Review

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Choosing which in-hospital laboratory tests to target for intervention: a scoping review

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Abstract

Introduction: Some laboratory testing practices may be of low value, leading to wasted resources and potential patient harm. Our scoping review investigated factors and processes that developers report using to inform decisions about what tests to target for practice improvement.
Methods: We searched Medline on May 30th, 2019 and June 28th, 2021 and included guidelines, recommendation statements, or empirical studies related to test ordering practices. Studies were included if they were conducted in a tertiary care setting, reported making a choice about a specific test requiring intervention, and reported at least one factor informing that choice. We extracted descriptive details, tests chosen, processes used to make the choice, and factors guiding test choice.
Results: From 114 eligible studies, we identified 30 factors related to test choice including clinical value, cost, prevalence of test, quality of test, and actionability of test results. We identified nine different processes used to inform decisions regarding where to spend intervention resources.
Conclusions: Intervention developers face difficult choices when deciding where to put scarce resources intended to improve test utilization. Factors and processes identified here can be used to inform a framework to help intervention developers make choices relevant to improving testing practices.

Keywords: laboratory testing; low-value; scoping review.

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Introduction

Laboratory testing is one of the highest volume activities in health care. While testing itself only accounts for 3–5% of all medical costs [1], it guides up to 70% of medical decisions which can determine subsequent, more costly care [1–3]. The demand for testing is also increasing [4, 5]. When tests are warranted and indicated, they provide a key tool informing care. However, many tests are overused, with results that either would not change care decisions, or worse, contribute to clinical error – potentially putting patients at risk [6, 7]. Inappropriate repeat ordering of six of the most common tests alone (cholesterol, hemoglobin A1c, thyroid-stimulating hormone, vitamin B12, vitamin D, and ferritin) is estimated to cost $160 million per year in Canada [8]. Overall, it is estimated that 20–30% of tests ordered are low-value (i.e. unnecessary, not indicated, or potentially harmful) [3, 9].

Studying and improving test-ordering practice is challenging because of the sheer volume of administrative test-ordering data available, the huge number of tests, and circumstances under which these tests are ordered that underpin these data sources. Test-ordering intervention developers, i.e. those tasked with determining how to improve test-ordering utilisation in their department, institution, or field, face difficult decisions about choosing

among the hundreds of candidate tests routinely ordered that could be targeted for optimization interventions, and how to measure the impact (and success) of these intervention efforts. These interventions must be worth the organization's time and resources in terms of improving utilisation outcomes such as costs, efficiency, provider workflow, and patient experience and outcomes.

Large-scale initiatives [10, 11] have provided broad guidance on many clinical practices that could help improve test ordering efficiency. For example, *Choosing Wisely* guidance statements include over 250 recommendations pertaining to reducing low-value care, including unnecessary testing, treatments, and procedures [10]. Such recommendations, intended to apply to many settings and institutions, do not always give direction on which specific tests to focus on for specific settings [12]. In addition, individual organizations often want to be informed by these recommendations, but not limited to such general recommendations, which often do not address local implementation environments and challenges. Choices about where to put scarce resources to improve utilization are often complex and site-specific, and many factors could be considered making such choices [13].

As a first step in developing guidance to support utilization intervention choices, we conducted a scoping review to identify factors that might inform these choices, and the processes that others have employed to make them.

Methods

Design

We conducted a scoping review of the literature. Based on methodological guidance established by Levac, Colquhoun, and O'Brien [14] and Tricco et al. [15] we defined our scoping review objectives as:

- Objective I: Identify the factors reported as informing choices about which specific test(s) should be targeted for intervention, as suggested by practice guidelines, recommendation statements or test-focused primary intervention studies.
- Objective II: Identify the processes used by intervention/guideline developers to select specific tests for intervention aimed to improve test-ordering practices.

Protocol and registration

Our results have been reported as per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines [16] (Supplementary Material, Appendix A). We registered this review with the University of Ottawa study registration database.

