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Carbon emissions and hospital pathology stewardship: a retrospective cohort analysis

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MAIN TEXT

Climate change threatens to undo the last 60 years of public health gains, through extreme weather, changing distributions of infectious diseases, and food and water insecurity.[1] Paradoxically, healthcare is itself a major contributor to carbon emissions: in Australia, healthcare is responsible for 7% of national greenhouse gas (GHG) emissions, whilst globally healthcare accounts for approximately 4.4% of the world's emissions.[2,3] There is growing awareness of climate-health impacts, with medical organisations in Australia describing it as a public health emergency[4,5] and health organisations, such as the National Health Service (NHS) starting to decarbonise.[6] In Australia, the Australian Medical Association (AMA) and Doctors for the Environment Australia (DEA) have called for Australia's healthcare sector to become net zero by 2040, with an interim target of 80% reduction by 2030.[7] Whilst the move towards renewable energy will achieve some of this reduction, there will also need to be changes in clinical care.

In 2020, a life cycle carbon footprint of five commonly used pathology tests in a hospital setting was reported,[8] showing that phlebotomy and collection tubes accounted for most of the impact. As these items are unable to be reused or recycled, the main opportunity to reduce emissions from laboratory tests is to reduce unnecessary testing.[9] According to a meta-analysis by Zhi et al, between 12 – 44% of ordered pathology tests are not indicated.[10] Given the high number of pathology tests performed in Australian hospitals, there are opportunities to reduce both carbon emissions and financial costs through improved pathology stewardship.

In September 2019, the Division of Medicine (DoM) at St George Hospital introduced a policy to limit non-urgent pathology testing to two days per week (Mondays and Thursdays), with pathology testing on other days only when urgently required. Whilst the initial driver was to reduce patient harm and economic costs, it was subsequently recognised that it could also reduce carbon emissions, which may in future further motivate clinicians to reduce unnecessary testing. The objective of this retrospective cohort study was to measure the difference in the number of pathology collections between the intervention period and a reference period, along with the corresponding difference in GHG emissions (in carbon dioxide equivalents (CO_2e)), financial costs and any adverse events.

METHODS

Study setting

St George Hospital is a 653-bed tertiary referral hospital in metropolitan Sydney. The DoM comprises the Departments of Cardiology, Endocrinology, Gastroenterology and Hepatology, Infectious Diseases and Immunology, Nephrology, Neurology, Respiratory, and Rheumatology. Approval for this project was obtained from the South Eastern Sydney Local Health District (SESLHD) Human Research Ethics Committee: 2020/ETH01470.

Study design

Intervention

The DoM's policy to limit testing to Mondays and Thursdays was developed in conjunction with heads of department, and a junior doctor interest group that designed posters promoting the policy change (e.g. "Twice weekly ordering" and "More is not always better", see Supplementary Fig 1). The policy was communicated via department meetings, staff orientations, and strategic placement of posters in areas frequented by junior doctors. The policy was implemented on 1 September, 2019 and is ongoing.

Study periods

Two periods were determined for the primary comparative analysis. The intervention period was defined as 1 September 2019 to 29 February 2020. A corresponding 6-month period from the previous year, 1 September 2018 to 28 February 2019, was selected as the reference period to minimise seasonal effect. Data from the intermediate period (1 March 2019 to 31 August 2019) was also analysed and included in all multivariable models.

Study Population

All admissions under the care of a DoM consultant for 24 hours or longer, insured by Medicare, Department of Veterans Affairs, or compensation schemes were included. Admissions covered by private health funds were excluded, as pathology is billed separately. Emergency Department (ED) and Intensive Care Unit (ICU) pathology tests were excluded as ordering is not directed by DoM staff. Any admissions that stretched over two study periods were split by date, with each portion analysed under their corresponding study period.

Data sources

The following de-identified DoM patient admission data for the study periods were extracted from the Health Information Exchange and NSW Health Pathology: patient age, sex, Aboriginal or Torres Strait Islander (ATSI) status, medical specialty, length of stay (LOS), emergency or planned admission, ICU admission, patient acuity measured by National Weighted Activity Unit 2019 (NWAU19), and in-hospital mortality.

