Climate, Health & Sustainable Care

Inaugural Symposium

UNIVERSITY OF TORONTO

COLLABORATIVE CENTRE FOR
Climate, Health +
Sustainable Care

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Research for Climate, Health & Sustainable Care

Jimin Lee, Jacques du Plessis, Jeffrey D'Souza

Moderator: Mahmood Bhutta

Evaluating the Environmental Effects of Simulation-Free Radiation Therapy for Palliative Treatments

Jimin Lee, Joanna Javor, C Jillian Tsai, Bernard Cummings, Aruz Mesci, Vickie Kong, Barbara-Ann Millar, Laura Dawson, Rebecca Wong, Katherine Del poso-Lee, Amir Safavi, Daphne Jo Valmonte, Sara Mheid, Tony Tadic, Edward Taylor, Philip Wong

TEMERTY FACULTY OF MEDICINE
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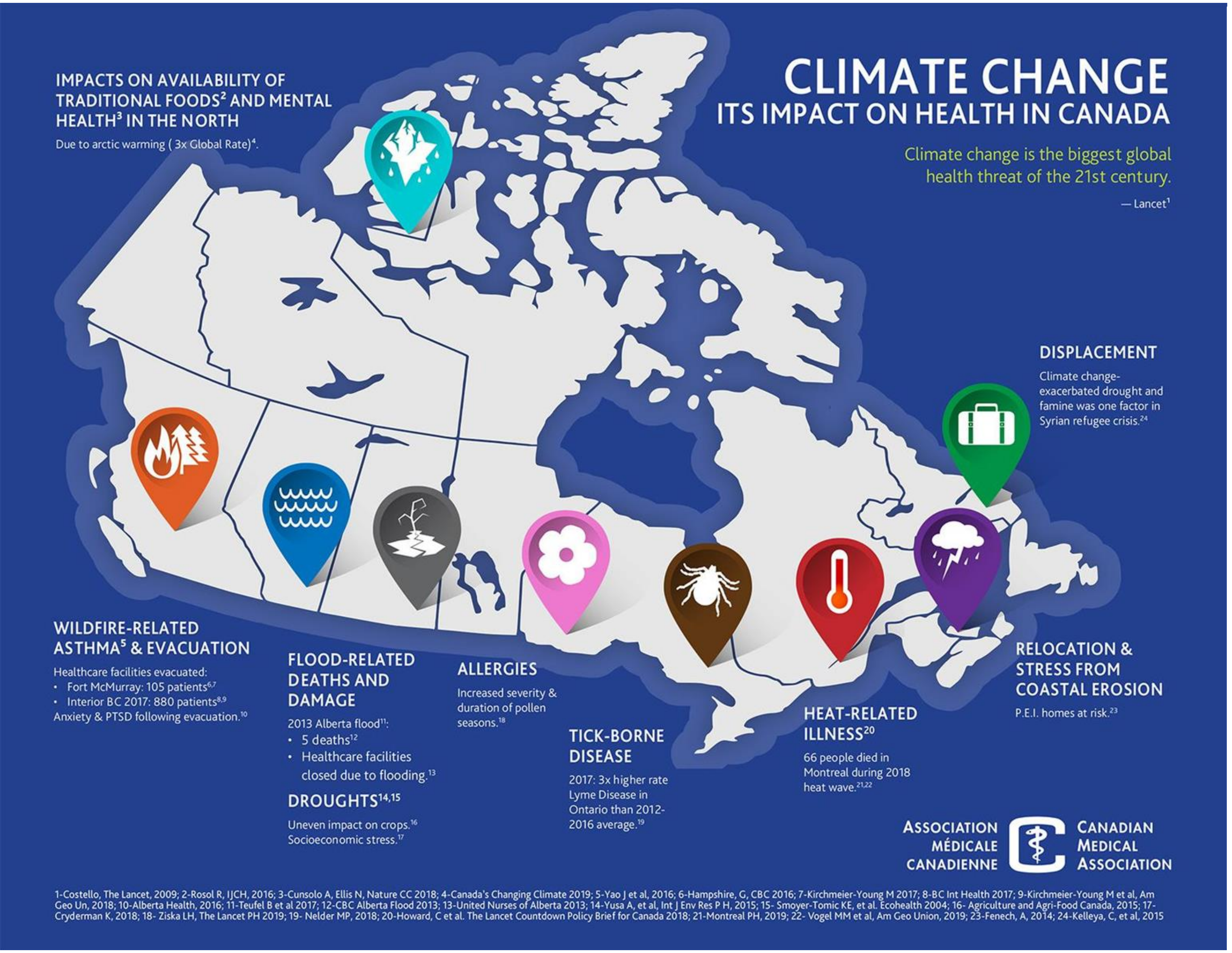
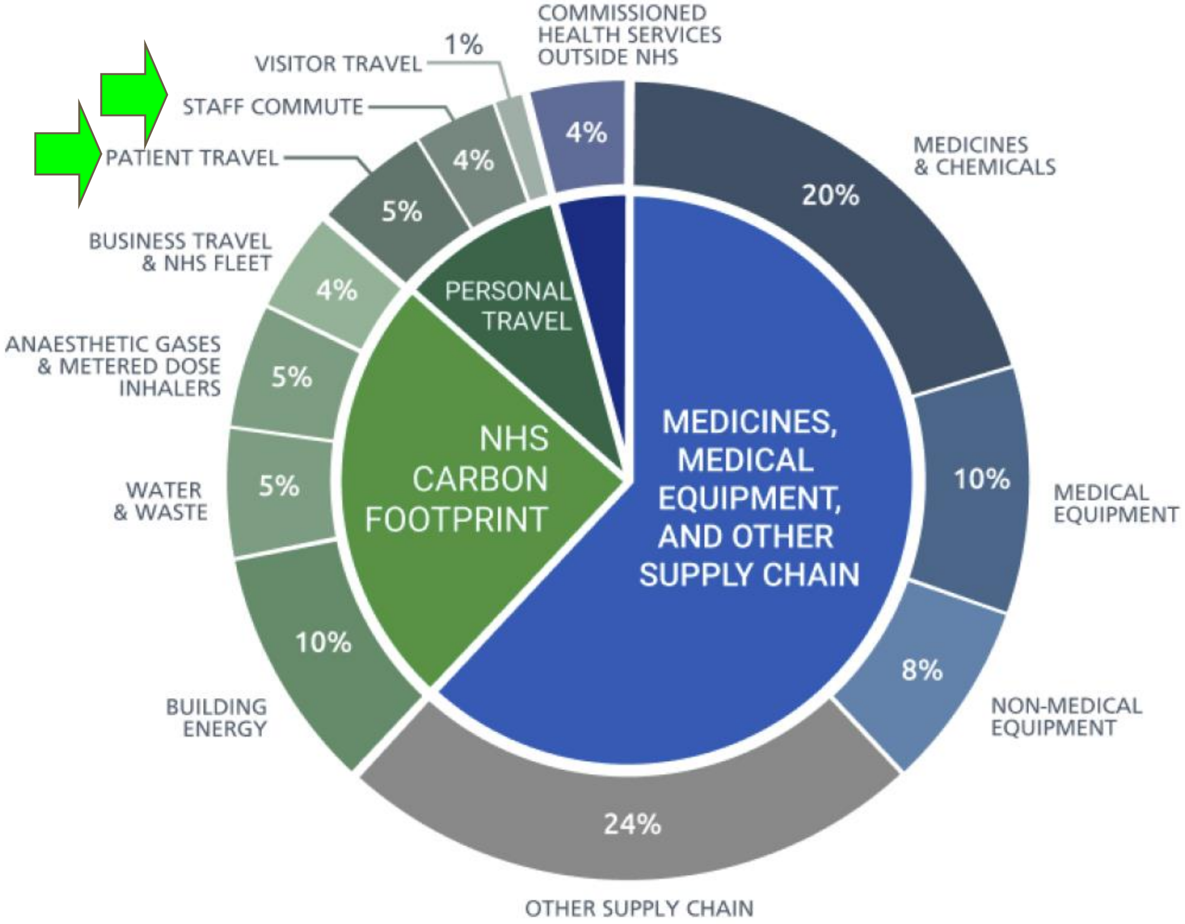
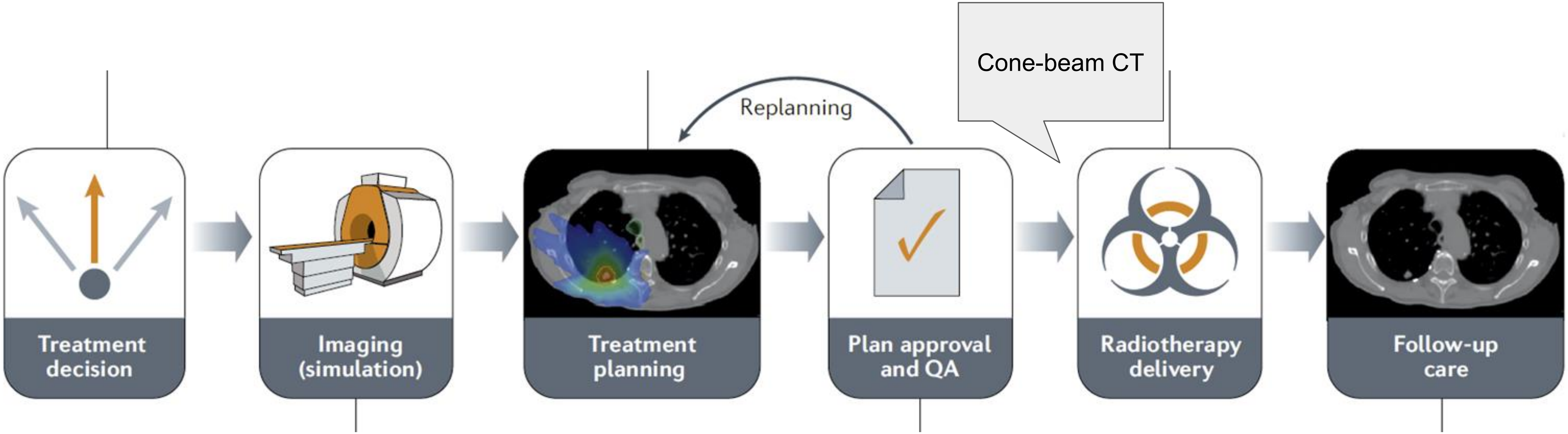
UHN Toronto General Hospital

