Behavioral Strategies in Diagnostic Stewardship

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KEYWORDS

• Antibiotic stewardship • Behavioral strategies • Diagnostic stewardship
• Implementation

KEY POINTS

- Diagnostic stewardship modifies the ordering, collecting, processing, and reporting of diagnostic tests to improve diagnostic safety and patient outcomes.
- Interventions used within diagnostic stewardship are often multifactorial, combining systems and automated functions with behavioral strategies.
- Understanding the impact of individual, interpersonal processes, organizational culture, and policy on diagnostic testing is critical to developing successful diagnostic stewardship interventions.

INTRODUCTION

Diagnostic stewardship refers to the practice of optimizing the selection, utilization, and interpretation of diagnostic tests to improve patient outcomes and reduce unnecessary health-care costs.[1,2] It involves a systematic approach to diagnostic testing, with the goal of ensuring that tests are ordered appropriately, and that the results are effectively used to guide clinical decision-making. Appropriate diagnostic testing is an essential component of high-quality patient care because it can help clinicians to accurately diagnose and treat various medical conditions. Inappropriate or excessive testing can lead to unnecessary health-care costs, patient harm, and potential overdiagnosis and overtreatment.[1,2]

There is tension between antibiotic stewardship programs (ASPs) and front-line clinicians despite promotion of evidence-based guidance by ASPs. This tension is likely, in part, due to competing priorities, different beliefs about consequences, and the autonomy of individual practitioners.[3–5] Additionally, behavioral factors such as cognitive biases, perceived risk, and lack of knowledge or awareness can lead to inappropriate

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or excessive test ordering and interpretation. However, behavioral and social theories seem underused in antimicrobial and diagnostic stewardship interventions.[3] In this article, we will explore the importance of behavioral strategies in promoting appropriate diagnostic testing, and how these strategies can be effectively implemented in clinical practice.

DISCUSSION

Understanding the Behavioral Determinants of Diagnostic Testing

Behavioral determinants of diagnostic testing refer to the factors that influence an individual's decision-making and behavior regarding seeking and undergoing diagnostic tests.[6] Understanding these behavioral determinants is vital for improving testing uptake, reducing disparities, optimizing resource allocation, enhancing patient-centered care, informing policy decisions, and fostering informed decision-making. It supports efforts to promote testing, improve public health outcomes, and ensure equitable access to diagnostic services.[6] Although there are several theories, models, and frameworks that can be used to understand diagnostic testing behavior.[7–12] The Health Belief Model (HBM) highlights the factors influencing health-related behaviors, including how we perform diagnostic testing.[13] According to the HBM, a clinician's decision to perform a diagnostic test depends on perceived susceptibility to the disease, the severity of the disease, perceived benefits of testing, perceived barriers to testing, and cues to action (**Table 1**). In summary, the HBM can help to explain some of the reasons behind overtesting or inappropriate testing, and understanding these factors can inform interventions, such as improving the accuracy of risk assessments, providing evidence-based information on the benefits and risks of testing, and reducing external cues to action that promote unnecessary testing.

Behavioral Strategies to Promote Appropriate Diagnostic Testing

Behavioral strategies, also known as behavior change strategies or behavior change techniques, are specific actions or approaches designed to influence and modify human behavior. These strategies are used to promote positive behavior change or discourage negative behaviors. Behavioral strategies are typically based on principles derived from behavioral theories and research, and they aim to address the determinants of behavior to facilitate desired outcomes.[6] There are several ways in which

Table 1
Health belief model

Perceived susceptibility	Clinicians may think that their patients are more susceptible to a disease or condition than they are. This may lead them to order diagnostic testing unnecessarily, even if the likelihood of having the disease is low (eg older adults with confusion and bacteriuria)
Perceived benefits	Clinicians may think that testing provides more benefits than it does. They may think that testing will provide reassurance, prevent disease, or lead to early detection, even when the evidence does not support these beliefs
Perceived barriers	Clinicians may perceive barriers to alternative approaches such as watchful waiting (such as lack of time or support) and perform diagnostic testing anyway, even if the benefits are low
Cues to action	External factors such as fear of litigations and patient expectations may serve as cues to action for testing. These cues may encourage clinicians to perform testing, even if they do not perceive patients to be at risk or the benefits are low

ASPs can use behavioral strategies to improve testing practices and promote diagnostic stewardship. Behavioral strategies can target cognitive biases identified using the behavioral determinants that lead clinicians to order unnecessary or inappropriate tests. For instance, anchoring bias, where clinicians rely too heavily on the first piece of information they receive, can lead to inappropriate test ordering.[14] By identifying these biases, targeted interventions such as decision support tools can be developed to provide clinicians with real-time guidance on appropriate test selection and interpretation.