Eligibility criteria

Our review included: (a) published guidelines, recommendation statements, or empirical studies describing efforts to improve or optimize test-ordering practice of at least one clearly identified laboratory test-orienting practice in a tertiary care setting. The optimization process was defined as increasing test-taking of clinically effective tests, decreasing test-taking of clinically ineffective tests, or increasing appropriate use of testing (e.g. ensuring appropriate patients being targeted). Exclusion criteria included: (a) conference abstracts, commentaries, and letters to the editor; (b) articles not published in English; (c) empirical studies not primarily focused on improving test-ordering practices or that did not clearly identify a specific laboratory test ordering practice; (d) non-laboratory test practices (e.g. imaging); (e) studies not focused on tertiary care; and (f) guidelines and recommendation statements that were not focused on clinician test-ordering practices.

Search strategy development and information sources

An initial set of ten target articles was selected from the reference list of *Choosing Wisely* recommendations related to test ordering that we considered to be exemplars for inclusion in the review (i.e. focused on one or more specific tests, and included information on factors and/or processes used to decide which tests should be targeted for intervention) [17–26]. These papers were used to inform our Medline search strategy (Supplementary Material, Appendix B) led by an information specialist, using the Peer Review for Electronic Search Strategies (PRESS) as guidance [27]. The search strategy was also reviewed by a second information specialist. Medical Subject Headings (MeSH terms) and title and abstract terms ('.tw') were chosen for the two broad categories of terms for 'laboratory tests', and 'clinical practice guideline' and empirical studies were eligible if they contained these terms as well. Medline was the only database searched due to the large number of results and time/resource constraints. The initial search included all available years to May 30th, 2019. A second search was conducted to identify any new articles from June 2019 to June 28th, 2021. We conducted a supplemental search on bibliographies of selected articles where potentially relevant references were noted to identify any additional articles meeting the inclusion criteria.

Study records

Data management: Citations retrieved from the search were imported into the reference manager software Mendeley Desktop 1.17.12 [28] for de-duplication, and then imported into Covidence [29] for screening.

Selection process: Abstracts were reviewed independently and in duplicate by two reviewers (EP, NH); screeners searched articles that included discussion of improved test-ordering practice through a clinical practice guideline or empirical study to improve testing. One author (EP) reviewed the abstracts of records identified through reverse bibliography searching. Full text screening was conducted independently and in duplicate (EP, NH) and justifications for excluded studies were noted; the articles needed to focus on the appropriate use of a test(s), including underuse and overuse, provide guidance about use of one or more specific clinical laboratory tests, and to discuss at least one factor or process guiding the decision to target the test for

intervention. All conflicts (abstracts, full text screening, and reason for exclusion) were resolved through consensus or by a third reviewer (JCB).

Data extraction: All data were extracted by two of three independent reviewers (EP, NH, SY) using a standardized data extraction form in Microsoft Excel 2011. All reviewers piloted the form on the same six randomly selected articles and minor refinements were made. Conflicts between data extraction forms were identified, and consensus was reached between reviewer pairs through discussion (EP, NH, SY). If reviewers were not able to come to an agreement, a third reviewer (JCB) was consulted to reach consensus.

We extracted four categories of information: (1) descriptive study/guidelines details, including publication date, journal of publication, funding source, type of study (empirical study, guidance document, or other), (2) test information, including test name(s), clinical specialty, and number of tests discussed, (3) factors guiding prioritization decisions, and (4) test selection process.

Risk of bias

In this study, we did not collect quantitative outcomes and thus an assessment of risk of bias was not considered necessary, as is typical of scoping reviews [30].

Data analysis

Descriptive statistics were used to summarize the basic characteristics of included publications. We aggregated test names into basic categories based on the details reported in each publication; categories are not mutually exclusive. Frequencies were tabulated for each factor and decision process identified.