Healthcare CO2eq footprint is 2x Aviation





Sequence of events in radiotherapy



Many patients have diagnostic CTs prior to consultation.

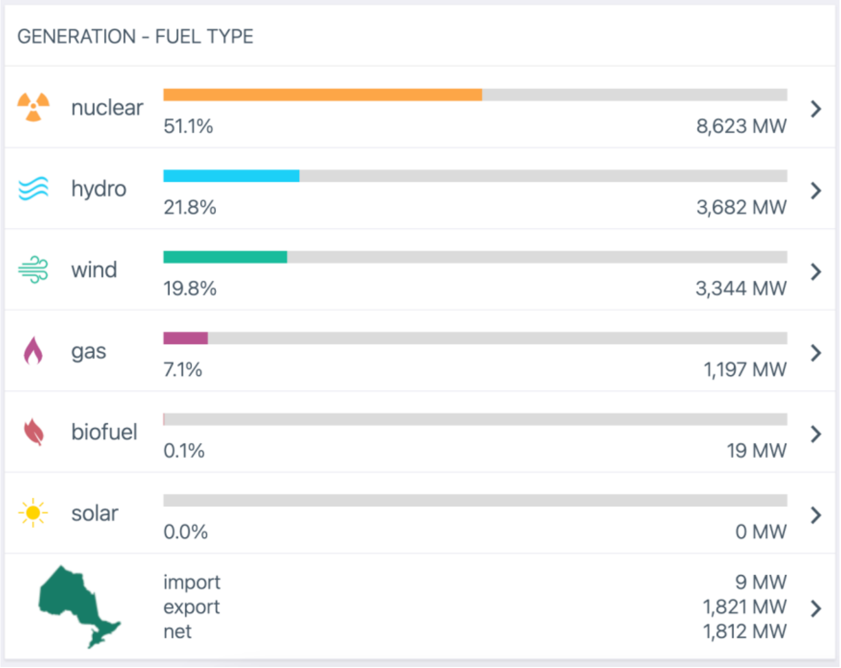
What if we substituted the CT-sim with the diagnostic CT?

How do radiation oncology treatments contribute?

1. Patient roomed
2. Patient positioning
3. **Simulation CT**
4. Treatment planning
5. **Cone beam CT**
6. **LINAC treatment**

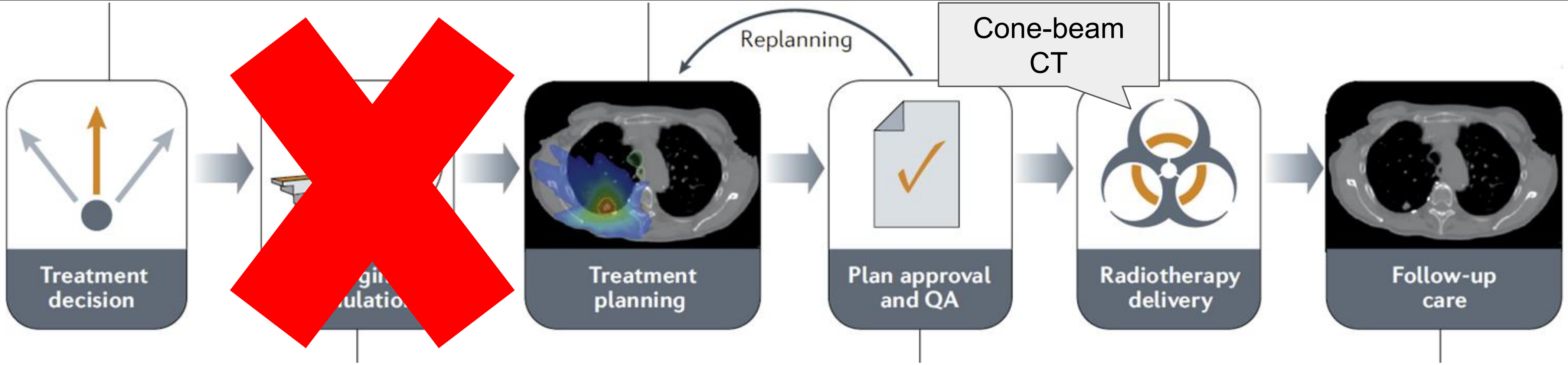
Transportation to and from hospital

Power usage of various machines for treatment planning and therapy



Gridwatch Webapp:

