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Platinum Priority – Prostatic Disease

Environmental Impact of Prostate Magnetic Resonance Imaging and Transrectal Ultrasound Guided Prostate Biopsy

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Abstract

Background: Reducing low-value clinical care is an important strategy to mitigate environmental pollution caused by health care.
Objective: To estimate the environmental impacts associated with prostate magnetic resonance imaging (MRI) and prostate biopsy.
Design, setting, and participants: We performed a cradle-to-grave life cycle assessment of prostate biopsy. Data included materials and energy inventory, patient and staff travel contributed by prostate MRI, transrectal ultrasound guided prostate biopsy, and pathology analysis. We compared environmental emissions across five clinical scenarios: multiparametric MRI (mpMRI) of the prostate with targeted and systematic biopsies (baseline), mpMRI with targeted biopsy cores only, systematic biopsy without MRI, mpMRI with systematic biopsy, and biparametric MRI (bpMRI) with targeted and systematic biopsies. We estimated the environmental impacts associated with reducing the overall number and varying the approach of a prostate biopsy by using MRI as a triage strategy or by omitting MRI. The study involved academic medical centers in the USA, outpatient urology clinics, health care facilities, medical staff, and patients.
Outcome measurements and statistical analysis: Greenhouse gas emissions (CO_2 equivalents, CO_2e), and equivalents of coal and gasoline burned were measured.
Results and limitations: In the USA, a single transrectal prostate biopsy procedure including prostate MRI, and targeted and systematic biopsies emits an estimated 80.7 kg CO_2e. An approach of MRI targeted cores alone without a systematic biopsy generated 76.2 kg CO_2e, a systematic 12-core biopsy without mpMRI generated 36.2 kg CO_2e, and bpMRI with targeted and systematic biopsies generated 70.5 kg CO_2e; mpMRI alone contributed 42.7 kg CO_2e (54.3% of baseline scenario). Energy was the

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largest contributor, with an estimated 38.1 kg CO_2e, followed by staff travel (20.7 kg CO_2e) and supply production (11.4 kg CO_2e). Performing 100 000 fewer unnecessary biopsies would avoid 8.1 million kg CO_2e, the equivalent of 4.1 million liters of gasoline consumed. Per 100 000 patients, the use of prostate MRI to triage prostate biopsy and guide targeted biopsy cores would save the equivalent of 1.4 million kg of CO_2 emissions, the equivalent of 700 000 l of gasoline consumed. This analysis was limited to prostate MRI and biopsy, and does not account for downstream clinical management.
Conclusions: A prostate biopsy contributes a calculable environmental footprint. Modifying or reducing the number of biopsies performed through existing evidence-based approaches would decrease health care pollution from the procedure.
Patient summary: We estimated that prostate magnetic resonance imaging (MRI) with a prostate biopsy procedure emits the equivalent of 80.7 kg of carbon dioxide. Performing fewer unnecessary prostate biopsies or using prostate MRI as a tool to decide which patients should have a prostate biopsy would reduce procedural greenhouse gas emissions and health care pollution.

1. Introduction

The health care industry is a major source of carbon emissions and pollution worldwide [1]. If emissions are compared with those of individual nations, health care would be the fifth largest producer of greenhouse gases (GHGs) in the world. Inclusive of resources, energy, and transportation, health care is responsible for approximately 5% of total global and 9% [2,3] of US GHGs [4]. Globally, one-quarter of the total volume of health care services are characterized as low value or inappropriate, resulting in harms or costs of delivery that outweigh their benefits [5]. Overuse of medical care also generates economic and resource demands that challenge the long-term viability of health systems, and can directly harm patients [6,7]. Efforts are urgently needed to mitigate health care pollution and excessive utilization of resources to improve sustainability and care value [8,9].

Early-detection practices for prostate cancer such as a prostate biopsy are overused; however, their environmental impacts have not been defined [10]. Modifying or reducing prostate biopsies is a promising strategy to improve the sustainability of prostate cancer evaluation based on the frequency of the procedure, with an estimated 1 million cases performed annually in the USA alone [11]. The potential benefit of deimplementing a low-value prostate biopsy is substantial. More than half of those who undergo a prostate biopsy for the evaluation of an elevated prostate-specific antigen (PSA) level are found to not have prostate cancer [10]. Furthermore, screening is common among patients who are unlikely to derive benefit due to limited life expectancy [12–14]. Efforts to refine selection for prostate biopsies are further informed by direct patient harms associated with the procedure, health care expenditure, and downstream consequences of overdetection such as overtreatment [11,12]. Within the past decade, the diagnostic algorithm for prostate cancer has been refined by the incorporation of magnetic resonance imaging (MRI; prostate MRI), which improves detection of significant prostate cancer by approximately 30% [15,16]. Prostate MRI can reliably triage patients prior to a biopsy and has been used to guide a directed prostate biopsy without the use of systematic sampling [17]. As a result, prebiopsy MRI is widely recommended by clinical practice guidelines [18,19]. However, the optimal sampling strategy including the necessity of prior MRI, the preferred imaging sequences (eg, multiparametric vs biparametric) to include, and the number of biopsy cores to obtain are unsettled [20,21].