Billing records were retrieved within the study periods for commonly ordered tests: full blood count (FBC), coagulation profile (activated partial thromboplastin time (aPTT) and international normalised ratio (INR)), urea, electrolyte and creatinine (UEC), C-reactive protein (CRP), calcium, magnesium, phosphate (CMP), liver function tests (LFT). Additional tests processed at the same time (d-dimer, fibrinogen, thrombin time, amylase, lipase, lactate, creatine kinase, urate, and ammonia) were also retrieved. Admission and pathology billing data were linked using a de-identified patient and admission identifier.
Environmental impacts were obtained from a previous study investigating the consequential life cycle assessment (LCA) of pathology testing.[8] Environmental impacts were calculated per collection, and included phlebotomy (collection tubes, tube holders, needles, gloves, alcohol and cotton swabs, specimen bags) and the impacts of laboratory analysis (laboratory consumables, and analyser's electricity and reagent) (Supplementary Table 1). The financial costs were derived from the laboratory initiation fee for collection and the cost of test analysis.

Outcomes

The primary outcome was the number of pathology collections per admission in DoM patients, with key secondary outcomes being CO_2e emissions and financial cost resulting from these collections. Additional outcomes were the number of collections and rate of collections (per day admitted under DoM) overall and by medical specialty, the proportion of collections on a Monday or Thursday (versus other days of the week), and in-hospital mortality. All outcomes were compared between the intervention and reference period.

Statistical analysis

Patient and admission characteristics were summarised overall and by study period. Categorical variables were summarised by number and percentage; continuous variables (all non-normally distributed) were summarised by median and interquartile limits (IQL). Between group differences were assessed using the Pearson chi-squared test or Kruskal-Wallis test, as appropriate.

The difference in pathology collections per admission per study period was modelled using negative binomial regression adjusted for age, sex, NWAU19, and type of admission (emergency, planned), with LOS included as an offset variable. Generalised linear regression adjusted for admission length, age, sex, NWAU19, and type of admission (emergency, planned) was used to model the differences in CO_2e and financial costs. To account for hospital admissions that spanned multiple periods, robust variance estimates adjusted for within-admission correlation were used in all models. Bootstrapped estimates of the standard error were obtained from 20 replications, clustered by admission. All models

included study period as a categorical variable (reference period, intermediate period, and intervention period). The risk of in-hospital mortality in each study period was compared using multivariable logistic regression, including the same covariables as the generalised linear models described above.

The estimated savings after adjustment for confounding variables for CO_2e and financial costs between the intervention and reference periods (i.e. associated with the intervention), was calculated by multiplying the number of admissions during the intervention period by the coefficient for the intervention period (with respect to the reference period) derived from the CO_2e and financial cost per admission models. The likelihood of a pathology collection occurring on Monday or Thursday (as opposed to other days of the week) in the intervention period was compared to the reference period using univariable logistic regression. To explore differences in testing days by specialty, a likelihood ratio test was used to compare the models with and without an interaction between study period and specialty.

The three periods (reference, intermediate, and intervention) were included in all analyses. However, for simplicity, results from the intermediate period are generally excluded from the main manuscript. They are presented in the supplementary appendix. All analyses were conducted using Stata 16.1 (StataCorp, TX).

RESULTS

A total of 7,603 admissions in 5,695 patients were included in the analysis, of which 134 spanned more than one study period, resulting in a total of 7,738 analysable episodes. The median patient age was 70 years (IQL 55-80), 46.3% were female and 1.1% identified as ATSI. The median length of admission was 4.0 days (IQL 2.2-7.6), 87.7% were unplanned, 9.2% included time in the ICU and the median NWAU19 was 1.21 (IQL 0.67-2.09). Patient and admission characteristics were similar during all periods, with the exception of more patients of ATSI identity in the intervention period, and higher median NWAU19 and longer time under DoM in the reference period (Table 1, Supplementary Table 2).

A total of 24,585 pathology collections were identified (15,685 in the reference and intervention period), with 75.8% of admissions being linked to at least one pathology collection (admissions without collections were typically short, being elective admissions for procedures or where pathology testing was ordered in the ED only and so not included in the present analysis). The number of admissions without a collection was higher in the intervention period, whilst the median number and rate of collections was lower (Table 2, Supplementary Table 3).

The total GHG emissions was 4,038 kg CO_2e. The median CO_2e was 337.9g per admission (IQL 97.3, 677.8), and 81.1g per day (IQL 14.3, 138.3). Median pathology fee per admission was $125.42 (IQL 32.74, 293.36), or $34.91 per day, totalling $1,144,656. The median CO_2e and fees per admission were lower in the intervention period compared to the reference period ($P<0.001$) (Table 2) and the intermediate period (Supplementary Table 3).