Social factors, such as peer pressure and financial incentives, can influence test ordering and interpretation.[5] Behavioral strategies can help to identify these social factors and develop targeted interventions to address them. For instance, financial incentives that reward appropriate test ordering and interpretation can be put in place to counteract incentives that may promote overuse or misuse of tests. Behavioral strategies can also target individual and organizational barriers to diagnostic stewardship, such as lack of knowledge or awareness, and competing demands on clinicians' time.[5] By addressing these barriers through targeted interventions such as education and feedback to clinicians and changes to clinical workflows, health-care clinicians and policymakers can improve the overall quality of care and reduce potential harms associated with overuse or misuse of tests.

Finally, behavioral strategies should be used to promote patient engagement in the diagnostic testing process. For instance, by providing patients with information on the purpose and potential harms of tests, and involving them in shared decision-making, patients can become more informed and involved in their care, leading to improved adherence to testing recommendations.

Examples of Behavioral Strategies

There are numerous examples of diagnostic stewardship interventions that aim to change testing practices through both individual and institutional changes. Current evidence supports numerous behavioral strategies, which are often combined into multipronged interventions. These strategies are also frequently combined with system-level interventions that force automation, such as test order canceling, or alter availability of test results, such as selective culture reporting. Below are examples of successfully implemented interventions, which often span multiple strategies.

Education and Feedback

Providing education and feedback to clinicians can help to improve their knowledge and awareness of appropriate testing practices. Education and feedback are often combined with other types of automated or behavioral-based interventions.[15,16] An example is a multilayered diagnostic stewardship intervention to decrease hospital onset-*Clostridium difficile* infection (CDI), which included education and feedback from a CDI Task Force.[16] The first intervention focused on an electronic medical record (EMR)-based alert to ordering clinicians of laxative administration, bowel movement frequency/quality within the past 24 hours, and previous *C difficile* test results within the past 7 days. The second intervention focused on nursing education and empowering them to not send stool that did not meet clinical criteria. This was followed by another EHR-based alert that completely prevented ordering of *C difficile* tests in the presence of laxative use or previous testing. All 3 phases of the intervention significantly decreased testing, which resulted in stepwise decreases in reported hospital onset-CDI cases.[16]

Several examples of education and feedback also exist for the management of urinary tract infections (UTIs).[17,18] A cluster-randomized trial of 25 nursing homes implemented a multifaceted intervention that consisted of webinars, educational pocket cards on diagnosis and treatment recommendations, and physician order-sets.[17] Compared with control sites the educational initiative resulted in a 21% decrease in inappropriate antibiotic prescribing. Among hospitalized patients, educational initiatives have also been used to decrease rates of catheter-associated urinary tract infections (CAUTI).[19–21] One center used a dedicated urine culture stewardship program to conduct monthly 1-hour educational discussions with intensive care unit (ICU) staff regarding appropriateness of urine culturing and avoidance of pan-culturing.[21] This was accompanied by a root cause analysis for all identified CAUTIs, with feedback provided to the ICU teams. During the study period, the CAUTI rates significantly declined from 2.1 CAUTIs per 1000 catheter days to 1.03 CAUTIs per 1000 catheter days.

Clinical Decision Support Tools

Clinical decision support (CDS) tools can be used to provide clinicians with real-time guidance on appropriate test selection and interpretation if implemented appropriately.[22] These tools can be integrated into EMRs or provided as standalone applications. There are numerous examples of leverage computerized CDS tools to improve diagnostic testing across infectious diseases (**Table 2**).