An improved understanding of the environmental impact of common diagnostic procedures, such as prostate biopsy, is required to inform a more holistic approach to their clinical use. Effectiveness studies that have examined the tradeoffs of prostate cancer screening and surveillance have conventionally focused on considerations of cost and quality of life, but have not considered environmental impacts [22]. Therefore, we aimed to comprehensively examine the life cycle GHG emissions of a prostate biopsy, including the incorporation of an MRI-enhanced approach as a means to triage or modify the sampling strategy and add additional motivation for quality improvement. Further, we estimate emission reductions that could arise from implementing evidence-based practices aimed at biopsy mitigation more broadly.

2. Patients and methods

2.1. Study design

We performed a life cycle assessment (LCA) to estimate GHG emissions associated with a single transrectal ultrasound (TRUS) guided prostate biopsy. The prostate biopsy pathway was divided into three process steps, as shown in Figure 1: (1) prebiopsy prostate MRI, (2) a TRUS biopsy in an outpatient clinical setting, and (3) pathologic processing of biopsy specimens in a clinical laboratory. We assumed that staffing included a physician performing the procedure, a nurse, and a medical technician. The duration of each process step, energy and supply inputs, and waste outputs were based on prostate biopsy procedures within our institution, a tertiary care center located in the Northeastern USA. For process step 1, we used a base case of multiparametric MRI (mpMRI) with an average patient visit duration of 90 min, including 45 min in preparation, 25 min of active MRI scan time, and 20 min of standby MRI time. For biparametric prostate MRI, we assumed shorter durations of active and standby time as well as the omission of MRI contrast and associated materials. For process step 2, we assumed a 90-min clinic visit wherein a 30-min ultrasound-based procedure was conducted by one