In multivariable analysis, the intervention period was a significant predictor of CO_2e, fees and pathology collections (Supplementary Table 4). CO_2e per admission were estimated to be 53 g (95% CI, 24 to 83g; P<0.001) lower during the intervention period than during the reference period. Similarly, fees per admission were $22 (95% CI, $9 to $34; P=0.001) lower, and the incidence rate ratio comparing number of collections per admission was 0.90 (95% CI, 0.86 to 0.95; P<0.001), consistent with a 10% reduction in the rate of pathology collections. Savings associated with the intervention period were estimated as 132 kg CO_2e (95% CI, 59 to 205 kg), equivalent to driving an average passenger vehicle between Melbourne and Adelaide (733km[11]; and a cost saving of $53,573 (95% CI, 22,076 to 85,096).

There were 217 in-hospital deaths during the 18-month period, including 65 in the reference period and 58 in the intervention period. In hospital mortality did not differ between the two study periods (OR for intervention period 1.09 (95% CI 0.75 to 1.59), although it was higher during the intermediate period, OR 1.61 (95% CI 1.15 to 2.25), which covered winter. (Supplementary Table 5).

The change in collection rates within specialities across the study periods was variable, with four of eight showing significant reductions between the intervention and reference periods and one showing a significant increase (Supplementary Table 6). Overall, there was evidence of effect modification by specialty on the relationship between collection rate and study period (P-interaction<0.001). There was evidence of a change in pathology collection pattern by day of the week, with the odds of a pathology collection occurring on a Monday or Thursday being higher in the intervention period compared to the reference period (odds

ratio 1.08, 95% CI 1.01 to 1.16; P=0.024). This association was not modified by specialty (P-interaction=0.58).

DISCUSSION

Principal findings

All Australian states and territories have net-zero 2050 targets, which will have to include healthcare.[12] Indeed, if reductions cannot be made, offsets will have to be purchased. The UK's National Health service has suggested that healthcare's path to net-zero will require multiple small interventions[13], such as from this study. The 10% decrease in the number of pathology collections in the intervention period resulted in a 132 kg decrease in greenhouse gas emissions, alongside a financial saving of $53,573, with no apparent increase in adverse health outcomes during the intervention period. Whilst not captured in this study, additional reductions in GHG emissions could potentially occur through the reduction of iatrogenic anaemia, or from avoiding the clinical cascade of post-hospital care that can result from unnecessary testing.[15,16]

The DoM contributes to 20% of hospital pathology activity, and if a similar 10% reduction were achieved over the whole hospital, annual savings would be approximately 1,300 kg CO_2e, and $500,000. Extrapolated nationally[14], this could lead to savings in the vicinity of 135,000 kg CO_2e and $56 million. We are unable, however, to give this potential saving as a percentage of healthcare's total footprint. The carbon footprint of Australian healthcare was calculated using the top-down methodology of input-output, which includes the indirect carbon impacts of all purchases made by the healthcare sector (e.g. legal or labour supply sectors), and additionally uses the average electricity grid (primarily coal) from 2014 when

the input-output tables were calculated. By comparison, our study used a consequential analysis to calculate the impact of pathology, which only included the things that change as a consequence of a test being performed, such as the difference in power when an analyser moves from standby to active, and similarly used the current electricity suppliers that respond to an increased demand, which is renewables and gas.

In terms of behaviour change, consistent with the intervention's testing policy there was a significant increase in the odds of a test being performed on a Monday or a Thursday, accompanied by a decrease in the number of tests performed overall. The pattern of change was not uniform between specialties, with overall testing decreasing for some specialities but not others, while the increase in Monday or Thursday testing was statistically the same between specialties. This is consistent with different specialties responding to the request in different ways. "Cultural" differences in testing behaviour may also vary widely between the same department at different hospitals, as demonstrated by a recent Australian study of ED departments.[17]

Whilst the degree of residual unnecessary testing during the intervention period is unknown, there may be potential to reduce this further, especially if environmental considerations are a policy driver. Studies have shown that providing the cost of tests to practitioners can reduce testing rates [18,19], and that outside of healthcare, carbon labelling can change consumer behaviour.[20] Junior doctors, who belong to an age cohort that strongly supports climate action were involved in this policy and medical associations now have clear goals to decarbonise healthcare.[21] Given these factors, providing information about the carbon costs of tests to doctors may be an additional motivation to reduce unnecessary testing. This could

be enhanced by an ongoing multi-faceted behaviour change program, using implementation science methodology, including educational initiatives, changing computer ordering systems, and promoting benchmarking [22]; and including both ED and ICU within the program, as both have been shown to have high rates of unnecessary testing.[17,23]

Comparison with other studies

Whilst other studies have shown comparable reductions of 11-12% due to interventions reducing unnecessary pathology testing [24,25], this study is the first to estimate the associated reduction in greenhouse gas emissions.

