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From patient to planet: integrating climate impact into a hospital medicine initiative reducing blood urea nitrogen testing

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ABSTRACT

Background Pursuing climate-conscious care has become a key focus of quality improvement (QI) efforts. Hospitals across Alberta, Canada, implemented a multicomponent intervention to reduce unnecessary blood urea nitrogen (BUN) testing. This study evaluated the broader environmental impact of the intervention across multiple hospital medicine settings.

Methods Using a pre–post study design, monthly BUN test counts were compared before and after implementing the initiative across six hospital medicine wards to calculate percentage reductions. A secondary analysis assessed the initiative's environmental impact using the Lab Wisely Carbon Calculator, which converted reduced BUN testing into equivalent travel distances. Avoided carbon dioxide (CO_2) emissions were estimated at 32.1 g/test and tree equivalents were calculated using an annual absorption rate of 21.77 kg CO_2/tree.

Results Hospitals showed monthly reductions in unnecessary BUN testing between 51% and 95%, saving an estimated 5101.92 km of travel and avoiding 169.39 kg of CO_2 emissions monthly, equivalent to planting about 93 trees annually. The climate impact varied by hospital, reflecting differences in the intervention strategies used.

Conclusions Integrating environmental metrics into QI initiatives offers a strategic path to climate-conscious care, promoting sustainability alongside fiscal responsibility and resource efficiency.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The healthcare sector is a significant contributor to greenhouse gas emissions with major sources including energy use, supply chains and clinical activities such as diagnostic testing and pharmaceuticals.

WHAT THIS STUDY ADDS

⇒ Integrating environmental outcome metrics into quality improvement initiatives aimed at reducing unnecessary diagnostic testing enhances research by providing a practical framework for implementing climate-conscious healthcare practices.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ It broadens the scope of healthcare research by including environmental sustainability as a measurable outcome, encouraging interdisciplinary studies that connect clinical practice, resource utilisation and environmental impact.

INTRODUCTION

Healthcare systems exist to protect the health of all individuals; yet paradoxically, it plays a significant role in the climate crisis, a continuously growing threat to global health.[1 2] It is, therefore, essential to explore how physicians and healthcare institutions can reduce environmental strain without compromising the quality of patient care.[1 3] In this context, resource stewardship and climate-conscious care have become central priorities within quality improvement (QI) initiatives.[1 3] Globally, the healthcare sector accounts for an estimated 5% of net carbon emissions exceeding the contribution of the aviation industry.[4] In Canada alone, healthcare activities generate approximately 33 million tonnes of carbon dioxide equivalents (CO_2e) each year, contributing to an estimated 23 000 disability-adjusted life years lost annually.[5]

Modern healthcare relies heavily on laboratory testing, with billions of tests performed worldwide.[6] Clinical laboratories consume approximately 3–6 times more energy than typical office buildings[6–8] and generate large quantities of biomedical waste,[9] with blood collection supplies accounting for approximately 60%,[6–9] however, the environmental consequences of unnecessary laboratory testing are often overlooked.

A 15-year meta-analysis found between 16% and 56% of laboratory tests is ordered inappropriately.[10] Such overuse contributes to the healthcare ecological footprint through the carbon emissions generated in the production, transportation and disposal of laboratory materials.[11] Integrating Choosing Wisely recommendations and evidence-based laboratory test ordering, along with increasing awareness of the climate impacts of unnecessary laboratory testing, may further encourage clinicians to order tests more appropriately.[12 13] An opportunity for reducing waste and CO_2 emissions may involve changing the behaviour of clinicians to avoid and reduce unnecessary laboratory testing.[12 13]

No published studies to date have quantified the proportion of healthcare-related carbon emissions attributable to clinical diagnostic laboratories.[14] However, lifecycle assessments demonstrate laboratory testing does contribute to healthcare emissions through cumulative test volumes, energy-intensive equipment, single-use plastics and reagent consumption.[15 16] Studies have focused on specific disciplines or test protocols, such as a pathology laboratory emitting 117 tonnes of CO_2e annually (approximately 0.5% of hospital emissions), from consumables and logistics.[17] Another study reported 0.5–116 g CO_2e/routine blood tests, with the majority of emissions from the blood collection materials rather than analytical processes.[18] Laboratory sample collection and processing have similarly been estimated to account for approximately 9% of total emissions in clinical trials.[19] Reducing unnecessary laboratory testing may represent an opportunity to align QI initiatives with environmental sustainability goals.[20]

To promote resource optimisation, hospitals across Alberta, Canada implemented a multifaceted QI initiative designed to reduce unnecessary blood urea nitrogen (BUN) testing among hospital medicine physicians.[21] This study aimed to evaluate the environmental impact of this initiative.