Computerized CDS tools have been successfully used to decrease inappropriate urine testing, culture processing, and downstream detection and treatment of ASB.[23] A multicenter study involving implementation of a CDS tool that educated clinicians on appropriate indications for urine culturing and leveraged patient-specific data to prompt urine catheter-exchange decreased both testing and antimicrobial use.[24] A separate multicenter study also found significant decreases in urine culturing and antimicrobial use through a CDS tool that guided clinicians to the appropriate urine test, required clinical indications, and prioritized conditional urine culture when an infectious process was suspected.[25] Investigators were able to demonstrate a significant decrease in both urine-culturing rates by 40.4% as well as UTI antibiotic days of therapy (DOTs) by 15.2%. Conditional urine culturing, in which ordered urine cultures are only processed based on predefined urinalysis criteria, can also be considered a form of CDS.[26] Conditional urine culturing has shown benefit in decreasing the number of urine cultures processed by 30% to 40%.[27–29] The downstream impact of conditional urine culturing on antimicrobial use remains to be fully explored but has been shown to influence decisions on UTI antibiotics at the patient level.[30]

There also exists numerous examples of CDS to improve diagnosis of CDI.[31–33] In a recent meta-analysis of 11 studies, 6 demonstrated significant decreased rates of *C difficile* testing.[32] In a longitudinal cohort study involving 15 sites, 9 academic medical centers and 6 community hospitals, implementation of CDS consistently decreased inappropriate testing.[34] Nine sites implemented hard stops on *C difficile* tests, 4 implemented soft-stops, and 2 used non-CDS tools that leveraged the antibiotic stewardship (ASP) team to perform audit and feedback on ordered tests. Incidence rates of *C difficile* test ordering decreased by 33% with hard stops and 23% with soft stops. Hard stops were significantly more effective than either soft stops or ASP interactions at decreasing testing rates. A retrospective case-control study compared patient outcomes between those with a *C difficile* NAAT that was prevented through CDS to those who had a negative test.[35] Among 673 cases, patients with prevented tests did not have worse outcomes, such as inpatient mortality or escalation of care, compared with those who had negative tests (adjusted OR 0.912, $P = .747$). This study highlighted the safety of CDS tools to reduce inappropriate *C difficile* testing in the inpatient setting.

Table 2
Examples of clinical decision support tools to improve diagnosis

Infectious Disease	CDS Intervention Example	Outcomes
UTIs	CDS tool with passive education, patient specific prompts for catheter exchange, adjustable list of urine cultures recommended actions[24]	Reduction in urine cultures performed by 1.4% per month ($P < .001$) and UTI antibiotics by 2.3% per month ($P = .006$)
	Order-set with guidance for appropriate urine test and requirement of clinical indications[25]	Reduction in urine cultures performed by 40.4% ($P < .01$) and UTI antibiotics by 15.2% ($P < .01$)
	Replace default inpatient urine culture order with UA and conditional urine culture (urine WBC > 10); CDS to limit urine culturing without reflex[29]	Monthly culture order rate decreased 47.2% (35.2–18.6 per 1000 patient days)
C difficile infection	EMR-embedded order set preventing enteric multiplex panel when admitted >3 d and *C difficile* testing with laxatives in the preceding 48 h[92]	Decrease in *C difficile* test ordering by 28.2%, no difference in hospital-onset CDI rate
	Two-part EMR-embedded CDS to guide testing based on signs/symptoms and pretest probability of infection[72]	Reduction in *C difficile* ordering by 41% (208–122 per 10,000 patient days, $P < .001$)
	Electronic hard stop to prevent repeat *C difficile* testing that was negative in preceding 96 h[93]	Decreased *C difficile* test use (9.12–6.94 per 100 per admissions, $P < .01$)
Bloodstream infections/sepsis	Alert with link to obtain blood cultures if not already ordered before antibiotics for suspected sepsis[94]	Improved rate of collection (46.1% vs 58.8%); 13.1% increase in timeliness
Lower respiratory tract infections	Electronic pneumonia CDS with real-time EMR data extraction to assist in diagnosis[36,95]	Decreased 30-d all-cause mortality after adjusting for patient severity (aOR 0.62, 95% CI 0.49–0.79, $P < .001$), improved antibiotic prescribing (83.5% vs 90.2%, $P < .001$)

Abbreviations: aOR, adjusted odds ratio; CDI, *C difficile* infection; CDS, clinical decision support; CI, confidence interval; EMR, electronic medical record; UTI, urinary tract infection.

Tools to guide diagnosis of bloodstream infections and pneumonia are more limited, with most focused on improving antimicrobial prescribing decisions after a diagnosis has been made. One example of a diagnostic CDS tool extracted clinical features from the EMR to determine probability of pneumonia in patients presenting to the emergency department (ED).[36] When the probability surpassed 40%, ED clinicians would be notified of the potential diagnosis and, after confirmation, would be guided to management recommendations. With the intervention, those diagnosed with community-acquired pneumonia experienced lower 30-day all-cause mortality (OR 0.53; 95% CI 0.28, 0.99).