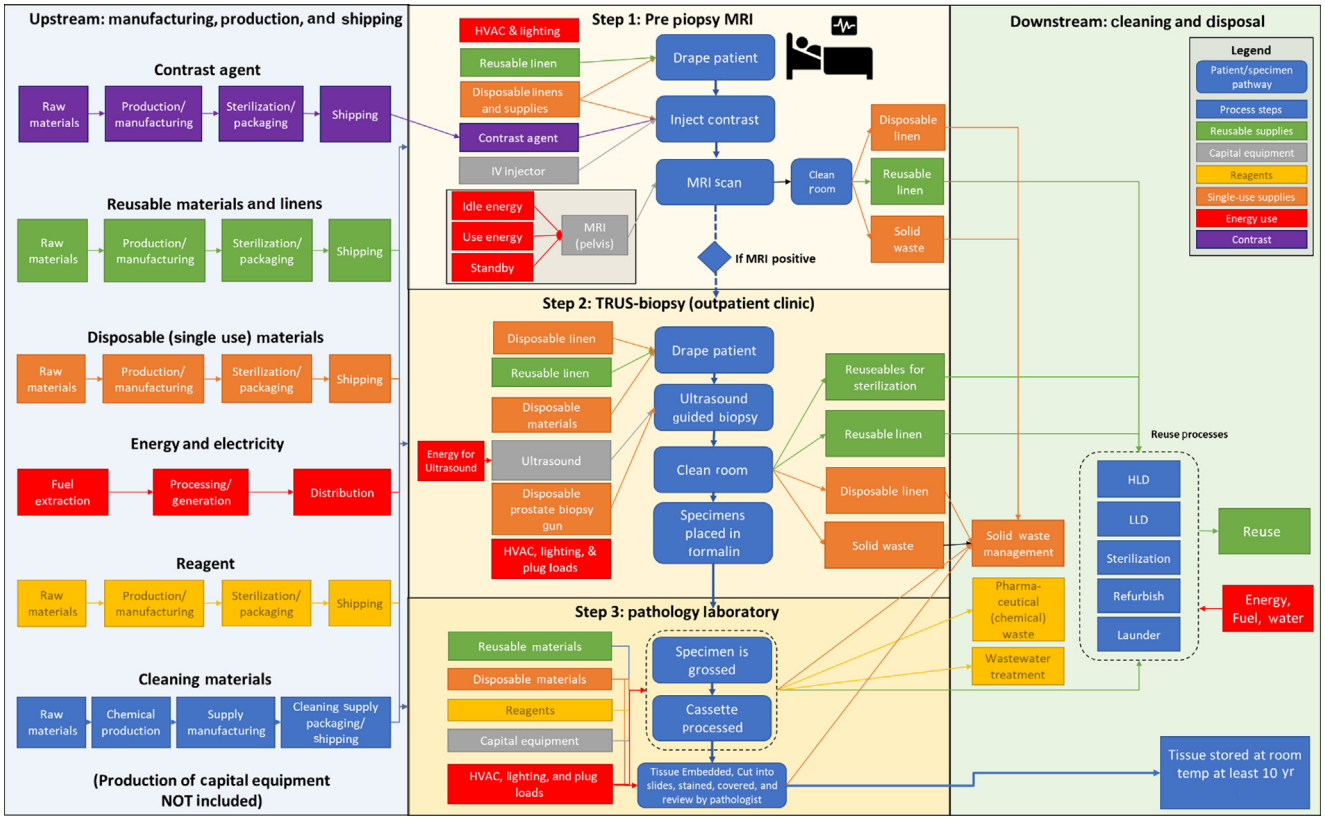

Fig. 1 – Flow chart depicting the clinical process of prostate biopsy for the evaluation of known or suspected prostate cancer. HLD = high-level disinfectant; HVAC = heating, ventilation, and air conditioning; IV = intravenous; LLD = low-level disinfectant; MRI = magnetic resonance imaging; TRUS = transrectal ultrasound.

clinician, one nurse, and one technician. For the biopsy procedure, we explored biopsy sampling strategies including combined systematic and MRI-ultrasound fusion biopsies, MRI-ultrasound fusion alone, and systematic biopsy alone (Supplementary Table 1). Process step 3 involved five laboratory staff, including a pathologist, and is conducted in a series of substeps previously described by our group [23].

The cradle-to-grave environmental LCA method is an internationally standardized (ISO 14040) comprehensive assessment of the stages of a process, incorporating the raw material extraction, manufacturing ("cradle"), packaging, distribution, energy use, transportation, and final disposal ("grave"), which has extensively been applied in health care, including medical devices used in urologic surgery [24–27]. The unit of analysis for this study was a single prostate biopsy procedure and anatomic pathology analysis with prostate MRI obtained beforehand. The primary study endpoint was GHG emissions in units of kg CO_2 equivalents (CO_2e), as calculated using LCA interface software SimaPro version 8.5.2.3 (Pre Consultants, Amersfoort, The Netherlands) [28], the life cycle inventory database Ecoinvent 3.3 [29], and the Environmental Protection Agency's life cycle impact assessment method TRACI 2.1 version 1.04 (Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts). For laboratory chemicals and reagents not found in the Ecoinvent database, we used the Chemical Life Cycle Collaborative (CLiCC; University of California, Santa Barbara, CA, USA) Life Cycle Impact Assessment Estimate tool [30,31]. Conversions of GHG emissions from kg CO_2e into tangible units of measurement (such as kg of coal) was performed using the Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator [32]. The individual GHG emissions for all supplies and energy for all three process steps are shown in Supplementary Table 2. We did not incorporate resources associated with initial PSA testing, or downstream consequences such as procedural complications, treatment, or subsequent monitoring after a prostate biopsy. In addition, we regarded capital equipment (other than use-phase energy), including upstream and downstream emissions of MRI, ultrasound, image registration, and laboratory process steps as out of scope. Additional information about data collection procedures is presented in the Supplementary material.

2.2. *Modeling scenarios and sensitivity analyses*

We generated estimates for five strategies used in contemporary care. The baseline scenario was a MRI-fusion biopsy including separate targeted (two to seven, assuming the possibility of more than one lesion) and systematic biopsy (12) cores, for a possible 14–19 samples. Additional scenarios included mpMRI with two to five targeted biopsy samples only (scenario 1), systematic 12-core biopsy without prostate MRI (scenario 2), mpMRI with 12-core systematic biopsy only (scenario 3), and biparametric MRI with targeted and systematic biopsy, 14–19 samples (scenario 4). We estimated population-level reductions in the use of a prostate biopsy that may be contributed by the use of prebiopsy MRI as a triage tool. The primary analysis was conducted using a 28% incidence of negative MRI reported in the PRECISION trial [17]. In these scenarios, a biopsy was omitted after negative MRI and only targeted biopsies were obtained. We conducted sensitivity analyses at lower (5%) and upper (50%) boundaries of negative MRI findings based on varying reports within the literature [15,33–38]. We assumed equivalent cancer detection using biparametric MRI and mpMRI [21,39].

We performed sensitivity analyses to assess variation in the results when changes are made to model assumptions. These included variation in the number of single-use disposable supplies consumed, longer or shorter lifespans (0.5 or 1.5 × assumed average value) for reusable sup-

plies, and variation in waste disposal through a biohazardous treatment pathway. We also assessed the effect of different commuting patterns, including longer average commutes or travel conducted entirely by car or entirely by bicycle, as well as by national energy grids. Finally, we assessed variation due to changes in energy use from more or less intense power consumption of the equipment and heating, ventilation, and air conditioning (HVAC) systems.