METHODS

Design, setting and participants

This study represents a secondary analysis of data collected from a previous pre–post intervention study,[21] conducted across six hospital medicine programme wards in three health zones in Alberta, Canada (table 1). A provincial laboratory test utilisation report identified high (>500 tests/month) BUN test ordering in these health zones, which used (at the time of the audit report) paper-based charting before the implementation of a province-wide electronic medical record (EMR) system that began in 2020 and was implemented in a phased approach across hospitals in this province. In addition, laboratory testing was ordered primarily by physicians, as nurse-initiated orders were not in place. Orders were written on paper forms and transcribed into paper laboratory requisitions by clerks or nurses on hospital medicine wards. In the emergency department, clerks entered laboratory requests directly into the electronic emergency department system.

The BUN test often adds little value to patient management and there are clinical indications and guidelines for when the BUN test should be ordered making it a target for improvement.[22–24] As such, these Alberta hospital wards participated in a 6-year (2017–2022) QI initiative that was supported by a physician-led coalition, called the Strategic Clinical Improvement Committee,[25] aimed at reducing physician ordering of BUN testing through the *Laboratory Test Ordering Overuse* (LTOO) programme.[26] The initiative targeted laboratory test ordering practices among hospital medicine physicians using six interventions, categorised as either person-focused (PF) or system-focused (SF).[21 27] LTOO intervention components included (1) intervention bundle (PF), (2) BUN-test justification label (SF), (3) educational presentation and display of BUN poster (PF), (4) performance (total monthly BUN test order volume) audit feedback (PF), (5) paper-order form update (SF) and (6) physician champion informally reminding staff (PF). Each hospital implemented a distinct sequence of these interventions, resulting in variable levels of BUN test reduction.[21]

Table 1 Hospital characteristics

Characteristic	A	B	C	D	E	F
Health zone	1	1	1	1	2	3
Geographic region	Urban	Urban	Urban	Urban	Rural	Rural
Number of beds	885	869	309	363	345	270
Academic hospital	✓	✓				
Community hospital			✓	✓	✓	✓
Resident training	✓	✓	✓	✓		
Number of involved medicine wards	5	6	3	4	3	4
Years participated in QI initiative	2017–2019	2018–2019	2018–2019	2018–2019	2019–2022	2021–2022
EMR implementation month and year	November 2019	May 2022	N/A	N/A	November 2022	N/A
Medicine programme Intervention implementation Month and year	None	None	March 2021	None	None	June 2022

Rural<100 000 population; urban>500 000 population.
None-The hospital participated in the provincial initiative but did not implement a local medicine program intervention
EMR, electronic medical record; N/A, not applicable; QI, quality improvement.

Hospitals (labelled A–F) were distributed across three health zones: zone 1 (urban), which included academic (A and B) and community (C and D) hospitals with resident training; and zones 2 and 3 (rural), which included community hospitals (E and F) without resident training. Hospital participation periods varied: hospital A (2017–2019), hospitals B–D (2018–2019), hospital E (2019–2021) and hospital F (2021–2022).

Following completion of the LTOO initiative, three hospitals (A, B and E) implemented an EMR system featuring standardised, evidence-based order panels in 2019 and 2023. Two hospitals (C and F) extended the initiative in March 2021 and June 2022 through ongoing local medicine program educational presentations, visual reminders (eg, BUN posters), performance audits with feedback and informal peer reminders from physician champions. Four hopsitals (A, B, C and D) did not implement additional local medicine program interventions (table 1).

Patient and public involvement

No patient or public involvement in this study.

Data collection and analysis

The monthly average number of ordered BUN tests for each of the six hospital medicine programme wards was extracted from the provincial laboratory information system by a laboratory data analyst. Data included a minimum of 12 months pre and postimplementation of the LTOO initiative and was compiled in an Excel spreadsheet.