Clinical Algorithms and Guidelines

Clinical algorithms and guidelines can be developed to standardize test ordering and interpretation in order to reduce variability in testing practices and improve overall appropriateness. Clinical algorithms are often developed as part of multifaceted interventions, which often include provider education and can also been integrated into CDS.

An EHR-integrated clinical algorithm coupled with clinical guidelines for urine culturing was associated with a significant 23.5% decrease in urine cultures performed postimplementation.[37] The kicking CAUTI campaign, detailed below, developed a diagnostic algorithm to help clinicians differentiate ASB from true infection.[38] Diagnostic stewardship algorithms can also be implemented to assist bedside nursing to deter urine collection in the absence of genitourinary symptoms.[39]

Guidelines and algorithms have been shown to be effective diagnostic stewardship strategies to improve the appropriateness of blood culturing in both adult and pediatric patients. A 2-part practice guideline that consisted of a checklist and decision algorithm for blood culture orders in critically ill pediatric patients was able to demonstrate significant reductions in collection rates.[40] Within the 36-bed pediatric ICU, the intervention was associated with an overall 46% reduction in blood culture collection and an immediate 25% decrease in rate of cultures per 100 patient-days. This initiative was then expanded to a multisite quality improvement (QI) project that consisted of 14 pediatric ICUs.[41] Across all sites, there was a 33% relative reduction in blood culture rates postimplementation (149.4–100.5 per 1000 patient-days per month). This intervention was also associated with a 13% relative reduction in broad-spectrum antibiotic use and reportable central line-associated bloodstream infections. Balance measures such as inpatient mortality, sepsis, and length of stay were unchanged.

Similarly, positive findings have been seen in adult patient populations.[42] Investigators created an algorithm for indications for initial and repeat blood culturing and coupled this was clinical detailing and peer-to-peer feedback. For initial blood culturing, the algorithm separates clinical indications based on pretest probability of bloodstream infection, recommending against cultures in patients with low-risk (<10% probability) conditions such as nonsevere cellulitis without sepsis. Among medical ICU patients, there was an 18% decrease in the rate of blood culturing (27.7–22.8 per 100 patient-days) and 30% (10.9–7.7 per 100 patient-days) reduction among the 5 participating medical units. Balance measures such as compliance with the Severe Sepsis and Septic Shock Management Bundle (SEP-1) and in-hospital mortality were unchanged.

Audit and Feedback

Regular audit and feedback can be used to monitor test utilization and provide clinicians with advice on their test ordering and interpretation practices.[43] This can help to identify areas for improvement and promote the appropriate use of testing. Prospective audit and feedback are already a cornerstone of ASP.[44] These methods can also be applied to decrease ordering of unnecessary diagnostic tests.[45]

Several studies have used audit and feedback techniques to decrease rates of CAUTI.[46,47] After reviewing CAUTI cases, a large academic medical center found that almost half of their reportable events were secondary to routine fever workups and not patient-specific symptomatology.[48] After initial clinical detailing on appropriate urine culture ordering for clinicians and nursing champions, the facility leveraged their QI team for longitudinal interventions. The QI team performed chart reviews every month and provided service chiefs with information on the percentage of inappropriate urine cultures as well as distributed overall performance data to all faculty and trainees. These interventions resulted in a decrease of 230 urine cultures per month and significantly decreased the CAUTI standardized infection ratio.

A seminal example of a multifactorial intervention that included audit and feedback was the Kicking CAUTI Campaign and its efforts to decrease inappropriate treatment of ASB by decreasing urine culture ordering.[38] The first phase focused on the development and validation of a CAUTI diagnostic algorithm, followed by the audit and feedback intervention, which was informed by previous study to identify barriers to evidence-based care and the feedback intervention theory.[49] Feedback was provided to clinicians on a case-by-case basis with investigators choosing cases where positive urine cultures were managed either appropriately or inappropriately with illustrative teaching points across each node of their diagnostic algorithm. Urine culturing decreased significantly from 41.2 to 23.3 per 1000 bed-days during the intervention period. The rate of ASB overtreatment also significantly decreased (1.6–0.6 cases per 1000 bed-days). Importantly, both measures continued to drop during the maintenance phase where active audit and feedback was stopped, highlighting sustainability of the interventions.