Results

Study selection

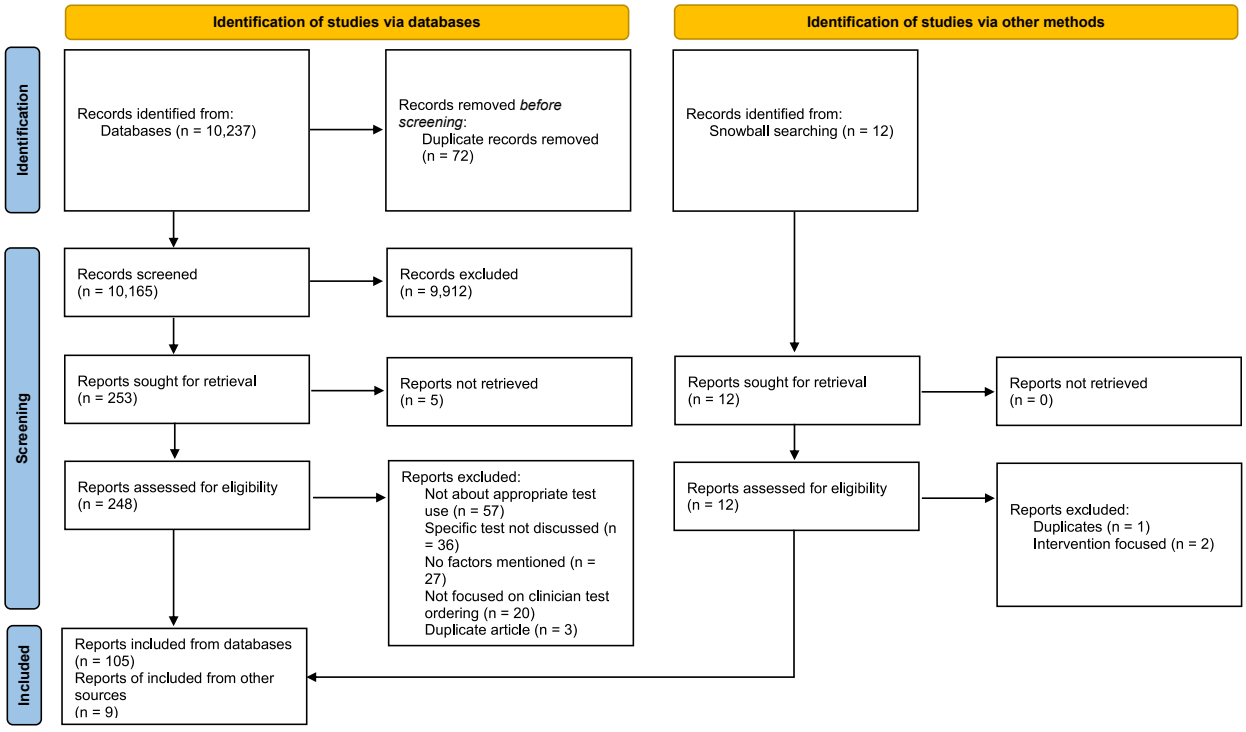
Figure 1 describes our screening process. Initial searches yielded a total of 10,238 citations (retrieved from Medline database on May 30th, 2019, and the June 28th, 2021 update). After removal of duplicates, 10,165 records underwent title and abstract screening with 9,912 screened out as not related to tertiary care laboratory test ordering or not published in English. Two hundred and sixty papers underwent full-text screening and 105 were maintained. Articles were excluded when they were not about improving testing (n=57), where no specific test was discussed (n=36), where no factors were reported related to test choice (n=27), where articles were not relevant to clinician ordering (n=20), where no full-text was available (n=5), or for duplicate articles (n=3). An additional 12 articles were identified through reverse bibliography searching; of these, two were excluded for being focused on intervention choice rather than test choice for intervention, and one was excluded as a duplicate. The final sample included 114 unique articles [17, 19–21, 24, 25, 31–138].