Skipping the Simulation Scan



→ Single-day palliative treatments differ from curative treatments

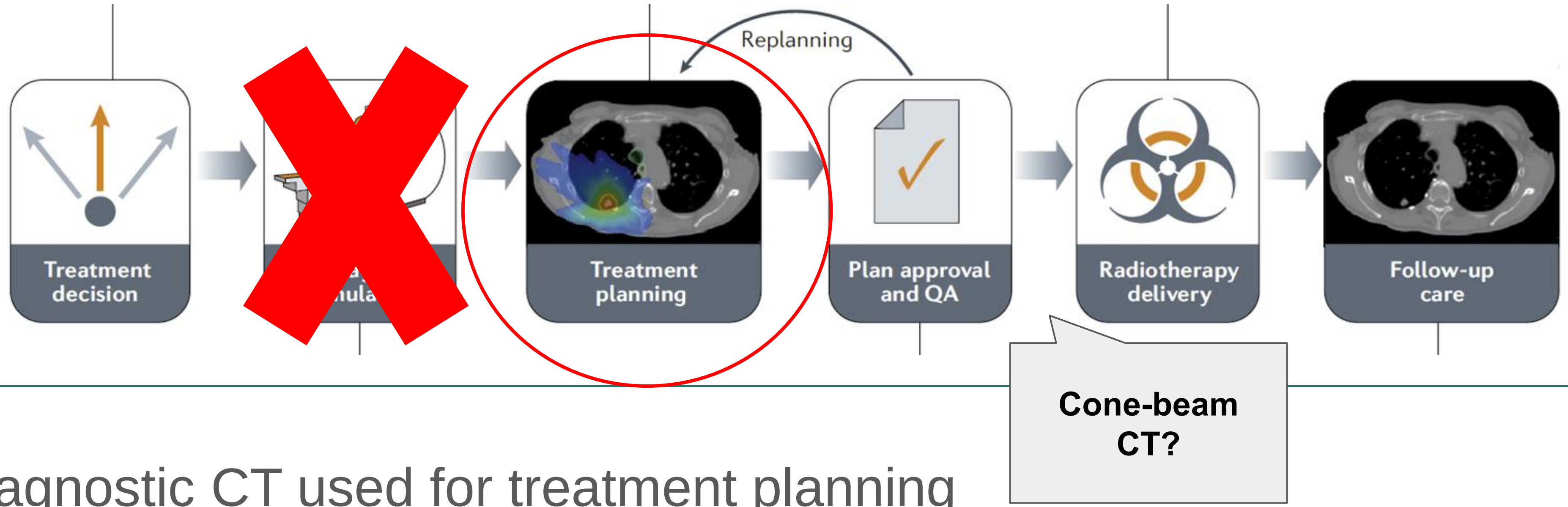
- Timely treatment for symptom control is the goal, rather than preciseness!

→ Simulation scans may be **unnecessary** and **non-contributory**

→ Omitting simulation step has the potential to reduce greenhouse gas emissions by:

- Reducing number of trips to hospital
- Energy savings from simulation CT scanners

Simulation CT-Free Workflow



- Diagnostic CT used for treatment planning
- Cone beam CTs further leveraged to match and confirm patient positioning in real-time before treatment
    - Cone beam CTs taken as needed (up to 3 tries)

Aim

Assess the environmental impact of **simulation-free treatment workflow** for patients undergoing palliative radiotherapy treatments

→ **Calculate** greenhouse gas emissions from simulation-free treatment workflow

→ **Compare** treatment with control group

Patient Selection

Eligibility:

- Able to tolerate lying flat for 45 minutes
- Planned to receive a single palliative radiation fraction
- Had a diagnostic CT within the past four weeks

**Patients requiring target motion management or radiation immobilization devices were excluded

→ **16 treatments** of simulation CT-free palliative radiation workflow between December 2023 to June 2024 included

Control Patients

Eligibility:

- Underwent the traditional simulation CT workflow
- Receive a single palliative dose of radiation
  - **Controlled for treatment site (site-matched with simulation-free patients)**

→ **16 treatments** of conventional palliative radiation workflow between April 2021 to March 2022 included

Treatment sites:

- 1 Sacrum left
- 2 LS spine
- 1 SBRT sternum
- 1 Tibia left
- 1 Scapula left
- 7 Pelvis
- 1 Back
- 1 Liver
- 1 Abdomen