3. Results

3.1. Prostate MRI with targeted and systematic biopsies

The carbon footprint of a TRUS prostate biopsy including prebiopsy mpMRI, and targeted and systematic biopsies, and pathology processing on a per-patient basis was 80.7 kg CO_2e (Fig. 2), the equivalent of burning 34.4 l of gasoline or 40.5 kg of coal. Overall, energy was the largest contributor to GHG emissions, with an estimated 57.8% of the total impact (46.6 kg CO_2e). Of the energy-related emissions, 8.5 kg CO_2e were derived from off-hour energy use by MRI. Staff travel was the next largest emission category, contributing 20.7 kg CO_2e or 25.6% of the total. Supply production emitted 11.4 kg CO_2e (14.1%), followed by waste treatment at 1.4 kg CO_2e (1.7%) and reusable material reprocessing at 0.6 kg CO_2e (0.8%). Solid waste generation was estimated at 1.6 kg trash per biopsy, based on the weight of consumable supply components including packaging; mpMRI had the largest contribution to carbon emissions with an estimated 42.7 kg CO_2e (52.9% of total), primarily through energy associated with the procedure (21.1 kg CO_2e). HVAC during the MRI procedure was the largest consumer of energy (an estimated 24 kWh per case on average), followed by plug loads, particularly for the MRI when in standby (4.2 kWh per case) or idle (8.5 kWh per case) modes. Pathology processing was the smallest contributor with 4.8 kg CO_2e. The use of biparametric MRI with targeted and systematic biopsies would result in 70.5 kgCO_2e, a 10.7% reduction relative to mpMRI.

3.2. Variation in emissions by biopsy strategy

A strategy of a 12-core systematic biopsy without prostate MRI generated the fewest emissions (36.2 kg CO_2e), the majority of which (33.0 kg CO_2e, 91.3%) were contributed by the biopsy procedure itself and 3.2 kg CO_2e (8.7%) from pathology analysis (Fig. 3). Incorporation of prostate MRI increased estimated CO_2e, primarily due to the MRI step, and smaller contributions from additional biopsy core acquisition and processing (Table 1). MRI with systematic biopsy sampling resulted in 78.9 kgCO_2e, while an approach of obtaining two to five MRI-fusion cores alone without a systematic biopsy generated 76.2 kgCO_2e. Emissions associated with pathology varied between 3.1% and 8.1% of total emissions based on the biopsy approach, primarily through supply consumption [23].

3.3. Impact of MRI as a triage strategy

Based on the GHG emissions associated with a single MRI-ultrasound fusion prostate biopsy with targeted and systematic sampling, performing 100 000 fewer diagnostic evaluations would avoid 8070 metric tons of CO_2e, the equivalent of 4.1 million liters of gasoline consumed or 4.0 million kg of coal burned (Table 2). Per 100 000 patients an approach of a systematic biopsy only without MRI would reduce emissions by 4.5 million kg CO_2e, the equivalent of 2.3 million liters of gasoline consumed. The use of MRI as a triage strategy to select candidates for a biopsy and limit sampling to MRI-evident areas would result in reduced CO_2e. Operationalizing the paradigm established in the PRECISION study, under the assumption that 28% of biopsies could be avoided due to nonsuspicious prostate MRI and by performing a targeted-only biopsy, would reduce 1.4 million kg of CO_2e, the equivalent of 7.0×10^5 l of gasoline, or 8.0×10^5 kg of coal burned. Emission reductions were sensitive to variation in the estimates of MRI findings and biopsy avoidance.

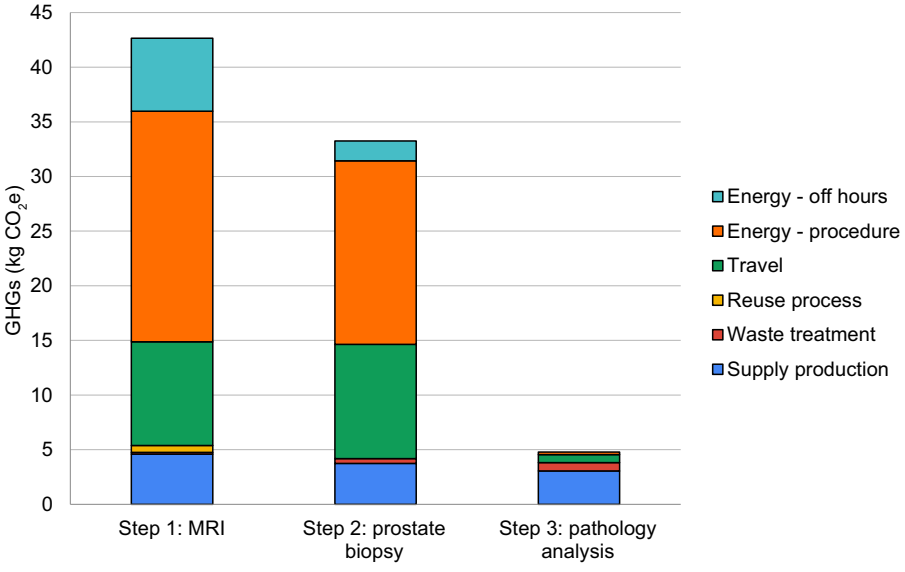

Fig. 2 – Greenhouse gas emissions from prostate biopsy by process steps reflecting prebiopsy multiparametric prostate MRI, prostate biopsy procedure, and pathology analysis. CO_2e = carbon dioxide equivalents; GHG = greenhouse gas; MRI = magnetic resonance imaging.