A recent intervention leveraged the ASP team to review *C difficile* test orders and provided real-time feedback on appropriateness.[50] *C difficile* tests ordered during the intervention periods required ASP preauthorization and verbal feedback to ordering clinicians. This was preceded by education on the importance of avoiding inappropriate testing, false-positive tests, and predisposing risk factors for true infection. Postimplementation, the rate of hospital-onset CDI decreased significantly (8.5–6.6 cases per 10,000 patient-days, $P < .001$). This was through both immediate and month-to-month decreases. Moreover, oral vancomycin demonstrated significant month-to-month decreases.

Auditing for potentially unnecessary repeat test ordering can help to target diagnostic stewardship interventions within your facility and, similar to antimicrobial stewardship, identify clinicians or services that may require specific attention.[51] Additionally, working with the clinical microbiology laboratory and respective hospital services, regular audit of test ordering menus and order sets can help remove unneeded tests.[52] Removing urine cultures from routine ordering sets and instead replacing with urinalysis with conditional urine culturing has been shown to significantly decrease daily rates of urine cultures ordered in the ED by 46.6% and by 45% in hospitalized patients.[53,54] Additionally, stewardship programs can also consider meeting with microbiology stakeholders regularly to have real-time conversations about potential new diagnostic tests the laboratory may be considering bringing on and potential diagnostic stewardship implications.

Behavioral Nudges

Behavioral nudges are originally derived from behavioral economics to develop choice or decision architecture that moves clinicians toward preferred decisions while maintaining clinical autonomy.[55] Nudges take several forms (**Fig. 1**); examples of nudges include default settings in EMRs, prompts to reconsider test ordering, or downstream antimicrobial decisions. These can occur at multiple stages of the diagnostic process and are used to encourage appropriate test utilization and discourage overuse or

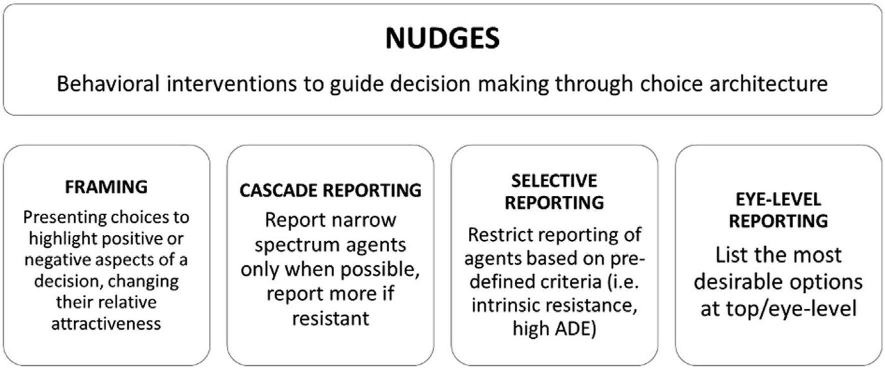

Fig. 1. Definition and examples of nudges in diagnostic stewardship.

misuse of tests and antibiotic treatment. As such, these strategies are commonly used in diagnostic stewardship efforts by stewardship programs.

Nudges placed when a clinician orders a diagnostic test are often placed in the form of best practice alerts (BPAs) or memos embedded in the EMR and are a straightforward form of CDS. For example, an information memo recommending against urine testing in the absence of genitourinary symptoms decreased culture orders by 6.3%.[56] Nudges have also been successful in decreasing *C difficile* test ordering.[57,58] An alert programmed to display when a test was ordered in a patient who received a laxative or stool softener within the last 24 hours nudged clinicians away from testing by canceling the order if they clicked "OK" instead of overriding the notification.[57] Immediately postintervention, order rate decreased significantly by 21%. A similar nudge combined a perceived soft-stop with hard-stop BPAs wherein clinicians were alerted about potentially inappropriate testing and advised to gain secondary approval for testing before proceeding.[58] If clinicians click "OK" on the soft stop, they are moved to the hard-stop. Only 15.4% of clinicians followed the first soft-stop BPA and 57.7% followed the hard-stop. Interns and residents were less likely to follow the BPA compared with fellows and attendings. Weekly average orders rates significantly decreased by 24%, 37%, and 31% at participating hospitals. Oral vancomycin use was also significantly decreased (IRR 0.69, 95% CI 0.48, 0.99).