Study characteristics

Table 1 describes characteristics of the included publications (n=114). Most were from the USA (61%), with smaller percentages coming from the UK, Italy, Canada, Israel, Spain, or international collaborations. The number of articles in this area has increased over time, with 62% being published since 2010. Most of the articles did not report on their funding source (61%), 23% reported receiving funding, and 16% reported receiving no financial support. Articles included test-taking across a broad range of clinical specialties including internal medicine (11%), hematology (10%), oncology (9%) and gastroenterology (8%). There was a wide range of tests targeted by the articles; the most frequent groups of tests included coagulation studies (41%), complete blood count (CBC; 29%), and electrolytes (20%). Almost half of the publications were categorized as a guideline or recommendation statement (44%), with other publication types being empirical primary studies (29%), reviews (7%), guidance on processes to make decisions rather than decisions on specific tests themselves (4%) or a combination of publication types (18%). Most publications (53%) focused on reducing the use of laboratory tests while many others focused on appropriate use (i.e. both increasing and decreasing test use; 41%), and a few focused on increasing test use (5%).

The factors identified as being used to inform test choices are summarized in Table 2. A total of 28 factors were identified. The most frequently reported factors for choosing a test were the perceived clinical value of the test (82%), test cost (74%), and prevalence of the test (61%). Other commonly cited factors included consideration for patient care (55%), actionability of the test results (54%), test quality (51%; i.e. measurement properties such as sensitivity, specificity, etc.), impact of false positives or negatives (47%), relevance to current practice (47%), the quality of evidence for/against using the test (47%), the existence of a guideline (45%), and the prevalence or seriousness of the target condition (45%). Several other factors were reported less frequently, such as testing out of habit/routine/convenience (16%), test availability/access (14%), variation in test use across providers (9%), medicolegal concerns (7%), and the availability of data on test utilization (6%).

Table 3 outlines the processes that authors reported in choosing a test to focus on for intervention or guideline



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

Figure 1: PRISMA flow diagram.

development. Among the identified processes, authors frequently reported literature searches to find evidence in support of or against the test-ordering practices (e.g. evidence of sensitivity/specificity, evidence of misuse, etc.; 54%), formal consensus processes among experts about what test-taking strategy should be employed (33%), identification and adoption of internal/implied test-taking clinical standards (33%; e.g. referring to a guideline or suggesting an internal institutional standard), identification and adoption of an external/explicit test-taking clinical standard (27%; e.g. noting the test use is a standard practice in their field of medicine), or consulting local data, such as medical records or requisitions, to identify areas of inappropriate test use locally (19%). Processes less frequently reported included: informal discussion amongst a local team (16%), vetting of a guideline (e.g. applying a guideline locally to determine if it results in changes to patient care as intended; 4%), survey of providers (4%), and values proposition framework (a structured method to determine the value of an individual test; 2%). Twenty six percent of articles did not clearly report a process used in choosing the test(s). Of the reported processes, most studies reported using a combination of two (36%) or three (32%) different processes. Others reported using one process (25%), or four to six different processes (7%).

Discussion

Our scoping review describes the range of factors and processes informing choices about which laboratory tests become targets for interventions designed to improve utilisation. Across 114 articles, we identified 28 factors thought to be relevant to these kinds of decisions, and 9 different processes that were or could be used to inform them. These findings underline the potential complexity of decisions about where to put scarce test utilization improvement resources, and suggest that a framework to support intervention developers tasked with designing these interventions may be helpful.

Our review showed that some processes used to make test prioritization decisions are relatively common. Literature reviews and consensus processes with experts in the specific field were commonly employed when recommendations were intended for relatively broad distribution. Our findings suggest a potential range of different processes which may be considered depending on the specific context of the test ordering behaviour(s) of interest.

Overall, we identified 28 unique factors indicated as reasons for targeting certain tests over others for intervention. The most frequent factors identified included the test's

Table 1: Characteristic of articles in test-ordering interventions scoping review (n=114).