The pre-LTOO monthly average BUN test counts and corresponding postinitiative percentage reductions for each hospital medicine programme were entered into the *Canadian Society for Medical Laboratory Science (CSMLS) Lab Wisely Calculator*,[28] which represents modelled, test-attributed emissions to estimate (does not reflect precise measures of absolute emissions) the avoided travel distance (in km) for the diagnostic test category 'urea (BUN)'. The 'distance by CO_2 (km)' metric represents the equivalent distance a vehicle would travel if the carbon emissions from unnecessary BUN testing were released entirely as carbon dioxide (CO_2). A 1999 Toyota Corolla was used as the reference vehicle for this comparison.[29]

Based on an estimated 32.1 g CO_2 emissions per BUN test, as reported by Spoyalo *et al*,[2] the monthly reduction of BUN tests at each hospital was multiplied by this emission factor. The reduction in test volume was calculated as the difference between the average number of monthly BUN tests before and after the LTOO initiative (table 2; figure 1). This calculation yielded the estimated average monthly reduction in CO_2 emissions for each hospital,

Table 2 Comparison of monthly BUN test counts and environmental impact for participating hospitals

	Monthly average BUN test							
Hospital	Pre-LTOO	Post-LTOO	Intervention category and components	Post-EMR or post-medicine programme intervention or no intervention	% Reduction*	Distance saved (km/month)†	Carbon dioxide emission CO_2e avoided (kg/month)‡	Tree equivalent (annual)§
H-A	1885	448	PF: 1, 3, 4, 6 SF: 5	85	95%	1740.25	57.78	31.85
H-B	1615	764	SF: 5	242	85%	1327.51	44.07	24.29
H-C	1136	331	PF: 1, 3, 4, 6 and SF: 2	77	93%	1023.84	33.99	18.74
H-D	532	352	PF: 3, 4, 6	261	51%	262.01	8.699	4.80
H-E	536	201	SF: 5 PF: 3, 4, 6	168	68%	355.80	11.81	6.51
H-F	713	456	PF: 3, 4, 6	307	57%	392.51	13.03	7.18
Total	6417	2552	N/A	1140	N/A	5101.92	169.39	93.37

LTOO intervention components are: (1) intervention bundle (PF), (2) BUN test justification label (SF), (3) educational presentation and display BUN poster (PF), (4) performance (total monthly BUN test order volume) audit feedback (PF), (5) paper-order form update (SF) and (6) physician champion informally reminding staff (PF).

*Percentage reduction calculated using the pre-intervention monthly average divided by the postintervention monthly average minus 1×100%.

†Distance as if mass of waste were carbon emissions of a 1999 Toyota Corolla.

‡Kilograms of CO_2e were calculated using Spoyalo *et al*[2] estimation of additional 32.1 g CO_2e from each BUN testing, multiplied by the number of monthly BUN tests reduced.

§Based on conservative estimate of 21.77 kg CO_2 absorbed per tree per year, as reported by Ecologic Life[12]

BUN, blood urea nitrogen; CO_2e, Carbon dioxide emission; EMR, electronic medical record; LTOO, Laboratory Test Ordering Overuse; PF, person-focused interventions, defined as knowledge and awareness[27]; SF, system-focused interventions, defined as forcing functions and automation[27].

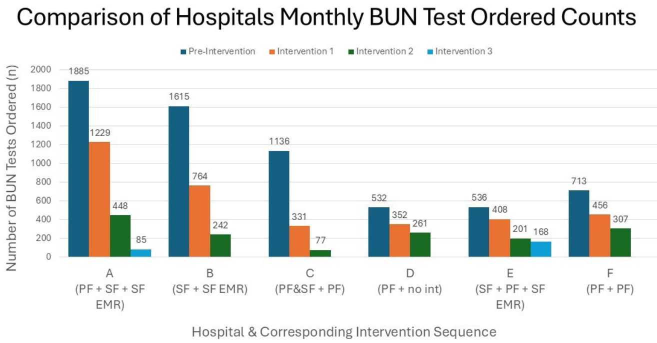

Figure 1 Comparison of hospitals monthly BUN test ordered counts and intervention categories used. BUN, blood urea nitrogen; EMR, electronic medical record; PF, person-focused; SF, system-focused.

providing clearer representation of the carbon footprint avoided through reduced BUN test ordering.

Ecologic life[30] estimates that a mature tree absorbs approximately 21.77 kg of CO_2 per year, which was adopted as a conservative benchmark for this analysis. Using this estimate, a 'tree equivalent' value was calculated for each hospital to represent the number of trees theoretically required to offset CO_2 emissions equivalent to those avoided post-LTOO implementation. The previously calculated monthly CO_2 emission reductions were annualised and then divided by 21.77 kg CO_2 per tree to obtain the corresponding tree equivalence. Detailed methods and calculations are available in online supplemental file 1.