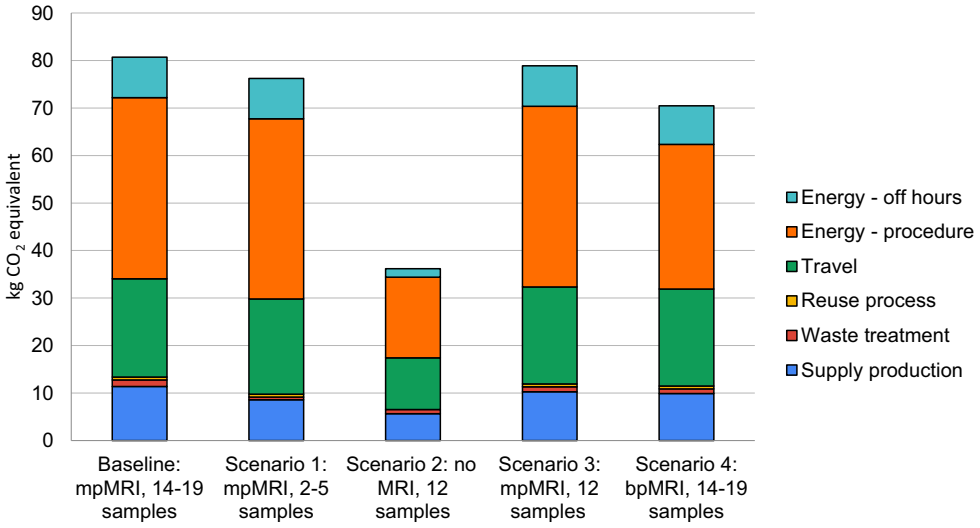

Fig. 3 – Comparison of greenhouse gas emissions from prostate biopsy scenarios. The baseline scenario involves multiparametric prostate MRI (mpMRI), and targeted and systematic biopsies with pathology analysis. Modifications to the baseline scenario include mpMRI with targeted biopsy cores only (scenario 1), systematic 12-core biopsy without prostate MRI (scenario 2), mpMRI with systematic 12-core biopsy alone (scenario 3), and biparametric prostate MRI (bpMRI) with targeted and systematic biopsy (scenario 4). MRI = magnetic resonance imaging.

Table 1 – Carbon emissions (kg CO_2e) by prostate biopsy sampling approach

	Supply production	Waste treatment	Reuse process	Travel	Energy—procedure	Energy —off hours	CO_2 total	% Difference from baseline
Baseline scenario: mpMRI, 14–19 samples								
Step 1: MRI	4.6	0.17	0.62	9.50	21.1	6.7	42.7	–
Step 2: prostate biopsy	3.7	0.45	0.00	10.5	16.8	1.81	*33.3*	–
Step 3: pathology analysis	3.05	0.76	0.00	0.73	0.24	0.00	*4.8*	–
Combined	**11.4**	**1.37**	**0.62**	**20.7**	**38.1**	**8.5**	***80.7***	–
Scenario 1: mpMRI, 2–5 samples								
Step 1: MRI	4.6	0.17	0.62	9.50	21.1	6.7	42.7	0
Step 2: prostate biopsy	3.40	0.29	0.00	10.5	16.8	1.81	*32.8*	–1.5
Step 3: pathology analysis	0.61	0.10	0.00	0.08	0.03	0.00	*0.81*	–83.1
Combined	**8.6**	**0.55**	**0.62**	**20.0**	**37.9**	**8.49**	***76.2***	–5.5
Scenario 2: no MRI, 12 samples only								
Step 2: prostate biopsy	3.60	0.38	0.00	10.5	16.8	1.81	*33.0*	0.6
Step 3: pathology analysis	2.05	0.49	0.00	0.46	0.15	0.00	*3.2*	34.2
Combined	**5.65**	**0.87**	**0.00**	**10.9**	**17.0**	**1.81**	***36.2***	–54.1
Scenario 3: mpMRI, 12 samples								
Step 1: MRI	4.6	0.17	0.62	9.50	21.1	6.7	*42.7*	0
Step 2: prostate biopsy	3.6	0.38	0.00	10.5	16.8	1.8	*33.0*	0.6
Step 3: pathology analysis	2.05	0.49	0.00	0.46	0.15	0.00	*3.15*	–34.0
Combined	**10.3**	**1.04**	**0.62**	**20.4**	**38.1**	**8.5**	***78.9***	–2.26
Scenario 4: bpMRI, 2–5 samples								
Step 1: MRI	4.3	0.09	0.62	9.5	13.5	6.3	*34.3*	–20.0
Step 2: prostate biopsy	3.4	0.29	0.00	10.5	16.8	1.8	*32.8*	–19.1
Step 3: pathology analysis	0.61	0.10	0.00	0.08	0.03	0.00	*0.81*	–31.9
Combined	**8.3**	**0.48**	**0.62**	**20.0**	**30.3**	**8.1**	***67.8***	–20.4
Scenario 5: bpMRI, 14–19 samples								
Step 1: MRI	4.3	0.09	0.62	9.5	13.5	6.3	*34.3*	–20.0
Step 2: prostate biopsy	3.6	0.38	0.00	10.5	16.8	1.8	*33.0*	0.0
Step 3: pathology analysis	3.1	0.76	0	0.7	0.2	0.00	*4.8*	0.00
Combined	**9.90**	**0.97**	**0.62**	**20.4**	**30.5**	**8.1**	***70.5***	–12.6

