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Determing the Costs Associated with Diagnostic Laboratory Testing in Canada

Summary report of the literature for CSMLS interal use.

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Abstract

Following a search of the literature related to the costs associated with laboratory testing, our review identified 41 studies that evaluated or attempted to determine costs associated with laboratory testing and, more specifically, the cost savings that can be realized from implementing laboratory ordering interventions. This literature review contributes to the existing body of research that articulates the challenges posed by increased laboratory testing in developed countries and the ongoing challenges associated with inappropriate or minimally helpful diagnostic tests. This literature review is particularly interesting to those exploring overtesting practices, determining costs associated with complex diagnostic laboratory testing in developed economies, and evaluating the impact of laboratory testing interventions.

Background

The CSMLS and the University of Alberta (UofA) Medical Laboratory Science Division have partnered on a project to consolidate the medical laboratory professions' position in reducing unnecessary testing and resource waste in health care. A vital aspect of this partnership has been the development of an assortment of tools, resources, and products that encourage MLP participation in improving laboratory utilization. In addition to contributing to the broader literature on the overuse of diagnostic testing in Canada, this scoping review has been compiled for consideration in developing a web-based financial simulation widget that will aid in determining savings and waste reduction metrics of implementing Choosing Wisely Canada recommendations. The widget will provide medical professionals and laboratory administrators with an evidence-based tool to support the adoption of recommendations of Choosing Wisely Canada and better equip them to impact change within their workplaces.

Methods

We conducted a scoping literature review using JBI methodology, incorporating articles that assessed the economic considerations associated with diagnostic laboratories in Canada and the broader OECD economic cluster. Using several databases and a review of the available grey literature, the review identified literature from 2003-2023. All identified studies that considered laboratory costs, including those that captured costs associated with laboratory analysis, incorrect testing, over-testing, and associated errors to provide a broad overview of the testing value, were utilized in the final analysis. Following initial automated and semi-automated screening, the final studies were selected for inclusion by two independent reviewers, followed by a further quality assessment of the evidence and thematic analysis of the remaining articles.

Results

Our database search resulted in 288 articles isolated for secondary screening. Following an independent evaluation of these articles by the primary and secondary reviewers for consideration in the final scoping review, forty-one records satisfied the inclusion criteria. The review attempted to answer the questions: (1) What is known from the existing literature about the "cost" of laboratory testing within the OECD member countries, and what should be included in a more comprehensive model that considers elements of labour, budgetary implications, environmental factors, clinical outcomes, and patient safety?; and (2) what are the broad economic impacts of overutilizing diagnostic laboratory tests within the Canadian Healthcare sector concerning financial, human, environmental, and patient resources?

Discussion:

Human resources, consumables, capital, and physical plant capacity all represent competing costs associated with diagnostic testing, creating a complex and difficult to decifer web of financial data.

Despite this complexity, little doubt remains that the overarching picture of medical laboratory testing is costly. Though diagnostic testing represents a fraction of the overall cost of delivery of health care (Hjelmgren, Heintz, Ygge, Andersson, & Nordlund, 2023), the total costs do represent a substantial burden and one that is worthy of continued discussion. Unfortunately, there is limited generalizable literature and few tools that laboratory administrators can use in determining potential savings associated with a responsible reduction in diagnostic tests. This review provides an overview of three primary themes of diagnostic cost evaluation that consider the impacts of diagnostic testing limiting interventions, total costs associated with laboratory testing on a per-test basis, and the underlying environmental impact on laboratory testing.

Keywords:

Medical Laboratory Science Costs; Laboratory Costs; Environmental Costs; Cost of Inappropriate Testing

INTRODUCTION

Background and Rationale

The Canadian Society for Medical Laboratory Science (CSMLS) is the national professional association and certifying body for medical laboratory professionals (MLPs) (medical laboratory technologists and assistants) in Canada. In 2018, the CSMLS and the University of Alberta (UofA) Medical Laboratory Science Division partnered on a project to consolidate the medical laboratory professionals' position in reducing unnecessary testing and resource waste in health care. In addition to developing a profession-specific list of items for Choosing Wisely Canada (CWC), the partnership involved creating a website (LabWisely.ca), primarily focused on two items. First, a searchable database to facilitate the discovery of laboratory-specific CWC recommendations based on several parameters, such as clinical discipline, which has 183 items to date. Second, an assortment of tools, resources, and products that encourage MLP participation in improving laboratory utilization. In addition to contributing to the broader literature on the overuse of diagnostic testing in Canada, this scoping review has been compiled for consideration in developing a web-based financial simulation widget that will aid in determining savings and waste reduction metrics of implementing CWC recommendations. The widget will provide medical professionals with evidence to support the adoption of recommendations and better equip them to impact change within their workplaces.

Medical laboratories in Canada account for millions of tests annually, carrying an incredible cost to the public sector. These costs expand beyond the realms of financial impact, as while the cost of delivery of diagnostic laboratory testing can account for 5% of total health care (Hjelmgren, Heintz, Ygge, Andersson, & Nordlund, 2023), additional costs arise in the form of environmental impact as healthcare is a substantial contributor to greenhouse gas emissions (Breth-Petersen, et al., 2022;

Gordon, Sherman, Leapman, Overcash, & Thiel, 2021; McAlister, Barratt, Bell, & McGain, 2020; Spoyalo, et al., 2023).