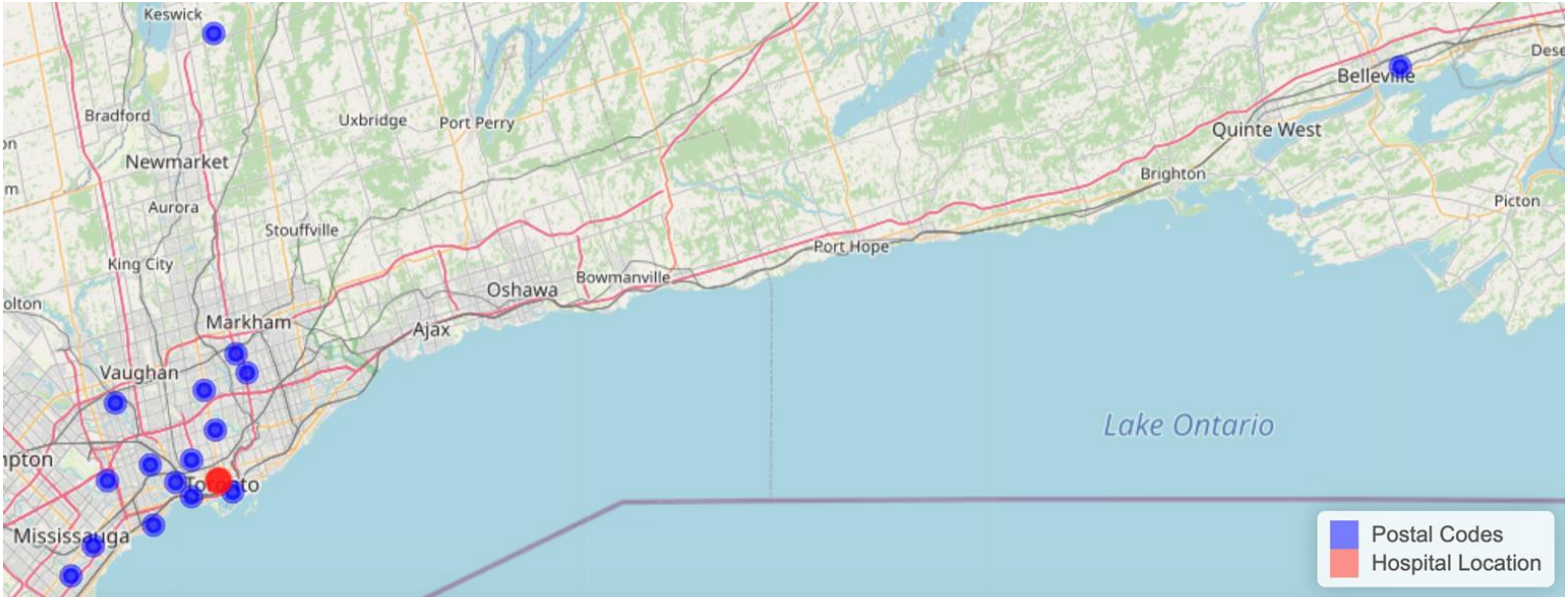
Carbon Emissions Calculation

	Calculation method	Assumptions
Transportation	(Distance from home) x (Average CO2e of common vehicles)	All patients travel using personal vehicles Patients travel by the shortest route to and from hospital
Simulation CT	(kWh of scan) x (intensity of Ontario's electricity GridWatch)	Energy consumption of scan is estimated to the nearest radiological scan type, based on a published paper
Cone beam CT	(kWh of scan) x (intensity of Ontario's electricity GridWatch) **ON state of Varian cone beam CT is indistinguishable from baseline power fluctuations	Energy usage based on manufacturer's supplied data
LINAC idle time and treatment	(Machine units from treatment converted to kWh) x (intensity of Ontario's electricity GridWatch)	Energy usage based on manufacturer's supplied data

Heye T, Knoerl R, Wehrle T, et al. (2020)