bpMRI = biparametric magnetic resonance imaging; CO2e = carbon dioxide equivalents; mpMRI = multiparametric magnetic resonance imaging; MRI = magnetic resonance imaging.

3.4. *Sensitivity analyses*

Owing to the dominant role of energy, we estimate that emissions will differ by energy grid mix. In Sweden, a country with a greater share of low-carbon electricity, we estimate that total emissions for MRI and prostate biopsy would be 38.2 kg CO2e, –53% of the US baseline estimate. Conversely, in countries with more carbon-intensive energy sources such as Australia, the total emissions would be 124.5 kg CO_2, +54% relative to the US estimate (Fig. 4). Sensitivity analyses also revealed that reducing or increasing the number of supplies typically used in the procedure changes total GHG emissions by –0.9 kg CO_2e (–1.1% of total) or +6.3 kg CO_2e (+7.3% of total; Fig. 5). Incinerating all solid wastes (instead of sorting for landfilling or recycling) would slightly increase CO_2e (+0.3%). Travel-related

Table 2 – Estimated environmental emissions associated with prostate biopsy and MRI triage strategies among 100 000 patients undergoing evaluation for elevated PSA[a]

	kg CO_2e per 100 000 patients	Gasoline consumed (l)	Equivalent kg of coal consumed	Barrels of oil consumed
Baseline assumption: all receive mpMRI, targeted and systematic biopsy	8.1×10^6	4.1×10^6	4.1×10^6	1.9×10^4
Strategy 1: no prostate mpMRI, all patients undergo systematic biopsy	3.6×10^6	1.8×10^6	1.8×10^6	8.4×10^3
Strategy 1 savings from baseline	4.5×10^6	2.3×10^6	2.3×10^6	1.0×10^4
Strategy 2: universal mpMRI, 28% negative MRI and biopsy avoided (targeted biopsy only)	6.7×10^6	3.4×10^6	3.3×10^6	1.5×10^4
Strategy 2 savings from baseline	1.4×10^6	7.0×10^5	8.0×10^5	4.0×10^3
Modification 1: 5% negative mpMRI and biopsy avoided (targeted biopsy only)	7.5×10^6	3.8×10^6	3.7×10^6	1.7×10^3
Strategy 2 savings from baseline	6.1×10^5	3.0×10^5	4.0×10^5	2.0×10^3
Modification 2: 50% negative mpMRI and biopsy avoided (targeted biopsy only)	5.9×10^6	3.0×10^6	3.0×10^6	1.4×10^3
Scenario 2 savings from baseline	2.1×10^6	1.1×10^6	1.1×10^6	5.0×10^3
Strategy 3: bpMRI, 28% negative MRI and biopsy avoided (targeted biopsy only)	5.8×10^6	3.0×10^6	3.0×10^6	1.4×10^4
Strategy 3 savings from baseline	2.3×10^5	1.1×10^5	1.1×10^6	5.0×10^3
Modification 1: 5% negative bpMRI and biopsy avoided (targeted biopsy only)	6.6×10^6	3.4×10^6	3.3×10^6	1.6×10^4
Strategy 3 savings from baseline	1.5×10^6	7.0×10^5	8.0×10^5	3×10^3
Modification 2: 50% negative bpMRI and biopsy avoided (targeted biopsy only)	3.6×10^6	1.8×10^6	1.8×10^6	8.5×10^3
Strategy 3 savings from baseline	4.5×10^6	2.3×10^6	2.3×10^6	1.1×10^4

bpMRI = biparametric magnetic resonance imaging; CO_2e = carbon dioxide equivalent; mpMRI = multiparametric magnetic resonance imaging; MRI = magnetic resonance imaging; PSA = prostate-specific antigen.
[a] Source: United States Environmental Protection Agency Greenhouse Gas Equivalencies Calculator based on carbon dioxide emissions.