RESULTS

Among the four urban health zone hospitals (A, B, C and D), hospital A achieved the largest reduction in carbon emissions from interventions aimed at reducing BUN test ordering, equivalent to an estimated 1740.25 km of CO_2 emissions from driving per month, or 57.78 kg of CO_2 saved monthly (table 2). This corresponds to the estimated carbon absorption of over 31 trees annually. Hospital B followed, with monthly savings of 44.07 kg of CO_2 emissions equivalent to 1327.51 km drive or more than 24 trees annually. Hospitals C and D achieved smaller reductions, with 33.99 kg and 8.699 kg of CO_2 emissions saved per month, respectively, representing 1023.84 km and 262.01 km per month, or over 18 and 4 trees annually.

The rural zone hospitals (E and F) had monthly CO_2 estimated savings of 11.81 kg and 13.03 kg, respectively, equivalent to 355.80 km and 392.51 km driven per month, or approximately 6 and 7 trees annually. Despite variations in the interventions implemented and their sequence, all hospital medicine wards achieved measurable reductions in CO_2 emissions, ranging from 8.699 kg per month (123.75 km driven) after a single intervention at hospital E to 57.78 kg per month (1740.25 km driven) after multiple interventions at hospital A.

When aggregated across all six hospitals, the LTOO initiative resulted in an estimated monthly reduction of 169.39 kg of CO_2 per month, equivalent to 5101.92 km of driving or the carbon sequestration over 93 trees annually.

DISCUSSION

Healthcare providers increasingly witness the adverse health impacts of climate change, including higher rates of heat-related illness and mortality as well as respiratory conditions linked to air pollution.[31 32] Paradoxically, the healthcare system itself contributes substantially to greenhouse gas emissions through clinical practices, infrastructure and supply chains. This study demonstrates both the practicality and value of integrating environmental outcome metrics into the evaluation of a hospital medicine QI initiative aimed at reducing unnecessary BUN test ordering. Using the CSMLS Lab Wisely Carbon Calculator alongside published emission estimates from Spoyalo *et al*[2] and Ecologic Life,[30] environmental estimate impacts were quantified with relative ease.

All hospitals achieved measurable reductions in monthly carbon emissions, expressed as kilograms of CO_2 saved and translated into relatable metrics such as equivalent kilometres driven per month or trees needed to sequester the avoided emissions annually. Across the six hospitals, implementation of various intervention components and timelines produced a combined monthly estimated reduction of 169.39 kg CO_2, equivalent to 5101.92 km of travel or the annual absorption of approximately 93 trees. These findings illustrate the climate benefits of reducing unnecessary laboratory testing and highlight the real-world environmental waste that can be prevented in hospital medicine wards. Importantly, underscoring the critical role of physician ordering practices in advancing climate-conscious care is greatly needed.

These results are consistent with growing evidence that reducing low-value laboratory testing meaningfully contributes to healthcare sustainability.[1 2] Inpatient populations with higher rates of unnecessary testing, such as those admitted with gallstone pancreatitis, greenhouse gas emissions have been shown to be 3–3.5 times higher per admission,[2] indicating this as a key area for targeted improvement. A recent scoping review further emphasised the need to quantify and promote multidisciplinary discussions on reducing the environmental impact of laboratory testing,[33] aligning with the approach taken in this study.

Variation in carbon estimated savings across hospitals (ranging from 8.70 kg to 57.78 kg CO_2/month) reflects differences in intervention type, timing and local implementation strategies.[21 34] These findings support previous evidence that multifaceted interventions—such as education, audit and feedback, and EMR modifications—can effectively reduce test overuse when tailored to local context.[35] Although this analysis focused on a single laboratory test (BUN), the multicomponent initiative used in this study is transferable. Combining education, audit and feedback, order form modification and physician leadership has been successfully applied to other commonly overused laboratory tests across inpatient settings.[22 35] Extending this initiative to panels of high-volume or routinely bundled tests (eg, daily chemistry panels, liver function tests, coagulation studies, etc) may result in cumulative reductions in test volume and associated carbon emissions.[4 35] Given the high frequency with which these tests are ordered in hospital medicine wards, even modest per-test reductions may translate into meaningful system-level environmental benefits.[12 13 20] This supports the growing recognition that laboratory test stewardship represents an implementable clinician-led strategy for advancing climate-conscious care within existing QI initiatives.[31 36]

