Availability Statement: The data that support our study's findings are available from the primary author (AF) and the corresponding author (RR) upon reasonable request.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

DCLS	Doctorate in Clinical Laboratory Sciences
CDC	Center for Disease Control and Prevention
ASM	American Society for Microbiology
IDSA	Infectious Disease Society of America
SHEA	Society for Healthcare Epidemiology of America
CDI	*C. difficile* infection
ASB	Asymptomatic bacteriuria
CFU	Colony-forming units
CAUTI	Catheter-associated urinary tract infections
CMS	Center for Medicare and Medicaid Services
HER	Electronic health record
BPA	Best practice alerts
CDS	Clinical decision support

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