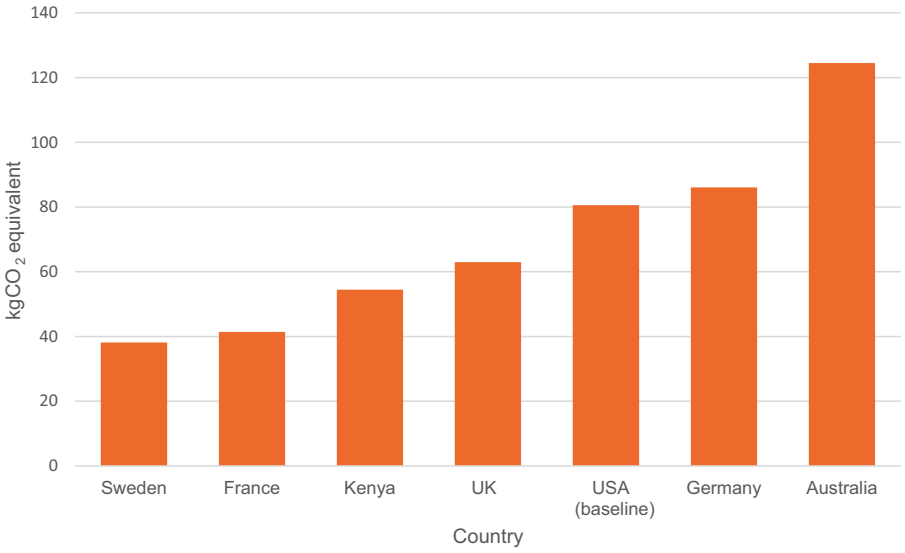

Fig. 4 – Sensitivity analysis showing variation in overall carbon emissions associated with prostate MRI and prostate biopsy contributed by differences between national energy grids. MRI = magnetic resonance imaging.

emissions had the widest variation, where doubling staff and patient commuting distances would lead to an additional 26.8 kg CO_2e (+34.0%) by a single-occupancy vehicle, while shifting all commuting to bicycle with the baseline assumption of a 25-km round trip would lead to a reduction in emissions by 18.6 kg CO_2e (–23.6%; Supplementary Fig. 1). Energy consumption variation in equipment, such as more efficient or less efficient equipment, would lead to shifts in emissions by –5.8 to +11.3 kg CO_2e (–7.4% to +14.2%).

4. Discussion

With growing awareness about the urgency of climate action, this work provides a model for conducting LCAs to promote greater environmental stewardship within urologic care [40]. We performed a comprehensive LCA of an office-based TRUS guided prostate biopsy with process steps reflecting a growing trend toward the use of prebiopsy MRI, prostate biopsy itself, and pathology processing. We found that prostate MRI and office-based prostate biopsy, as performed in an academic US medical center, resulted in a significant environmental footprint, similar to a round-trip flight from London to Paris. By extrapolating GHG emissions across varying evidence-based biopsy strategies, omitting prostate MRI and performing a systematic biopsy only, or widely incorporating MRI as a triage strategy, would likely generate significant procedural emission reductions on a global scale. These findings can be used to strengthen support for environmental harm reduction as a component of routine clinical care. This study is the first,

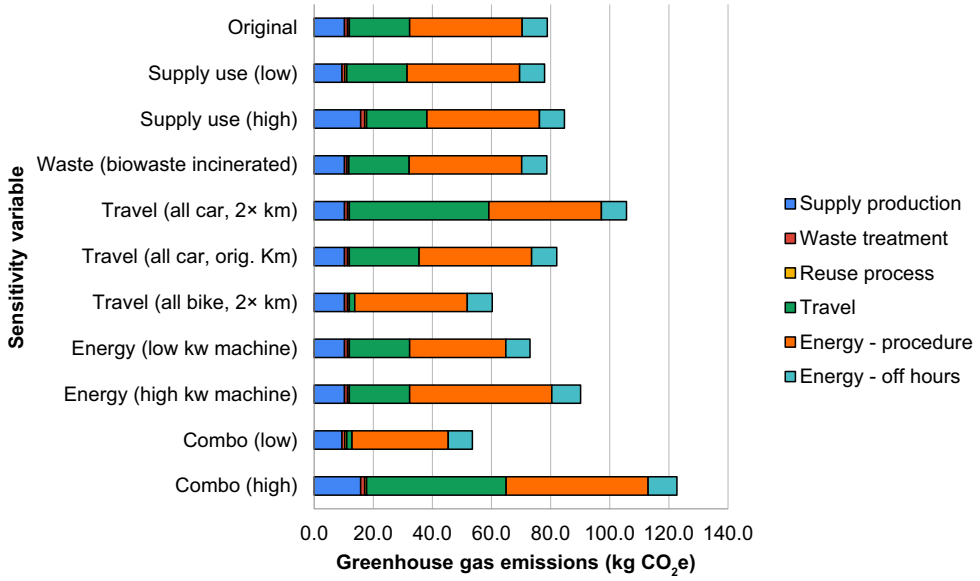

Fig. 5 – Sensitivity analyses demonstrating factors contributing to variation in total greenhouse gas emissions for a three-step prostate biopsy pathway including prostate MRI, office transrectal ultrasound guided prostate biopsy procedure, and pathology processing. MRI = magnetic resonance imaging.

to our knowledge, to generate life cycle GHG emission estimates of a prostate biopsy. This work can also provide previously undefined cost inputs that can be applied in future effectiveness research.