Strengths and limitations of the study

This study did have some limitations. It was performed at a single site in Sydney, although the results are comparable with similar interventions in other tertiary teaching hospitals [24,25]. The time period was short and so subject to fluctuations, even though a comparable seasonal reference period was used. We were unable to examine potential unintended harms in detail, although these are considered likely to have been minimal, given the opportunity for pathology tests to be ordered on any day if clinically indicated. Lastly, the study was not controlled, and therefore there are potentially other confounders which may have influenced the results.

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CONCLUSION

This study has demonstrated that institutional initiatives can effectively reduce GHG emissions and healthcare costs associated with pathology testing whilst not adversely affecting patient care. The intervention is both scalable and sustainable. Prospective interventional studies are required to determine if doctors may be influenced by environmental benefits to safely reduce unnecessary pathology testing, as efforts to develop and expand such programs would likely result in substantial environmental and financial benefits.

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ABSTRACT

Background: As healthcare is responsible for 7% of Australia's carbon emissions, it was recognised that a policy implemented at St George Hospital, Sydney to reduce non-urgent pathology testing to two days per week and on other days only if essential, would also result in a reduction in carbon emissions. The aim of the study was to measure the impact of this intervention on pathology collections and associated carbon emissions and pathology costs.

Methods: The difference in the number of pathology collections, carbon dioxide equivalents (CO_2e) for five common blood tests, and pathology cost per admission were compared between a 6-month reference period and 6-month intervention period. CO_2e were estimated from published pathology CO_2e impacts. Cost was derived from pathology billing records. Outcomes were modelled using multivariable negative binomial, generalised linear, and logistic regression.

Results: In total, 24,585 pathology collections in 5,695 patients were identified. In adjusted analysis, the rate of collections was lower during the intervention period (rate ratio 0.90, 95% CI, 0.86 to 0.95; P<0.001). This resulted in a reduction of 53 g CO_2e (95% CI, 24 to 83g; P<0.001) and $22 (95% CI, $9 to $34; P=0.001) in pathology fees per admission. The intervention was estimated to have saved 132kg CO_2e (95% CI, 59 to 205kg) and $53,573 (95% CI, 22,076 to 85,096).

Conclusions: Reduction in unnecessary hospital pathology collections was associated with both carbon emission and cost savings. Pathology stewardship warrants further study as a potentially scalable, cost-effective, and incentivising pathway to lowering healthcare associated greenhouse gas emissions.

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Table 1: Characteristics of Division of Medicine admissions and collections during study periods

	Reference period	Intervention period	P-value
Admissions	**2,590**	**2,486**	
Female – n (%)	1,204 (46.5)	1,114 (44.8)	0.30
Age (years) – median (Q1-Q3)	70 (56-80)	70 (54-80)	0.08
Aboriginal or Torres Strait Islander – n (%)	24 (0.9%)	37 (1.5%)	0.07
Admission type – n (%) Emergency Planned	 2,169 (83.7%) 421 (16.3%)	 2,131 (85.7%) 355 (14.3%)	0.051
NWAU19 – median (IQL)	1.31 (0.73-2.14)	1.21 (0.67-2.09)	0.007
ICU during admission – n (%)	255 (9.9%)	214 (8.6%)	0.13
LOS (days) – median (IQL)	4.2 (2.2-8.1)	4.0 (2.2-7.8)	0.04
Div. Medicine time per admission (within each period; days)	4.0 (2.1-7.1)	3.7 (2.1-7.0)	0.01

Table 2: Pathology collection characteristics, and associated CO_2e emissions and fees per study period.

	Reference period	Intervention period	P-value
Collections (n) in admissions (N)	8,752 / 2,590	6,933 / 2,486	
Admissions with no collections – n (%)	585 (22.6%)	629 (26.1%)	0.02
Collections per admission – median (IQL)	2 (1-4)	2 (0-3)	<0.001
Collections per patient day	0.53 (0.14-0.85)	0.45 (0.00-0.82)	<0.001
Total CO_2e (kg)	1,443	1,126	
CO_2e per admission (kg) – median (IQL)	0.34 (116, 685)	0.22.4 (0, 550)	<0.001
Total pathology cost (AUD)	$641,316	$503,341	
Pathology cost per admission (AUD) – median (IQL)	$137 ($50, $304)	$106 ($0, $253)	<0.001