MLPs perform most diagnostic tests on the direction of attending health professionals, including most prominently attending physicians and nursing staff. The selection of diagnostic tests should ideally correspond to the associated assessment of each patient to facilitate the best possible treatment. However, over the past several decades, the practice has often been to cluster diagnostic testing procedures under a "testing panel." That is, diagnostic testing typically involves grouping several diagnostic tests that address related or connected pathologies. Some of the more common examples include renal function panels, liver function panels, or diabetic panels. While the utilization of panels creates potential benefits in the ease of ordering for non-laboratory professionals, they inevitably involve a degree of unnecessary testing, and corresponding panels must consider several complex factors such as patient population, epidemiology, and economic factors.

OBJECTIVES

As noted, this review is part of a broader research project on developing a laboratory cost widget connected with Choosing Wisely Canada, funded under a grant obtained in partnership with the CSMLS. The purpose was to provide laboratory professionals with a simple online approach to reasonably estimate potential cost savings associated with modifications of laboratory tests with an underlying assumption that some degree of diagnostic testing is unnecessary. This approach necessitates understanding the intersection of several key elements of diagnostic testing within the Canadaian clinical laboratory environment, including economics, financial resources, human resources, environmental considerations, and patient safety. As such, the review served to address three primary questions.

Overarching Questions:

(1) What is known from the existing literature about the "cost" of laboratory testing within the OECD member countries?

(2) What should be included in a more comprehensive model that considers elements of labour, budgetary implications, environmental factors, clinical outcomes, and patient safety?

(3) What are the known economic impacts of overutilizing diagnostic laboratory tests within the Canadian Healthcare sector concerning financial, human, and patient resources?

METHODS

JBI Selected Methodology

For several reasons, we selected a scoping review as the ideal approach for reviewing the costs associated with laboratory testing in Canada. According to Arksey & O'Malley (2005), unlike other reviews that address relatively precise questions, scoping reviews can map key concepts that underpin a particular field of research and clarify a topic's working definitions or conceptual boundaries. Unlike systemic reviews, scoping reviews aim to provide a map of evidence and work to assess the nature and diversity of the evidence or knowledge available. The Canadian medical laboratory sector has several substantial literature gaps, and given that it is well understood that calculation of laboratory costs is complex, a scoping review was deemed an appropriate and timely strategy.

Search Strategy

The initial framework proposed by Arksey & O'Malley (2005) has been influential in the conduct of scoping reviews across several disciplines; however, several enhancements have been proposed by Levac et al. (2010). The JBI methodology has incorporated these enhancements to which this study has

largely subscribed. Accordingly, the review followed the primary 5-stage structure, including (1) identifying the research question, (2) identifying relevant studies, (3) selecting studies, (4) charting the data, and (5) collating, summarizing, and reporting the results.

Several key databases, including SCOPUS, PUBMED, MEDLINE and EMBASE, were systematically searched for articles from 2003 - 2023 to identify those articles published in English that examined the economic impact of laboratory diagnostic testing overuse and the costs associated with laboratory medicine using database data. Each initial article assessment was categorized using an economic implications lens that considered human resources, operations implications, capital resources, environmental factors, and patient safety/clinical outcome. In addition to a comprehensive review of the selected databases, our review utilized the Memorial University of Newfoundland library to broadly search the extant literature. We further used Google Scholar and the Memorial University of Newfoundland library to search for grey literature with search parameters including (magazine articles, newsletter articles, conference proceedings, and dissertations). Primary criteria included those articles published in English between 2003 and 2023 and those that focused primarily on middle to high-income countries, including those within the OECD.

Keyword Search Variables

Keyword search variables were established based on the primary research questions, which focused on costs associated with medical laboratory tests and an accepted acknowledgement of the prevalence of concerns regarding over-testing in Canada per the rationale for Choosing Wisely Canada. Accordingly, our primary keyword search included (1) cost-effectiveness, (2) resources, (3) diagnostic tests, and (4) medical laboratory, with secondary keyword searches including (1) stewardship, (2) healthcare expenditures, (3) test utilization, (4) demand management and (5) budget. Appendix A of the accompanying data document details the search parameters.