Characteristics	Number of articles, n (%)
Country	
USA	69 (60.5)
UK	10 (8.8)
International	9 (7.9)
Canada	6 (5.3)
Italy	6 (5.3)
Israel	3 (2.6)
Spain	3 (2.6)
Other	8 (7.0)
Year of publication	
1980–1989	6 (5.3)
1990–1999	14 (12.3)
2000–2009	23 (20.2)
2010–2019	60 (52.6)
2020–2021	11 (9.6)
Funding	
Not discussed	70 (61.4)
Reported funding source	26 (22.8)
Reported no funding	18 (15.8)
Clinical specialty	
Internal medicine	12 (10.5)
Hematology	11 (9.6)
Oncology	10 (8.8)
Gastroenterology	9 (7.9)
Rheumatology	8 (7.0)
Infectious disease	7 (6.1)
Pathology	7 (6.1)
Pediatrics	6 (5.3)
Anesthesiology	5 (4.4)
Critical care	5 (4.4)
Cross-discipline	4 (3.5)
Other (e.g. emergency medicine, endocrinology)	30 (26.3)
Frequently targeted tests	
Coagulation studies (e.g. INR[a], PT[b], PTT[c])	47 (41.2)
Complete blood count (CBC)	33 (28.9)
Electrolytes (e.g. sodium, potassium)	23 (20.2)
Thyroid function tests (e.g. TSH[d], T3[e], T4[f])	16 (14.0)
Liver function tests (e.g. ALP[g], AST[h], ALT[i])	11 (9.6)
Glucose	10 (8.8)
C-reactive protein	9 (7.9)
Creatinine	8 (7.0)
Arterial blood gas	7 (6.1)
Immunoglobulins	6 (5.3)
Basic metabolic panel	5 (4.4)
Hemoglobin	5 (4.4)
Calcium	4 (3.5)
Type of publication	
Guidance document	50 (43.9)
Empirical study	33 (28.9)
Review	8 (7.0)
Decision guidance	4 (3.5)
Combination	20 (17.5)
Aim of guidance or intervention	
Decrease testing	60 (52.6)
Both (i.e. appropriate use)	47 (41.2)
Increase testing	6 (5.3)

[a]INR, international normalized ratio; [b]PT, prothrombin time; [c]PTT, partial thromboplastin time; [d]TSH, thyroid stimulating hormone; [e]T3, triiodothyronine; [f]T4, thyroxine; [g]ALP, alkaline phosphatase; [h]AST, aspartate aminotransferase; [i]ALT, alanine aminotransferase.

perceived clinical value, cost, and prevalence/frequency of use of the test. Given that these initiatives are often conducted in the context of shrinking budgets, their prevalence is not surprising. Patient care, implications of a false positive/negative result, and actionability of test results were also commonly reported, highlighting the importance of patient-centered considerations in these types of decisions.

Many of the identified factors can be thought of as sub-themes of an overarching concept. For example, the quality of the test (e.g. sensitivity and specificity) must be considered in relation to the prevalence rates of the target condition/disease in order understand the true predictive value of the test [132]. Another example is highlighted by Glasziou and Hilden [134], "When one test is more informative and less costly than another, the choice appears straightforward, … however, when the more informative test is also more costly the choice is not clear and a trade-off is necessary", suggesting a complex interaction between clinical value and cost. In many cases, then, these factors must be considered together in order to properly evaluate the test(s) being considered for intervention, however, further work is needed to organize and define these relationships in a way that would be most useful to intervention developers.

The factors identified need to be critically appraised by intervention developers within their specific clinical contexts in order to decide how they can inform decisions about which tests and testing practices to target for intervention and/or guideline development. For example, the implications of a false positive test can be critical in cancer

Table 2: Factors stated as rationale for choosing certain tests over others (n=114).