Clinicians are most familiar with nudges that occur at the reporting phase of the diagnostic process.[59] Nudges used by the clinical microbiology laboratory often in collaboration with stewardship programs include framing statements, selective reporting, and cascade reporting. A commonly cited example is nudging clinicians to de-escalate antimicrobial therapy for suspected pneumonia when sputum cultures are growing only normal commensal flora.[60] By including a statement in the final culture report that reiterated "No *Staphylococcus aureus*/methicillin resistant staphylococcus aureus (MRSA) or *Pseudomonas aeruginosa*," broad spectrum antimicrobial use was decreased (39% vs 73%, $P < .001$) and after adjusting for patient-related variables, the comment was associated with 5.5-fold increased odds of de-escalation. A nudge alerting clinicians to positive respiratory viral panel results, in combination with low serum procalcitonin, was also able to impact prescribing choices.[61] When patients had results indicative of viral cause of pneumonia, combined with existing orders for systemic antimicrobials, a BPA would alert and recommend reassessing the need for antibiotic therapy. This intervention resulted in decreased mean days of antimicrobial therapy (8.0 vs 5.8 days, $P < .001$) and more than 50% decrease in proportion of patients discharged on antibiotics.

Selective or modified reporting can range from restriction of specific antimicrobial agents, such as fluoroquinolones, to near complete restriction of culture results.[62,63] For instance, in a randomized controlled trial changed positive urine culture results for noncatheterized inpatients to: "This POSITIVE urine culture may represent asymptomatic bacteriuria or urinary tract infection. If urinary tract infection is suspected clinically, please call the microbiology laboratory."[63] The proportion of patients with treated ASB was nearly 30% lower in the modified, compared with standard reporting, arm. This intervention was also studied in catharized patients and long-term care facilities but results were not as impactful.[64,65]

Cascade reporting of antimicrobial susceptibilities is also considered a form of nudging.[66–68] Cascade reporting works by first presenting clinicians with preferred, narrower spectrum antimicrobial agents and only releasing information on secondary agents if resistance is present to preferred agents.[69] These interventions do not tend to change diagnosis but can influence antimicrobial consumption or shift prescribing practices to decrease the use of unnecessarily broad antimicrobials. Within a Veteran's Affairs Medical Center, implementation of cascade reporting for cultures growing *Enterobacterales* or *P aeruginosa* limited reporting of fluoroquinolones, and broad-spectrum beta-lactams such as carbapenems.[66] Mean DOTs of meropenem decreased 24% and piperacillin-tazobactam decreased 17%; however, cefepime consumption increased 2.7-fold.

Financial Incentives

Financial incentives can be used to promote appropriate test ordering and interpretation. For instance, incentives that reward appropriate test utilization and discourage overuse or misuse of tests can be implemented.[70] Value-based incentive programs have been leveraged to decrease health-care associated infections, such as hospital onset-CDI.[71] More direct financial incentives have also been used to decrease rates of CDI.[72] A computerized CDS tool was paired with a financial incentive for medical trainees. This incentive consisted of a 0.8% bonus if testing by trainees decreased by at least 25% during the academic year. The tool and incentives were associated with a 41% in overall *C difficile* resting rates (208 per 10,000–122 per 10,000 patient-days, $P < .001$).

Patient Engagement

Promoting patient engagement in the diagnostic testing process can help to improve adherence to testing recommendations and promote shared decision-making. This can include providing patients with information on the purpose and potential harms of tests and involving them in the decision-making process.[73] Engagement can occur at multiple levels across the patient care experience, from direct patient interactions to participation in hospital-level policies. Patient engagement has been shown to improve hospital services.[74] Despite this, there are wide variations in patient engagement policies and practices across health-care systems.[75,76] The Agency for Healthcare Research and Quality has developed guidance with multiples strategies for engaging with patients and family.[77]

Overall, the use of behavioral strategies can help to promote diagnostic stewardship and improve testing practices by addressing individual and organizational barriers to appropriate testing, providing real-time guidance and feedback, and promoting patient engagement and shared decision-making.

IMPLEMENTATION OF BEHAVIORAL STRATEGIES FOR DIAGNOSTIC STEWARDSHIP

Several theories, models, and frameworks can be useful for developing interventions that target specific aspects of diagnostic testing behavior, as well as for evaluating the effectiveness of these interventions. We will describe how to use the behavior change wheel framework to implement diagnostic stewardship interventions.