Study Selection and Screening Criteria

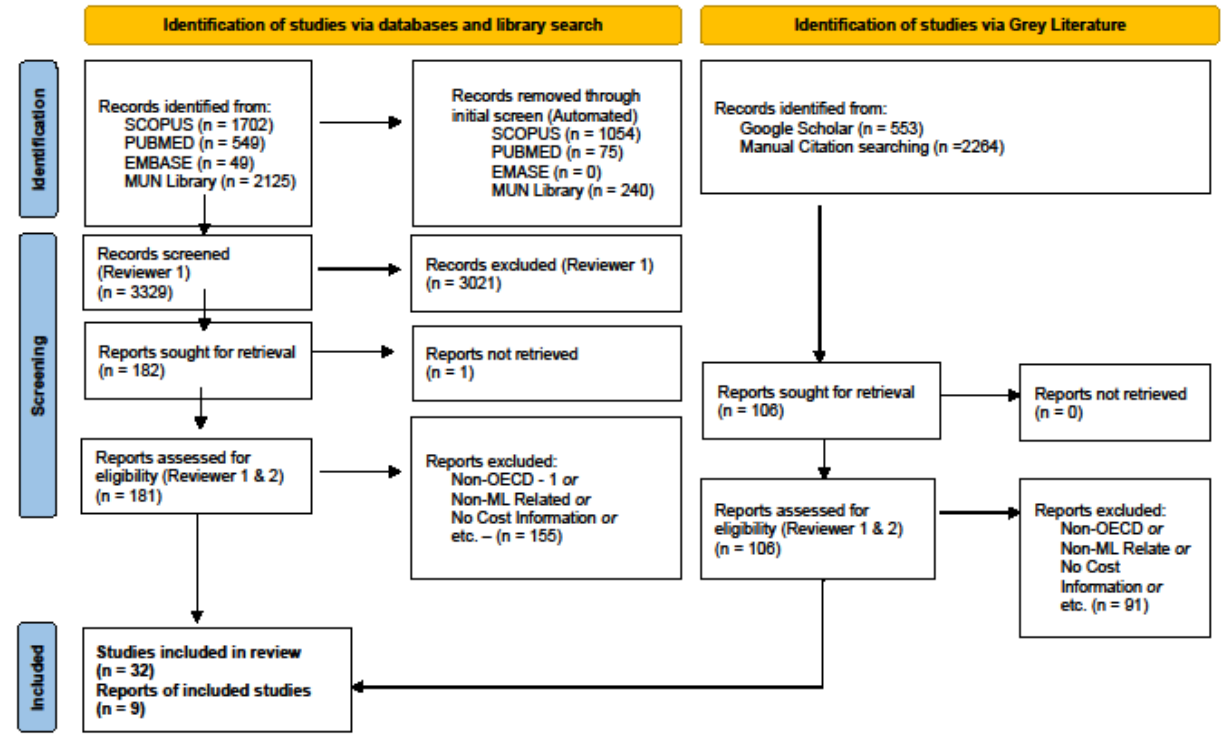
Initial search results from the primary search were screened for inclusion by the first reviewer and placed within a Covidence® collection. Covidence® was then utilized to provide a secondary review by two reviewers. Abstracts and titles were screened for eligibility by two reviewers. We included studies that quantified or described the overuse of diagnostic tests and those that provided a breakdown of costs associated with diagnostic testing. For this review, we defined low-value diagnostic testing (or over-testing) as the use of diagnostic testing that is unlikely to yield significant diagnostic value given the harm costs, available alternatives, or preferences of the patients. We excluded those studies that did not quantify or assess the costs associated with diagnostic testing and those not directly connected to the practices specific to MLPs in Canada. We also excluded those studies that did not originate from within the OECD list of countries due to the complexities of the associated economic variables and the similarities drawn between OECD members. The reviewers discussed disagreements regarding the eligibility of studies, and when a disagreement remained regarding exclusion, a third reviewer was consulted.

RESULTS

Our review identified 7242 records (including duplicates), of which 4413 were excluded using automated screening techniques (e.g., non-OECD, published before 2003, published in language other than English). Thus, automatic exclusion resulted in 3329 records being manually screened under the broad inclusion of those studies that considered the three exclusionary criteria within the title and abstract. Two hundred eighty-eight records were then included in secondary screening, which involved using the Covidence® platform. All identified studies were loaded within the tool and were screened independently by two independent researchers. Following the completion of the secondary screening

and subsequent evaluation of the selected papers, 41 records were identified for inclusion in the scoping review. Figure 1 provides the PRISMA flow diagram, highlighting the inclusion/exclusion process.

Figure 1: PRISMA Flow Diagram



Thematic Analysis

Using the JBI methodology for scoping review, it is essential to point out that scoping reviews do not synthesize the results/outcomes of included sources of evidence as this is more appropriately done within the conduct of a systematic review (Arksey & O'Malley, 2005). However, the extraction of results descriptively and subsequent categorization under broad themes or outcomes is appropriate and proved fruitful in attempting to answer the primary questions. As such, we chose to map our studies across the broad themes that emerged within our review. Across the studies identified, we were able to categorize the overarching goal of each study within three key groups, including (1) studies which involved an intervention related to reducing unnecessary testing; (2) studies that attempt to establish a framework

or estimation of cost, associated with one or more diagnostic tests, or more broadly the collective cost of laboratory testing; and (3), studies which attempt to establish an estimation of the broad economic or environmental impact associated with diagnostic testing. Several studies straddled multiple themes, but each identified study was categorized accordingly. Notably, most studies also fell within the primary categorization of pre-post hoc interventional or retrospective analysis.

Several themes emerged from the literature review and are examined further in this section. However, throughout our review, it became evident that the total costs of medical laboratory testing are both somewhat nebulous and represent a substantial burden on the healthcare sector that requires future review and attention.

Overview of Included Studies

We were able to categorize the studies located under three broad headings, including (1) those studies that consisted of a pre and posthoc analysis of a particular intervention; (2) those studies that consisted of a retrospective analysis to understand the total monetary costs associated with testing in general or a particular method, and (3) those studies that attempted to elucidate an environmental cost associated with laboratory testing under the broader heading of laboratory costs. Within this final category, there was significant overlap with the first theme as pre and post-analysis was utilized to extrapolate total greenhouse gas emissions in several studies.

Intervention Analysis

Table 1 demonstrates the data extracted from each paper, focusing on the underlying results of specific interventions. Overarchingly, it was demonstrated that interventions have varying degrees of success in reducing unnecessary laboratory testing and subsequent costs. Indeed, some savings were evident in all but one case and could be concluded as a successful intervention. Of note, interventions

varied from those that were educational and carried minimal monetary investment to those with an information technology aspect (i.e., pop-up alerts within LIS systems), which would notably incorporate substantial IT planning and coordination. Moreover, several studies incorporated a multi-tiered approach.