Factor	Definition	Example quote	Number of articles (%)
Clinical value	The clinical utility of the test according to the health-care provider	"We identify 5 common laboratory tests whose use persists in dermatologic practice despite evidence confirming their limited utility" [81]	93 (81.6)
Cost associated with test	The amount spent in order to collect, analyze and/or interpret the lab-test and associated fees	"… blood tests are expensive both in terms of economic costs of laboratory and equipment resources, in addition to increased workload incurred on junior medical staff and phlebotomists" [57]	84 (73.7)
Prevalence/frequency of the test	The number of times that a test is ordered and/or the volume that the test is ordered patient/day	"An evaluation of this issue should consider the frequency of abnormal test results within a given population …" [37]	69 (60.5)
Patient care	Impact of the test on patient experience (e.g. be physical pain due to test or feelings of wasted time or anxiety)	"… hidden costs incurred by screening with faecal occult blood tests must also be considered. These include the costs and hazards of diagnostic studies and loss of time from work, the emotional cost of worrying about having cancer, as well as the false sense of security engendered in patients with a negative test" [33]	63 (55.3)
Actionability of test results	Tests that directly impact the treatment or management plan for the patient	"…clinicians were likely to act on the results of the test" [86]	62 (54.4)
Test quality	The diagnostic characteristics/measurement performance of the test in question such as sensitivity and specificity	"Considering the low specificity of the ANA [antinuclear antibodies] test in the diagnosis of autoimmune diseases …" [70]	58 (50.9)
Implications of a false positive or negative	Any negative effects associated with an incorrect disease diagnosis (e.g. further testing, unnecessary invasive procedures, unnecessary cost incurred)	"…falsely abnormal test results may unnecessarily delay endoscopy and subject the patient to additional risks …" [37]	54 (47.4)
Relevance to current practice	Test being considered relates to clinician area of practice (e.g. test is outdated by newer test)	"…the usefulness of these autoantibodies in clinical practice still has to be determined" [51]	53 (46.5)
Quality of supporting evidence for/against using the test	High caliber evidence provided by clinical practice guidelines, systematic reviews or other peer reviewed publications which point to the utility or lack of utility of a test	"Arterial blood gas analysis is not supported by strong evidence and seems to be driven by cultural factors" [71]	53 (46.5)
Prior existence of a guideline for the specific test(s)	A well-established protocol backed by a governing body which provides direction on appropriate use of the test	"In 2006 the National institute for Health and Clinical excellence (NICE) published a guideline entitled, 'anaemia management in people with chronic kidney disease" [97]	51 (44.7)
Prevalence or seriousness of target disease	The prevalence rate and/or morbidity/mortality rate of the disease which is being detected using the test in question	"In one study of 5,003 patients tested prior to elective cholecystectomy, there were only four detected cases (0.08%) that could not have been anticipated by history and physical examination" [102]	51 (44.7)
Laboratory workload and resources	The quantity of human and other resources required to run, process and/or analyze a specific test within the pathology lab	"The anti-FXa assay can be carried out even in emergency settings, with little expertise …" [100]	34 (29.8)
Risk/harm of administering test	Any potential negative consequences for the patient in administering the test	"Blood tests can induce iatrogenic anaemia in patients …" [74]	30 (26.3)
Evidence of inappropriate use	Evidence that the test in question is used inappropriately compared to what would be expected based on practice guidelines or standard of practice	"We superimposed the guidelines on levels that were performed and found that 74% of inappropriately ordered inpatient serum AED [antiepileptic drug] monitoring was due to a common practice …" [48]	28 (24.6)
Expert experience	Guidance from local or external experts based on personal practice regarding the test	"The opinion of experts about the appropriateness of use of procalcitonin was assessed in different clinical settings" [42]	22 (19.3)

Table 2: (continued)