It is important to recognise for this study that BUN test ordering monthly count/volume was directly measured, downstream effects on phlebotomy frequency, specimen transport and laboratory reagent utilisation were not assessed. Therefore, reductions in BUN test ordering may not necessarily result in equivalent reductions in blood draws or specimen transport, as BUN is often ordered as part of multianalyte chemistry panels. The environmental impacts reported in this study should not be interpreted as direct measures of reduced phlebotomy or transport. This study attempted to demonstrate the test attributable emission estimates, illustrating how big and in what direction climate change may be impacted due to unnecessary test ordering. Sustained system-wide reductions in testing volume across a number of analytes and clinical services may be more likely to lead to significant cuts in emissions related to reduced blood collection and transportation.[12 13 20]

Another consideration is that the possibility of reductions in test volume may lead to unintended environmental wastes within the laboratory. For example, decreased analyser throughput could increase reagent wastage if reagent packs expire before use. However, reduced laboratory testing does not inherently increase expiries.[37] Within Alberta laboratory services, use of an integrated, province-wide inventory management system with real-time tracking of supplies and reagents limits waste. This system continuously monitors usage, stock levels and expiry dates, allowing laboratories to align ordering with actual demand.[38] By preventing overstocking, the primary cause of expiries it supports more efficient inventory control. Standardised processes also enable redistribution of supplies when needed. As a result, lower testing volumes, combined with data-driven inventory management, are more likely to reduce waste from reagent expiries while maintaining reliable access to materials required for patient care.[39] Reagent utilisation and laboratory waste were not assessed in this study, future evaluations of environmentally sustainable laboratory practice should consider incorporating these factors to ensure test reduction initiatives achieve net environmental benefit rather than shifting emissions upstream within the laboratory system.

The use of carbon and climate calculators represents a practical and accessible approach for quantifying the environmental impacts of laboratory testing. Converting abstract emissions data into concrete metrics, such as kilometres driven or trees planted, may enhance healthcare providers' awareness and motivation by making environmental impacts more tangible. Further research and collaboration between environmental scientists and healthcare professionals are needed[1 3] to establish standardised tools for estimating environmental impacts in healthcare, as multiple calculators tailored to clinical pathways are emerging, including the healthcare Emissions Impact Calculator (Practice Greenhealth),[40] the Healthcare-specific Smart Carbon Calculator (Newcastle Hospitals),[41] and the Care Pathway Carbon Calculator (Sustainable Healthcare Coalition).[42] Overall, these findings support the integration of environmental sustainability metrics into traditional QI frameworks, expanding the definition of healthcare quality to include ecological outcomes.[36]

Limitations

A limitation of this study is the focus on a single diagnostic test, BUN, within hospital medicine wards in one Canadian province, following a specific QI-initiative, which may limit generalisability. While this single-test focus does not capture the full carbon footprint of clinical laboratory services, it provides an example of how existing laboratory test stewardship initiatives may be used to estimate and reduce laboratory-related emissions. The multihospital nature of the initiative, with data collected over several years, demonstrated measurable and sustained reductions in carbon emissions. Suggesting that applying a similar approach to panels of high-volume or frequently overused laboratory tests could yield larger cumulative environmental benefits.

This study did not estimate the complete carbon footprint of laboratory operations, including upstream manufacturing, laboratory infrastructure or energy use. Estimates of environmental impact are influenced by the design and effectiveness of interventions as well as contextual factors such as hospital policies, infrastructure and waste management practices.[43] Carbon calculators also rely on standardised assumptions; in this study, for example, carbon emissions were translated into equivalent driving distances, requiring assumptions about vehicle type and emission rates. Additionally, assumptions regarding adult tree type and CO_2 absorption rates were needed to calculate tree equivalent values to illustrate climate impact. As such, the estimates should be interpreted as illustrative rather than precise measures of absolute emissions.

Furthermore, the generalisability of these findings may vary across health systems with different test-ordering cultures, levels of diagnostic stewardship maturity and EMR capabilities. All participating hospitals used paper-based ordering systems during the study period, and three later transitioned to EMRs with standardised order panels. Health systems with advanced electronic ordering, different baseline rates of overtesting or limited QI infrastructure may experience different effects; however, the underlying principles of clinician engagement, audit and feedback and system-level changes are broadly applicable across diverse healthcare settings.

CONCLUSION

Incorporating environmental outcome metrics into QI initiatives that target unnecessary diagnostic testing provides a practical and strategic approach to advancing climate-conscious care. Highlighting the environmental impact of ordering practices can further promote sustainable healthcare, where ecological stewardship, fiscal responsibility and efficient resource use are prioritised equally.

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