Table 1: Measures (Pre/Post Interventions)

Author	**Selection/Measurement of Outcomes or Type of Intervention**	**Bound Parameters of Analysis**	**Key Results**
(Attali, et al., 2006)	Multi-tiered program to continuously and sustainably reduce lab test use without negatively impacting patient care.	36 common laboratory parameters.	• There was a significant decrease in the number of tests per hospital admission for all the major laboratory tests ordered with intervention.
(Aesif, Parenti, Lesky, & Keiser, 2015)	Multi-tiered intervention of microbiologic send-out tests reviewed by the clinical pathology house staff before being sent to the reference laboratory, regardless of test type or cost.	Microbiology testing only.	• Cancelled tests represented a total savings of $53,719.13 in direct cost to the laboratory over one year. • 65% of cancellations included such reasons as a confirmation test ordered in the absence of a screening test order or a confirmation test ordered with a negative screening test. • 35% of cancelled tests included mistaken orders, duplicate orders, incorrect test orders, and insufficient specimen quantity.
(Ambasta, et al., 2020)	Multicomponent intervention bundle incorporating	10 common laboratory parameters	• 11% reduction was noted at the intervention site from the pre-intervention to post-intervention period • Total cost reduction of $C68,877 from the pre-intervention to postintervention period.
(Ambasta, et al., 2023)	A multifaceted intervention bundle using education and facilitated multilevel social comparison.	6 most routinely used tests	• A significant reduction of 14% in the incidence of routine laboratory tests, with the intervention amounting to a total cost savings of $C1.15 per patient day. • A 15% reduction in the incidence of all common laboratory tests (top 80 tests by volume). • A 20% increase in test-free patient days compared with control sites.
(Gill, Guo, Lau, &	Analysis of B12 utilization following the implementation of an	Vitamin B12 only.	• Vitamin-B12 tests ordered over the 37 months in Alberta were 2,444,724.

Naugler, 2020)	intervention for Alberta, Canada, between April 1, 2015, and April 30, 2018.		• Provincial monthly test volumes before this intervention ranged from 54,182 to 73,522 tests per month, and after this intervention, they ranged from 59,116 to 74,006. • The utilization management initiative did not result in the desired reduction in vitamin B12 testing.
(Juskewitch, et al., 2019)	An intervention analysis focusing specifically on ordering behaviours and cost savings of ESR and CRP simultaneous orders.	ESR only.	• Before implementing the CPOE decision support rule in December 2012, ESR/CRP co-ordering rates were 28.5%. • After implementation in December 2012, co-ordering rates dropped to 16.4%, representing an unadjusted 42% relative rate reduction.
(Lippi, et al., 2015)	An intervention analysis to limit the number of potentially inappropriate laboratory test requests for hospitalized patients within the University Hospital of Parma	15 common testing parameters.	• 3539 requests were generated from the two clinical wards for the 15 tests under monitoring throughout the study period. • 591 tests were annulled (17% of total tests requested and 77% of tests alerted, respectively). • There was a 22% reduction in the total number of tests performed and a 12.8% financial saving.
(Liu, et al., 2012)	An administrative intervention involving a letter to every physician who ordered a referred-out test costing more than $20 Canadian (CDN).	Select referred-out chemistry parameters.	• Of 910 requested tests, 428 (47.0%) were approved, and 482 (52.9%) were cancelled. • The estimated cost if all ordered tests had been completed is $133,749.36.
(Ma, Guo, Viczo, & Naughler, 2017)	An administrative intervention involving a laboratory bulletin.	HbA1C only.	• This resulted in a reduction of 41,549 HbA1c tests (or 3.3%) and a predicted reagent cost savings of approximately $145,422.
(Procop, et al., 2015)	Implementation of an intervention to address overuse incorporating a two-stop methodology.	All laboratory testing within the site.	• The Hard Stop CDST was 92.3% effective in averting duplicate orders. The calculated cost savings for this intervention was $94,225. • The Smart Alert CDST effectiveness was only 43.6%. The cost savings realized for the Smart Alert CDST was $45,681. • The cost savings per alert activation were also substantially more significant for the Hard Stop CDST ($16.08/alert) than for the Smart Alert ($3.52/alert).
(Procop, Yerian, Wyllie, Harrison, & Kottke-	Intervention examining the possibility of using a CDST to alert the ordering physician of duplicate test orders.	All laboratory testing within the site.	• 11,790 unnecessary duplicate orders were blocked by the hard stop CDST in 2 years of activity (2011 and 2012). • Of the 12,204 times that this CDST alerted, the clinician called to request that the duplicate

Marchant, 2014)			test still be performed only 414 times (3%). A cost avoidance analysis of the impact of this revealed a savings of $183,586, which included materials and labour for laboratory personnel.
(Tawfik, Collins, Fino, & Miller, 2016)	Intervention analysis from October 2013 through December 2013.	18 most ordered laboratory tests	• During the 3-month control period before the intervention was implemented, resident services ordered a mean of 5.56 laboratory tests PP/PD, generating laboratory charges of $488 PP/PD. • Hospitalists ordered a mean of 3.54 tests PP/PD, generating charges of $332 PP/PD. • The mean number of laboratory tests ordered PP/PD by resident service decreased during the intervention period.

Each of these studies calculated their savings as a sum of the total costs of testing multiplied by the number of reduced or unnecessary tests. For example, during a study conducted by Aesif et al. (2015), the result of an intervention related to microbiology send-out testings being reviewed for appropriateness, more than 50 thousand dollars materialized. Similarly, according to Ambasta et al. (2020), a multi-tiered intervention resulted in an approximately 11% reduction of unnecessary testing, resulting in more than 60 thousand dollars of savings.

While there are several limitations related to the generalizability of these results, as the determination of costs associated with laboratory testing is often specific to particular institutions, staffing, testing, and other variables, in each of the twelve studies identified, some degree of savings was evident with an apparent positive cost-benefit correlation when considering the operational costs of each intervention.