The Socio-Ecological Model

The socio-ecological model emphasizes the interaction between individuals and their social and physical environment in shaping health outcomes (**Fig. 2**).[78] It provides a framework for understanding how multiple factors at different levels, such as individual, interpersonal, organizational, community, and policy levels, influence health-related behaviors, including those related to the use of antibiotics and other diagnostic tools. To promote diagnostic stewardship interventions using the socio-ecological model, the following steps can be taken:

1. *Identify key stakeholders*: It is important to identify the key stakeholders involved in the diagnostic process, including clinicians, patients, health-care organizations, and policymakers.
2. *Understand the factors influencing diagnostic decision-making*: Identify the factors that influence the diagnostic decision-making process at different levels, such as individual-level factors (eg, knowledge, attitudes, beliefs), interpersonal-level factors (eg, communication between health-care clinicians and patients), organizational-level factors (eg, diagnostic protocols, and resources), community-level factors (eg, cultural norms), and policy-level factors (eg, regulations).[5]
3. *Develop a multilevel intervention strategy*: Based on the identified factors, develop a multilevel intervention strategy that targets the key stakeholders at different levels. For example, interventions targeting front-line clinicians could focus on improving their knowledge of diagnostic stewardship principles and providing them with decision-making support tools.[3] Interventions targeting patients could focus on improving their understanding of the risks and benefits of diagnostic tests and encouraging them to participate in shared decision-making with their clinicians.
4. *Implement and evaluate the intervention*: Implement the intervention and evaluate its effectiveness in improving diagnostic stewardship behaviors. The evaluation

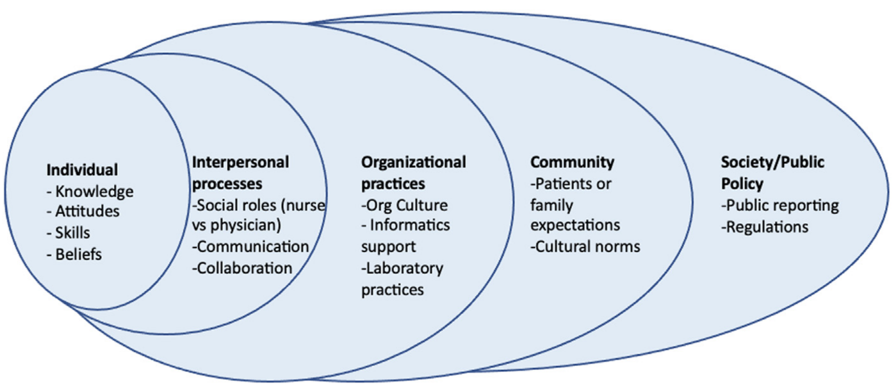

Fig. 2. Socio-ecologic model of behavior change.

should assess the intervention's impact on the different levels of the socio-ecological model and identify areas for improvement.

In summary, the socio-ecological theory provides a useful framework for promoting diagnostic stewardship interventions by identifying key stakeholders, understanding the factors influencing diagnostic decision-making, developing a multilevel intervention strategy, and evaluating the intervention's effectiveness.

The Behavior Change Wheel

The Behavior Change Wheel (BCW) is another framework that helps identify the factors that drive behavior change and provides a guide to design effective interventions based on these factors.[79,80] Here are the steps you can follow to use the BCW framework to design diagnostic stewardship interventions.

1. *Identify the behavior you want to change*: In this case, the desired behavior change is to avoid or reduce inappropriate use of diagnostic tests or antibiotics. For example, urine cultures for patients with asymptomatic bacteriuria.
2. *Understand the factors that drive this behavior*: Use the COM-B model (Capability, Opportunity, Motivation, and Behavior) to identify the factors that contribute to the behavior you want to change.[5,81] For example, a lack of knowledge about appropriate test use or antibiotic prescribing, financial incentives, fear of missing a diagnosis, or patient pressure for antibiotics can drive inappropriate urine culturing behavior.[3,5,24,82]
3. *Choose intervention strategies*: Once the factors that contribute to the behavior have been identified, choose intervention strategies that are most likely to be effective. These strategies can be chosen from the BCW's intervention functions (education, persuasion, incentivization, coercion, training, enablement, modeling, or environmental restructuring) and policy categories (communication/marketing, guidelines, regulation, legislation, or environmental/social planning).[5]
4. *Develop an implementation plan*: Once the intervention strategies have been identified, develop a plan for implementing them. This may include identifying stakeholders, setting goals, determining resource needs, and developing a timeline for implementation.
5. *Evaluate the intervention*: Finally, evaluate the effectiveness of the intervention and make any necessary adjustments. This can include measuring changes in behavior, gathering feedback from stakeholders, and assessing the impact on patient outcomes and health-care costs.[83]

Overall, the BCW framework provides a structured approach to design effective diagnostic stewardship interventions tailored to the specific behavior and context of the health-care setting.