Factor	Definition	Example quote	Number of articles (%)
Non-test specific resources	Resources used or saved by testing beyond the cost of the test itself (e.g. number of ventilator days)	"The added costs and length of hospitalization associated with false positive findings could be reduced. Adult studies have estimated that a false-positive blood culture result adds ~$6,000 to hospitalization costs and 4–8 days to the length of stay" [64]	22 (19.3)
Strain on health-care system	Overall negative impact on the health care system resulting from inappropriate use of the test (e.g. financial strain, as well as human-time costs incurred)	"Additional blood coagulation tests would yield nothing in the vast majority of the cases, thus creating unnecessary burdens to the child and his family, as well as to the economy of the health care system" [98]	20 (17.5)
Feasibility of changing test-ordering behaviour	The perception that the test-ordering practice behavior can be changed through various intervention strategies	"The feasibility of implementing any nationwide policy" [40]	20 (17.5)
Testing from convenience/habit/routine	Physicians performing tests or repeating a test out of convenience/habit/routine	"The reason for testing should never be that it is a habit, the departmental routine, or the policy, or what senior colleagues (are thought to) expect" [136]	18 (15.8)
Test being bundled with other tests	Test combined on paper or electronic ordering systems as bundles or order sets	"… avoid the predetermined packages offered by various laboratories because, in most instances, they provide a mix of useful tests and irrelevant tests" [60]	17 (14.9)
Test availability	Availability/access to the test, including both high and low availability	"FC [fecal calprotectin] meets many of these criteria, is available throughout Canada and has the potential to significantly enhance IBD [inflammatory bowel disease] care" [44]	16 (14.0)
Variation in test use	Variation in ordering test from physician to physician or across healthcare centers	"In general, AUC [area under the receiver operating characteristic curve] focus on tests that are widely and frequently used, consume significant resources, or have wide variations in their use" [96]	10 (8.8)
Medicolegal concerns	Medicolegal concerns around performing or not performing a test	"Many emergency departments routinely measure ethanol in trauma victims for medicolegal purposes, which often results in civil or criminal litigations" [102]	8 (7.0)
Governing body regulations	Testing is approved or required by a governing body (e.g. federal/provincial health/drug organization) according to regulations around patients care	"Trioplex rRT-PCR [real time reverse transcription-polymerase chain reaction] assay is the only diagnostic tool authorized by the food and Drug administration for zika virus testing of urine" [31]	8 (7.0)
Ease of implementation of intervention for changing test-ordering behaviour	The quantity of time, effort and financial as well as human resources that are needed in order to apply an intervention to change ordering behaviours of the test in question	"Because all NBS [newborn screening] is currently state regulated, the second option would be easiest to implement" [40]	7 (6.1)
Data availability	Data availability to assist with evaluation of test utilization. For example, comparison of own data to other institutions/publications to evaluate utilization, or patient records linked across service providers	"Other institutions have also studied utilization of this test, which allowed us to compare our local ordering patterns to those of other practices" [103]	7 (6.1)
Research	Selecting test based on their ability to contribute to research in addition to patient care	"… and inclusion of genes that are (currently) of research interest but not established as monogenic cause of disease, some panels include genes informed by polygenic risk loci" [129]	2 (1.8)

Table 2: (continued)

Factor	Definition	Example quote	Number of articles (%)
Local agreement	Consensus among test orderers and others (e.g. labs, insurance companies) that the test is being ordered inappropriately and should be targeted for intervention	"Discuss proposed changes in advance with the most influential physicians in the groups that will be affected' [by the changes]" [138]	1 (0.9)

Table 3: Processes reported to inform choices about which tests to target for intervention (n=114).