Cost Determinations

As noted, the determination of exact testing costs presents a substantial challenge, which has been identified as a challenge through multiple studies (Ma, Lau, Ramda, Jackson, & Naugler, 2019; MacMillan, 2014; Naugler, Thomas, Turin, Guo, & Vaska, 2015). Nevertheless, several studies identified

through the literature review attempted to establish detailed costing information across many of the most commonly encountered diagnostic tests. This information is of particular value when assuming that a significant amount of diagnostic testing performed is unnecessary and does not translate to any significant modification of patient care. For example, Kandalam et al. (2020) determined that the total annual cost for inappropriately repeated CBC and electrolyte panels in inpatient and emergency (i.e., repeated within 24 hours without clinical indication) resulted in over $2.4 million loss. Moreover, the determination of costs occurred as a topic of interest across numerous OECD member countries, including Italy, Chile, and Canada. Fourteen studies in Table 2 focused on detailed costing determination for various laboratory parameters ranging from individual tests to complete costing across entire laboratory panels.

Table 2: Establishment of Cost per test (Restrospective Studies)

Author	**Selection/Measurement of Outcomes or Type of Intervention**	**Bound Parameters of Analysis**	**Key Results**
(Andrade & Palma, 2018)	Retrospective analysis of total laboratory costs in Chile incorporating three variables of total cost analysis from July 2014 to June 2015	92 representative examinations.	• Overall laboratory costs can be calculated via the formula: CMT = CMDL+ CMIL+ CMII
(Declerck, Swaak, Martin, & Kesteloot, 2021)	Retrospective analysis of total laboratory costs in Belgium incorporating six activity centers of clinical chemistry analysis	156 tests were included, and an average cost per test in € was calculated for 2018.	• Cost per test was mainly determined by staff costs (57.4%), costs of support services (22.7%), reagents (13.7%), and costs of the analyzers (4.6%).
(Eker, 2022)	Retrospective analysis of total laboratory costs in a single health unit in Türkiye.	Incorporates all laboratory testing within the health unit.	• 1,939,650 patient samples and 46,534,532 tests were studied in 2019: ○ The total cost for hospital-related PA test errors was calculated as TRY 390,238.06 ○ The total cost for central laboratory-related PA test errors was TRY 48,046.45.

(Hjelmgren, Heintz, Ygge, Andersson, & Nordlund, 2023)	A cost analysis combines information from the hospital's laboratory register for 2013–2014 and clinical in-ward observations at a tertiary pediatric hospital.	Incorporates all aspects of costs, including staffing, support services, and reagents.	• Laboratory costs represent approximately 5% of the total budget. • The annual cost of PAE was estimated to be 74,267 euros per 54,040 blood drawings, corresponding to 13,756 euros per 10,000 blood drawings or 1.5 euros per draw. • The cost of PAEs per 10,000 blood drawings was estimated to be 13,756 euros.
(Kandalam, Lau, Guo, Ma, & Naughler, 2020)	Direct analysis of two common laboratory test panels.	CBC and Electrolyte panel total costs for repeat analysis.	• In Calgary, Alberta, Canada, the annual increase of 6–8% in laboratory test volume from 2004 to 2014 surpassed its annual population growth of 2.2%. • The total annual cost for an inappropriately repeated (or previously normal result) CBC and EP in inpatient and ER settings within 24 hours was over $2.4 million.
(Kulkarni, et al., 2020)	Retrospective analysis regarding the proportion of preanalytical errors associated with international normalized ratio (INR) testing.	INR only.	• Total cost of USD 25.09 per error • From 2009 through 2013, 557,411 INR tests were requested, and 73,042 (13.1%) were associated with the PA errors listed. • For the average unit cost of 1 INR test, we used USD 3.32, which represented the average cost of a stat INR test (USD 3.37) and a non-stat INR test (USD 3.28).
(Lagerquist, et al., 2017)	Retrospective Analysis of an eight-step costing model to determine the cost of PRBCs from the time of receipt at the hospital to the time of transfusion.	Costs associated with transfusion of 1 unit of RBCs.	• The total cost associated with the delivery, receipt, storage, testing and transfusion of the 10,475 PRBC shipped to the RAH in 2014 was calculated to be $2 546 485.59. This provides a total per unit cost of $243.10. • Hospital personnel, consumables and capital costs contributed 77.54%, 19.86% and 2.60% to this cost.
(Ma, Lau, Ramda, Jackson, & Naugler, 2019)	Retrospective analysis incorporating fifty-one laboratory and diagnostic tests.	51 laboratory tests and the associated direct and indirect expenses.	• In the 2015 calendar year, the three most ordered laboratory tests by total test volume in Calgary and the surrounding area were: (CBC, Creatine, and Electrolyte Panel)
(MacMillan, 2014)	Analysis of budgetary considerations in laboratory operations.	Methodology only.	• Calculation of cost savings should use standard accounting methods and include all relevant costs, including pre-analytic and analytic, variable, semi-variable and fixed costs.