EVALUATION OF BEHAVIORAL STRATEGIES FOR DIAGNOSTIC STEWARDSHIP

Evaluating behavioral strategies for diagnostic stewardship interventions is important for several reasons. Behavioral strategies are often a key component of diagnostic stewardship interventions. Evaluating these strategies' effectiveness is critical to ensure that the intervention is successful in changing health-care provider behavior and improving patient outcomes.[8,9,84,85]

- *To identify areas for improvement:* Evaluating behavioral strategies can help identify areas where the intervention can be improved. For example, if the intervention is not effective in changing the frontline clinician behavior, it may be necessary to modify the behavioral strategies or explore other approaches.

- *Optimizing resource allocation:* Evaluating behavioral strategies can help health-care clinicians allocate resources more efficiently. By identifying which strategies are most effective, stewards can focus their resources on the most promising interventions and avoid wasting resources on strategies that are not effective.
- *To build a strong evidence base:* Evaluating behavioral strategies can help build a strong evidence base for diagnostic stewardship interventions. This evidence can be used to inform best practices, guide policy decisions, and improve patient outcomes.

Implementation Evaluation Frameworks

Overall, the choice of evaluation framework will depend on the intervention's specific aims and objectives and the context in which it is implemented. There are several evaluation frameworks that can be used to assess the impact of diagnostic stewardship interventions that focus on behavior change.[8,9,86–88] It is important to choose a framework that is appropriate for the specific behavior change being targeted and that provides a comprehensive assessment of the intervention's impact. Here are 3 examples.

1. *Reach, Effectiveness, Adoption, Implementation, Maintenance framework*: This framework assesses the impact of interventions in terms of reach, effectiveness, adoption, implementation, and maintenance.[89] It can be used to evaluate how widely the intervention was implemented, how effective it was in changing behavior, how well it was adopted by health-care clinicians, how well it was implemented in practice, and how well it was maintained over time.
2. *Consolidated Framework for Implementation Research (CFIR):* The CFIR framework provides a comprehensive approach to evaluating diagnostic stewardship interventions, considering both internal and external factors that may influence the success of the intervention.[84,86] It includes 5 domains: intervention characteristics, outer setting, inner setting, individual characteristics, and process.
3. *Predisposing, Reinforcing, and Enabling Constructs in Educational/Environmental Diagnosis and Evaluation (PRECEDE)-Policy, Regulatory, and Organizational Constructs in Educational and Environmental Development (PROCEED) model*: This PRECEDE-PROCEED framework is a planning and evaluation model that includes multiple phases.[85,90,91] The PRECEDE phase focuses on identifying the behavioral and environmental factors that contribute to the problem, whereas the PROCEED phase focuses on designing and evaluating the intervention. This framework can be used to evaluate the diagnostic stewardship intervention's impact on behavior change and the contextual factors influencing its success.

Summary

In conclusion, this article highlights the critical role of behavioral strategies in promoting appropriate diagnostic testing. ASPs can leverage theories, models, and frameworks discussed above to better understand the behavioral determinants of diagnostic testing by incorporating the perspectives of patients, front-line clinicians, nursing staff, and health-care organizations. By harnessing the power of behavior change, ASPs can optimize diagnostic decision-making, reduce unnecessary testing, and improve patient outcomes. Moving forward, qualitative research and multidisciplinary collaboration are needed to advance our knowledge and implementation of behavioral strategies in diagnostic stewardship, ultimately contributing to more effective and responsible health-care practices.[83]

CLINICS CARE POINTS

- Diagnostic stewardship interventions should incorporate the perspectives of all stakeholders including patients, front-line clinicians, nursing staff, and health-care organizations for better engagement.
- Several theories, models, and frameworks discussed above can identify barriers and facilitators to appropriate test use. By identifying these barriers, targeted interventions such as decision support tools can be developed to provide clinicians with real-time guidance on appropriate test selection and interpretation.
- Behavioral nudges, originally derived from behavioral economics, can leverage choice or decision architecture to lead clinicians toward preferred decisions while maintaining clinical autonomy.

DISCLOSURE

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