Prostate MRI was the largest contributor of carbon emissions, primarily through direct energy use associated with active imaging. With guideline support for routine use of prostate MRI as a tool to increase the detection of high-grade cancer, these findings add depth to the environmental impacts that accompany widespread adoption [41]. Risk-adapted strategies, such as preferentially offering MRI to patients most likely to benefit (eg, in the setting of a prior negative systematic biopsy) and foregoing initial MRI in the setting of a high pretest probability of significant prostate cancer, could reduce cost, patient wait times while also increasing environmental sustainability. To more comprehensively anticipate the effects of modifying the diagnostic algorithm, additional environmental analyses are needed to incorporate the downstream clinical impacts that could differ among strategies. Our findings of fewer emissions with the use of prebiopsy MRI as a triage strategy highlight the potential for both mitigation of unnecessary biopsies and associated environmental benefit. Although MRI-based triage approaches have been integrated successfully in several countries, this practice has not been adopted widely in the USA and other countries with lower MRI availability [42–44]. Given the reliably high negative predictive value of prostate MRI, these findings can strengthen the support for prostate MRI as a tool for appropriate biopsy selection.

This study also reveals opportunities for improvement within the biopsy life cycle such as minimizing procedural waste. Other potentially modifiable contributors include emissions associated with staff and patient travel that can be addressed through increasing access to affordable clean-energy–fueled public transportation, increasing clean-energy–sourced electric vehicle charging stations, and bicycle-sharing programs (with added cobenefits of healthy lifestyle and fitness promotion), as components of broader reforms aimed at offsetting the environmental impact of health care [45]. When MRI is selected, these findings also suggest an opportunity to maximize efficiency of scans through scheduling to ensure maximum utilization during off-hours and other energy-saving measures [46]. In addition, improving the carbon intensity of the energy mix by increasing renewable/clean sources would improve results overall, although longer-term investments are required.

The dominant role of energy in the footprint of the emissions highlights the need to urgently decarbonize the energy sector. Energy is embedded within the supply chain, manufacturing, transportation, and waste treatment. Energy also directly supports health care facility operations including powering capital equipment such as MRI machines, HVAC systems, and sterilizing equipment. In this study, we assumed standard energy mix in the Northeastern USA, with sources derived predominately from fossil fuel. In areas with more or less clean energy sources, we expect that results will vary [47], supporting efforts to encourage health care organizations to switch to and lobby for cleaner energy sources to improve environmental performance and improve the health of the communities they serve. The results of this study can also elevate the environmental benefits of evidence-based initiatives to improve the quality of decision-making about PSA testing, such as enhanced decision support at the point of care. Based on a conservative estimate from our study, widespread use of other prebiopsy risk assessment tools could help avoid thousands of tons of climate changing emissions annually through avoiding unnecessary procedures [48–50].

There are important limitations to this analysis. The LCA methodology is sensitive to numerous assumptions regarding energy estimates, transit pathways, and resources that

were directly observed in a single institution. Although we accounted for variations in these assumptions using sensitivity analyses, differences in MRI, biopsy, and pathology analysis approaches between institutions may exist. An additional consideration is that the scope of an LCA was limited to the diagnostic procedure itself and did not incorporate the environmental emissions from prior workup, procedural complications, and prostate cancer detection and its treatment, which presumably outweigh those of a prostate biopsy. As this study focused on a TRUS guided approach, modifications to the procedure such as transperineal approach, which is now preferred in the European association of Urology guidelines, or the integration of hospital-based procedures (as opposed to clinic-based procedures) and anesthesia care are important areas for further investigation [51].

5. Conclusions

Prostate MRI and prostate biopsy procedures for the diagnosis and monitoring of prostate cancer contribute a substantial environmental footprint. We estimate that a single prostate biopsy, including prior prostate MRI with targeted and systematic biopsies, and pathology analysis generates 80.7 kg CO_2e emissions. An approach of a systematic biopsy only (without MRI) would result in a reduction of 4.5 metric tons of CO_2e emissions per 100 000 biopsies, the equivalent of 1.5 million liters of gasoline consumed. The use of mpMRI as a triage strategy to select candidates for a biopsy and limit sampling to MRI-evident areas would result in a reduction of 1.4 million kg CO_2e emissions per 100 000 patients, the equivalent of 700 000 l of gasoline. Our findings indicate opportunities to reduce health care pollution by increasing the use of evidence-based approaches for prostate cancer screening and biopsy selection.

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Study concept and design: Leapman, Sherman, Thiel.
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Supplementary data

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