			• Example of a process cost analysis for a 5-test panel including preanalytical and analytical costs.
(Morgen & Naugler, 2015)	Retrospective study establishment of costing incorporating across six Canadian laboratories.	6 test types for the current study.	• Nearly 400,000 test instances were included in the study, performed on just over 100,000 patients.
(Muirhead, Aoun, Powell, Junker, & Mollerup, 2010)	Retrospective analysis involving the implementation of the Pathology Economic Model Tool (PEMT)	Total cost per slide was calculated for routine, special, and immunohistochemical stains.	• Labour costs constitute the most significant component of laboratory expenses (70% when equipment and other expenses are excluded). • For H&E staining, a cost of $18 per slide is established, with high costs of labour and overhead, contributing approximately 80% of the total cost for a single H&E stain.
(Naugler, Thomas, Turin, Guo, & Vaska, 2015)	Retrospective analysis incorporating the calculation of the median test cost from data available from 10 Canadian laboratories.	Incorporates all laboratory testing across 10 Canadian laboratories	• Primary care physicians as a group accounted for 58% of total test costs but, on an individual basis, ranked well below several other specialties. • 670 clinical chemistry tests (chemistry, hematology, and microbiology) were requested more than 100 times in the one year of this study. • The mean cost attributed to all physicians was $27,945 per year.
(Rogg, Rubin, Hansen, & Liu, 2013)	Retrospective cohort study of patients transferred to a tertiary hospital.	11 common ED tests, including.	• For each laboratory test studied, the rate of repeat normal testing was between 46% (for CBC) and 100% (for UA). Calcium, magnesium, lipase, pt-INR, and UA were normal at both institutions greater than 90% of the time. • Extrapolating the data, the total yearly estimated charges of all repeat normal tests was $580,526.
(Tasse, Janzen, Ahmed, & Chung, 2008)	Retrospective analysis involving screening panels.	13 Testing Panels	• A total of 3,982 tests generated charges of $417,839. • A total of 1,292 abnormal tests (32%) cost $114,753. Of these, 253 (6%) were clinically significant tests, costing $36,703. ○ Savings of $381,136 could be realized if only the tests that were later found to be clinically significant had been ordered. • The most significant cost borne was for 341 unnecessary CMPs ($56,391, 92% unnecessary).

Given that determining costs associated with laboratory testing is challenging, the establishment of estimates, even with limited generalizability, may allow organizations to inform intervention practices, such as determining which tests may offer the most significant value regarding targeted intervention. For example, studies by Tawfik et al. (2016) and Lippi et al. (2015) determined that thyroid stimulating hormone (TSH) determinations represented one of the most expensive tests within the respective institutions. Indeed, the United States Department of Health and Human Services (2019) determined that TSH testing represented a substantial burden in diagnostic spending, demonstrating clear potential targets for future interventions.

Environmental Costs

While the determination of exact costs and the broad conclusion that interventions associated with laboratory testing can result in reduced savings, many of the studies identified took an exclusively financial or economic view. However, a select few of these studies further explored the underlying environmental costs of laboratory testing. It is well-accepted that healthcare environments are substantial contributors to waste (Breth-Petersen, et al., 2022; Gordon, Sherman, Leapman, Overcash, & Thiel, 2021; McAlister, et al., 2021).

Indeed, laboratories are substantial waste producers across various hazardous classifications, particularly biological or chemical ones, amplified through the increased use of single-use plastics and glass. As a simple example, a routine phlebotomy procedure incorporating two commonly used evacuated containers (tubes) plus a single-use needle collection set can produce anywhere from 10-20 grams of plastic and rubber waste alone. Given the amount of testing performed in a country like Canada within a given year, the waste generated from unnecessary testing is substantial. Table 3 provides an overview of studies incorporating aspects of environmental costs, with several focusing specifically on the total CO2 emissions.

Table 3: Studies Incorporating Environmental Costs

Author	**Selection/Measurement of Outcomes or Type of Intervention**	**Bound Parameters of Analysis**	**Key Results**
(Breth-Petersen, et al., 2022)	Retrospective assessment to quantify greenhouse gas emissions and costs associated with unnecessary Vitamin D testing	Vitamin D only	• 2020 total cost to Medicare of vitamin D tests providing no net health benefit was $87,229, and the total cost of all Vitamin D testing was $114,025,739 • 76.5% of Australia's vitamin D tests provide no net health benefit, equating to 3 410 108 unnecessary tests in 2020 • 2020 carbon footprint of unnecessary vitamin D tests was 28 576 kg (base case) and 42 012 kg (sensitivity) CO2 e • A 10-fold increase in vitamin D testing since 2001 in the UK
(Gordon, Sherman, Leapman, Overcash, & Thiel, 2021)	Retrospective Life Cycle Assessment to quantify greenhouse gas emissions within a US pathology laboratory	Specific to an 11-step biopsy process	• Scenario 1 (1 jar per biopsy) generated 0.29 kg of carbon dioxide equivalents (kg CO2 e), whereas scenario 2 (3 jars per biopsy) resulted in 0.79 kg CO2 • The most significant proportion of GHGs (36%) in either scenario came from the tissue processor step. • The second largest contributor (19%) was case accessioning, mainly attributable to the production of single-use disposable jars. • 20 million biopsies are performed in the US annually; emissions from biopsy processing are equivalent to yearly GHG emissions from 1,200 passenger cars.
(McAlister, Barratt, Bell, & McGain, 2020)	Retrospective assessment to quantify greenhouse gas emissions within the Australian Health care sector in two university-affiliated hospitals	Assessed the carbon footprint of five pathology tests	• For all tests except CRP, the primary sources of CO2e emissions were sample collection consumables • The proportions of emissions attributable to sample collection were 63% (74 of 116 g) for full blood examination (i.e., CBC); 90% (89 of 99 g) for U&E; 94% (46 of 49 g) for ABG; and 95% (78 of 82 g) for coagulation profile
(McAlister, et al., 2021)	An administrative intervention involving within a 653-bed tertiary referral hospital in Sydney, Australia	Assessed the carbon footprint and costs of six pathology tests	• 24,585 pathology collections in 5695 patients. • The rate of collections was lower during the intervention period. • The intervention was estimated to have saved 132 kg CO2e (95% CI, 59–205 kg) and $53 573 (95% CI, 22 076–85 096). • GHG emissions were 4038 kg CO2e.