Processes	Number of articles (%)	Definition	Example quote
Literature review	61 (53.5)	Systematic and informal literature searches to find evidence in support of or against the test-ordering practices	"SHM [Society of Hospital Medicine] staff conducted a literature review of the list of tests and treatments …" [45]
Consensus process	38 (33.3)	A formalized process among clinical experts, often from multiple institutions, to decide which tests should be pursued. Often includes a Delphi process	"Using nominal group technique,4 the ASH CWTF [American Society of Hematology Choosing Wisely Task Force] reduced the list of suggested choosing wisely items to a short list of 20" [65]
Clinical standard-internal	37 (32.5)	Identification and adoption of implied/internal test-taking clinical standards (e.g. referring to a guideline or suggesting an internal institutional standard)	"Laboratory testing and diagnostic imaging are routinely used for the management of children with community-acquired pneumonia" [84]
Clinical standard-external	31 (27.2)	Identification and adoption of an explicit/external test-taking clinical standard (e.g. noting the test use is a standard practice in their field of medicine)	"Because hemoccult II is the most studied and most commonly used of the faecal occult blood tests, it is appropriate to use it as the 'criterion standard" against which other faecal occult blood tests can be compared" [33]
Consulting local data	22 (19.3)	Review of local laboratory test requisitions and electronic medical record data to identify tests that are over-, under-, or misused	"The aim of the study was to evaluate the extent to which current celiac testing practice is consistent with the recommendations of the pediatric and adult guidelines; the results formed the basis for a clinical audit cycle to improve the utilization of serological tests" [67]
Local team/ expert(s)	18 (15.8)	An informal discussion among clinicians from the local environment to decide which test to pursue based on factors specific to their institution.	"The Medical evaluation committee of the hospital developed clinical guidelines for tumor marker ordering." [55]
Vetting a guideline	5 (4.3)	Applying a published guideline locally to determine if it results in changes to patient care as intended	"…to test the effectiveness of newly developed guidelines for obtaining blood cultures in pediatric patients with CAP [community-acquired pneumonia] through retrospective chart review before institutional guideline adoption" [64]
Survey of providers	4 (3.5)	Surveying a wide range of providers at a single instance to collect opinions on specific test-ordering practices. Excludes more intensive consensus processes and collaborative efforts from a local team	"A postal survey of current practice in testing patients in this group pre-operatively was undertaken in 2008" [19]
Values proposition framework	2 (1.8)	A structured method to determine the value of an individual test based on outcomes such as improved clinical care for patients, improved processes in delivering care, and resource use	"A useful value proposition approach for laboratory medicine has been described [4] where the value of an individual test is expressed in terms of outcomes resulting from its use in guiding clinical decision making, the process of care delivered, and resources required to deliver that care" (values proposition) [117]
Unclear	30 (26.3)	No clear process reported in choosing test(s)	N/A

screening, leading to over-diagnosis, over-treatment, and unnecessary biopsies for low-risk individuals [139]. Some factors may also be inter-related within the specific clinical context. For example, the low quality of the supporting evidence for tumor marker testing in neuron-specific enolase testing in neuroblastoma in children may be related to the low prevalence rates of this type of cancer [140, 141]. More detailed guidance on what to consider regarding each factor's potential relevance will be explored in future research.

Limitations

Our study had limitations that warrant consideration. First, our search strategy was implemented in only one database (Medline) due to limited resources. We sought to reduce the impact of this limited search by enhancing our review with reverse bibliography sampling to ensure that any relevant articles that may not have been captured in the initial search strategy were included. Other researchers have found that when searching for reviews [142] or information about diagnostic tests [143], Medline alone identified approximately 90% of relevant papers, increasing to 94% with bibliography searching [142]; and overlap between records found in Medline and EMBASE was approximately 88% [143]. Despite this, future work might expand the search to include other databases (EMBASE, CINHAL, Psycinfo). Second, while our review identified a wide range of relevant factors, we could not assess their absolute impact on patient outcomes, their relative importance to one another, or the clinical and contextual circumstances that may vary the salience of each factor. Additional research in these areas is warranted. Finally, we used an inclusive approach to identifying factors considered to be rationale for test selection, such that even brief mentions of a factor noted in relation to the selected test(s) were included. In some cases, that factor may not have been instrumental in the planning stage of the study, but rather only given limited post hoc consideration. While we tried to distinguish between factors that appeared to be generic introductory rationale and those that specifically justified selected test(s), additional research on the relative importance of each factor is warranted.

Future directions

We have identified an extensive list of factors and processes that may be relevant in choices around which tests should be targeted for intervention. However, the relative importance and best organizational structure of these factors is not yet clear and likely context-specific. Future work will include speaking to experts in the area to gain a deeper understanding of which factors actually influence test choice and how they should be organized in order to be most useful to those seeking to improve testing practices at their institutions.

Conclusions

Test-ordering intervention developers face difficult choices when deciding where to direct intervention resources to improve ordering, and how such tests should be selected. Our scoping review identified the range of factors thought relevant to such choices and the processes used to inform them. We see this work as the first step towards a prioritization framework to help developers decide which testing practices are worth their time, effort, and resources to attempt to change. Future work will include interviews with intervention development experts in order to help contextualize the factors and processes identified in this review and develop guidance for developers.

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