(Selvam, et al., 2023)	Prospective study conducted at The Ottawa Hospital, Ottawa, Canada, specific to bariatric surgery patients	POD1 laboratory testing consisted of a CBC, CR, and electrolytes.	• The study extrapolated financial and environmental costs from institutional costs and practices. • POD1, which costs $25.79 per patient in lab processing fees alone. • They estimated the environmental cost savings based on these laboratory tests utilizing two test tubes for each patient.
(Spoyalo, et al., 2023)	A retrospective cohort study of patients admitted to the acute care surgery service at Vancouver General Hospital	Assessment of six common tests	• 76% of evaluated patients underwent unnecessary bloodwork, resulting in a mean of 1.84 phlebotomies, 4.4 blood vials, 16.5 tests and 18mL of blood loss per patient • The hospital and environmental cost of these unnecessary activities was $C5,235, and 61 kg • The carbon footprint of a common set of investigations (was 332 g CO2) • Adding a liver panel (liver enzymes, bilirubin, albumin, international normalized ratio/ partial thromboplastin time) resulted in an additional 462 g CO2 e

Ultimately, the studies identified within the peer-reviewed literature paint a compelling picture of the increasing costs associated with laboratory testing. In addition to reviewing the peer literature, a thorough search of the grey literature was also conducted. This search revealed several analyses and reports, primarily within the United States and Canada, that allowed for a cost determination for the most frequently performed tests.

As an example, the US (United States Department of Health and Human Services: Office of Inspector General, 2018) produces reports for the 25 most commonly encountered tests as billed through Medicare, which were compared to the Canadian billing process in British Columbia, Ontario, and Saskatchewan (British Columbia: Ministry of Health, 2015; Government of Saskatchewan, 2023; Ministry of Health: Ontario Health Insurance Plan Laboratories and Diagnostics Branch, 2023).

DISCUSSION

As previously noted, enumerating the costs for medical laboratory testing presents a complex problem as a myriad of factors are associated with presenting a complete picture. This phenomenon is particularly evident within the Canadian health system as each province has unilateral and constitutional control over health care spending. When combined with a mixed economic system, including for-profit partnerships and publicly funded institutions, transparency of health spending becomes muddied. Human resources, consumables, capital, and physical plant capacity all represent competing costs, but little doubt remains that the overarching picture of medical laboratory testing is costly. Though diagnostic testing represents a fraction of the overall cost of delivery of health care (Hjelmgren, Heintz, Ygge, Andersson, & Nordlund, 2023), the total costs do represent a substantial burden and one that is worthy of continued discussion. Unfortunately, there is limited generalizable literature and few tools that laboratory administrators can use in determining potential savings associated with a responsible reduction in diagnostic tests.

Despite the apparent cost impacts associated with unnecessary testing, inappropriate use of laboratory diagnostic testing has been a well-identified concern amongst ordering professionals in Canada—and, more broadly, the entire developed world (Attali, et al., 2006; Aesif, Parenti, Lesky, & Keiser, 2015; Ambasta, et al., 2020; Ambasta, et al., 2023; Gill, Guo, Lau, & Naugler, 2020; Ma, Lau, Ramda, Jackson, & Naugler, 2019). Estimates on the degree of unnecessary testing vary considerably, but ultimately, there is clear agreement within the literature that interventions are required to reduce the overarching health care and public burden. The United States provides a particularly valuable exemplar of this saving potential as the United States Department of Health and Human Services (USDHHS) maintains detailed records related to laboratory testing. As an example, there were 433 million tests billed to Medicare at $7.1 billion across 655,771 medical providers ($16.40 per test).

Moreover, Medicare paid $4.5 billion for the top 25 lab tests paid under the clinical laboratory fee schedule. Thyroid stimulating hormone testing alone accounted for 484 million (21.5 million tests) in 2017 and 434 million (21.4 million tests) in 2018. This trend appears across several years of USDHHS data (United States Department of Health and Human Services: Office of Inspector General, 2018; United States Department of Health and Human Services: Office of Inspector General, 2020a; United States Department of Health and Human Services: Office of Inspector General, 2022).

At an average cost of approximately 20 USD per test, with even the most conservative estimates of interventions showing a marked reduction in unnecessary testing of 4.5% (Ma, Lau, Ramda, Jackson, & Naugler, 2019), an actual savings of nearly 20 million USD can be captured within the United States on a single test alone. The potential cost savings are remarkable when coupled with more assertive estimates of over-testing. While the US Medicare model is distinct from the Canadian single-payer model, it demonstrates a substantial cost associated with diagnostic testing and one mirrored in Canada.

Our evaluation within this literature review attempts to elucidate a compelling picture related to the environmental and economic costs connected with the overuse of diagnostic testing and advocate for prudence in the diagnostic testing system. This process involved a targeted view of those studies that provided detailed cost savings estimates specific to laboratory testing within OECD countries to provide a nuanced view of the potential financial and environmental savings associated with costs within and specific to the clinical laboratory environment.

However, it is essential to emphasize that the cost estimates presented are by their nature conservative as it is difficult to enumerate the savings outside of simply not performing particular tests as laboratory testing is by its very nature involves a complex matrix of professionals, appointments, downstream testing, and patient interactions.

Implications

The implications of generalizable estimates of laboratory testing costs have substantial implications for developing targeted policy interventions relating to laboratory testing. In particular, this review supports the development of a broader set of tools that administrators can use to establish cost estimates in conjunction with recommendations aligned with Choosing Wisely to limit testing that demonstrates limited patient benefit or treatment modification. As part of the broader scope of this systemic review, the literature will be used to inform the development of widget tools to aid laboratory administrators.

In addition, this review confirms and substantiates the collective literature that indicates substantial potential cost savings, environmental and economical, to be had with the reduction of unnecessary testing. Moreover, this review confirms that interventions can generate substantial savings with a substantially positive benefit versus intervention cost ratios. While multi-tiered interventions are likely to generate the most substantial cost-savings, in all but one of the studies identified, intervention was positively correlated with costs, and there appeared to be no negative patient impact.

Finally, the review establishes an approximate starting point for developing a formula to calculate associated environmental wastes connected with laboratory testing. Developing such a formula may encourage future conversations about reducing carbon-containing substances such as plastic and rubber and contribute to their accumulation within Canada's landfills.

Limitations

While scoping reviews are associated with several benefits, they are naturally subject to several inherent limitations. Scoping reviews, for example, focus on providing breadth rather than depth and do not incorporate a complete meta-analysis. Moreover, our study was specifically focused on those

conducted in English and those that fell within the OECD list of countries. Clinical laboratory analysis occurs at all economic levels, but within the OECD, it is recognized that these represent robust and relatively well-developed economies. We anticipate our results will have considerably limited generalizability across non-OECD countries.

Moreover, given that laboratory costing is naturally difficult due to factors such as proprietary pricing, bulk purchase discounts, wide labour variations, and complexity of analysis, it is fully understood that the synthesis of information provided is inherently an imperfect model and one that will result in substantially different costs across individual organizations, regions, and or countries. Nevertheless, we believe that the qualitative conclusions related to interventions and qualitative analysis of costs will be of value to laboratory administrators and will inform the development of reasonably accurate tools for assessing potential cost savings.

CONCLUSIONS

This scoping review will help provide a comprehensive overview of the costs associated with unnecessary medical laboratory tests in Canada and the United States. It can be a valuable resource for healthcare policymakers, practitioners, and researchers seeking to address the economic implications of over-testing in healthcare systems.

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DATA APPENDIX

The accompanying data appendix document shows a complete set of search parameters. A sample of the search parameters is shown below:

SCOPUS

Results

SCOPUS (Initial Process)

- Cost-effectiveness AND resources; AND diagnostic AND tests; AND medical AND laboratory; AND overtesting OR stewardship OR health AND care AND expenditures OR test AND utilization OR demand AND management

1702 total documents from 2003-2023

- Excluding Books, Book Chapters, Notes, Editorials

1212 in English

- 1041 OECD
- Limited to Include SCOPUS filters as follows:
    - Cost-effectiveness analysis; health care cost; laboratory test; Cost-benefit Analysis; systematic review; economics; health care utilization; diagnostic test

648 Results (Manually Reviewed)

- 72 Studies Exported to Convidence® for Secondary Review

SCOPUS (FINAL CODE)

cost-
effectiveness; AND resources; AND diagnostic AND tests; AND medical AND laboratory; AND overtesting OR stewardship OR health AND care AND expenditures OR test AND utilization OR demand AND management AND PUBYEAR > 2002 AND PUBYEAR < 2024 AND (EXCLUDE (DOCTYPE , "bk") OR EXCLUDE (DOCTYPE , "ch") OR EXCLUDE (DOCTYPE , "no") OR EXCLUDE (DOCTYPE , "ed")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (AFFILCOUNTRY , "United States") OR LIMIT-TO (AFFILCOUNTRY , "United Kingdom") OR LIMIT-TO (AFFILCOUNTRY , "Canada") OR LIMIT-TO (AFFILCOUNTRY , "Italy") OR LIMIT-TO (AFFILCOUNTRY , "Australia") OR LIMIT-TO (AFFILCOUNTRY , "Netherlands") OR LIMIT-TO (AFFILCOUNTRY , "Germany") OR LIMIT-TO (AFFILCOUNTRY , "Switzerland") OR LIMIT-TO (AFFILCOUNTRY , "France") OR LIMIT-TO (AFFILCOUNTRY , "Spain") OR LIMIT-TO (AFFILCOUNTRY , "Belgium") OR LIMIT-TO (AFFILCOUNTRY , "Denmark") OR LIMIT-TO (AFFILCOUNTRY , "Sweden") OR LIMIT-TO (AFFILCOUNTRY , "Japan") OR LIMIT-TO (AFFILCOUNTRY , "Ireland") OR LIMIT-TO (AFFILCOUNTRY , "Greece") OR LIMIT-TO (AFFILCOUNTRY , "Austria") OR LIMIT-TO (AFFILCOUNTRY , "Portugal") OR LIMIT-TO (AFFILCOUNTRY , "Israel") OR LIMIT-

TO (AFFILCOUNTRY , "Norway") OR LIMIT-TO (AFFILCOUNTRY , "Poland") OR LIMIT-TO (AFFILCOUNTRY , "New Zealand") OR LIMIT-TO (AFFILCOUNTRY , "Finland") OR LIMIT-TO (AFFILCOUNTRY , "Mexico") OR LIMIT-TO (AFFILCOUNTRY , "Colombia") OR LIMIT-TO (AFFILCOUNTRY , "Turkey") OR LIMIT-TO (AFFILCOUNTRY , "Czech Republic") OR LIMIT-TO (AFFILCOUNTRY , "Chile") OR LIMIT-TO (AFFILCOUNTRY , "Lithuania") OR LIMIT-TO (AFFILCOUNTRY , "Luxembourg")) AND (LIMIT-TO (EXACTKEYWORD , "Cost Effectiveness Analysis") OR LIMIT-TO (EXACTKEYWORD , "Health Care Cost") OR LIMIT-TO (EXACTKEYWORD , "Laboratory Test") OR LIMIT-TO (EXACTKEYWORD , "Cost Benefit Analysis") OR LIMIT-TO (EXACTKEYWORD , "Systematic Review") OR LIMIT-TO (EXACTKEYWORD , "Economics") OR LIMIT-TO (EXACTKEYWORD , "Cost-Benefit Analysis") OR LIMIT-TO (EXACTKEYWORD , "Health Care Utilization") OR LIMIT-TO (EXACTKEYWORD , "Diagnostic Test"))