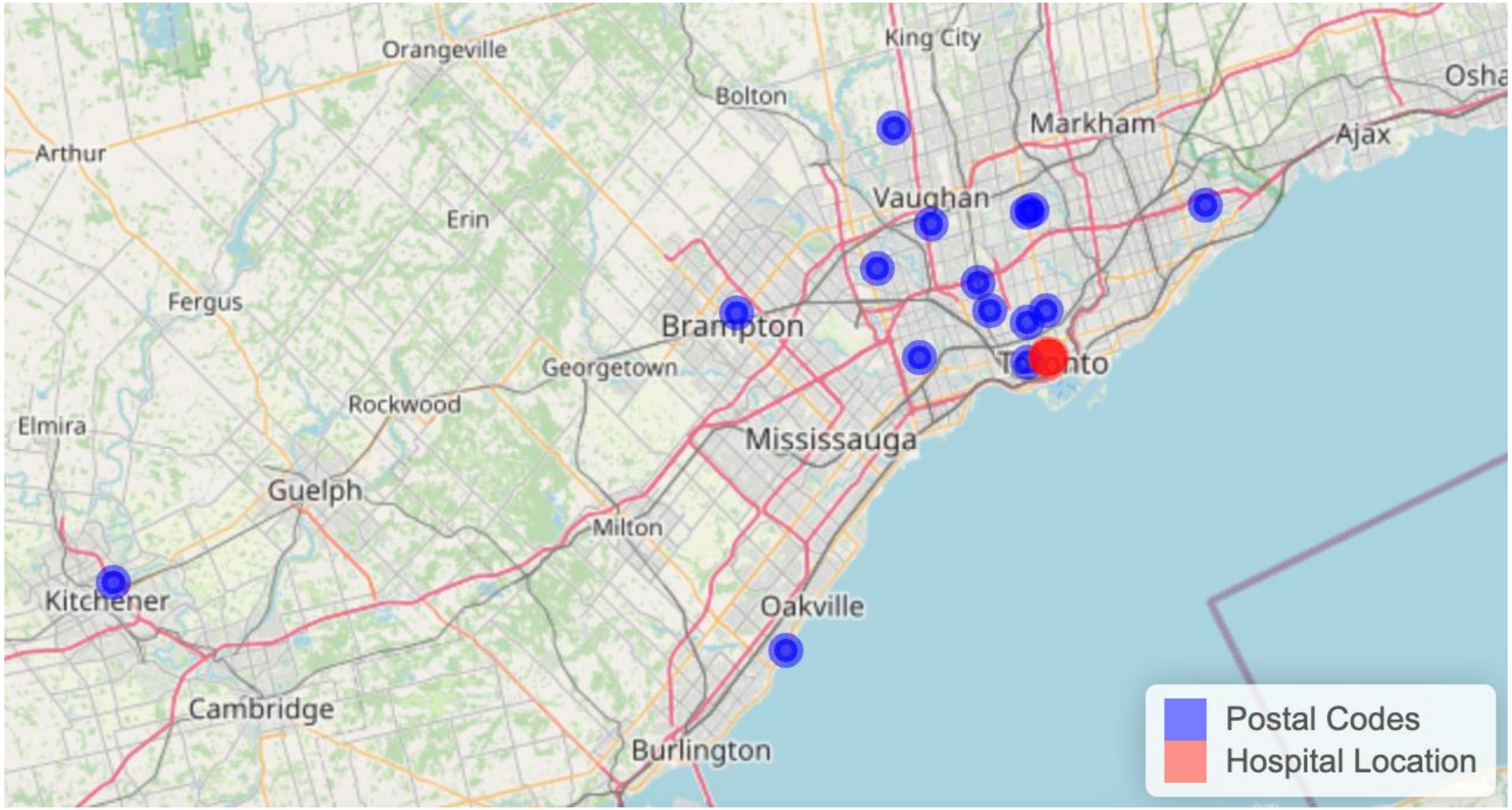
Results

Simulation-Free Distances



Mean distance: 15.4 km; **Total: 404 km**

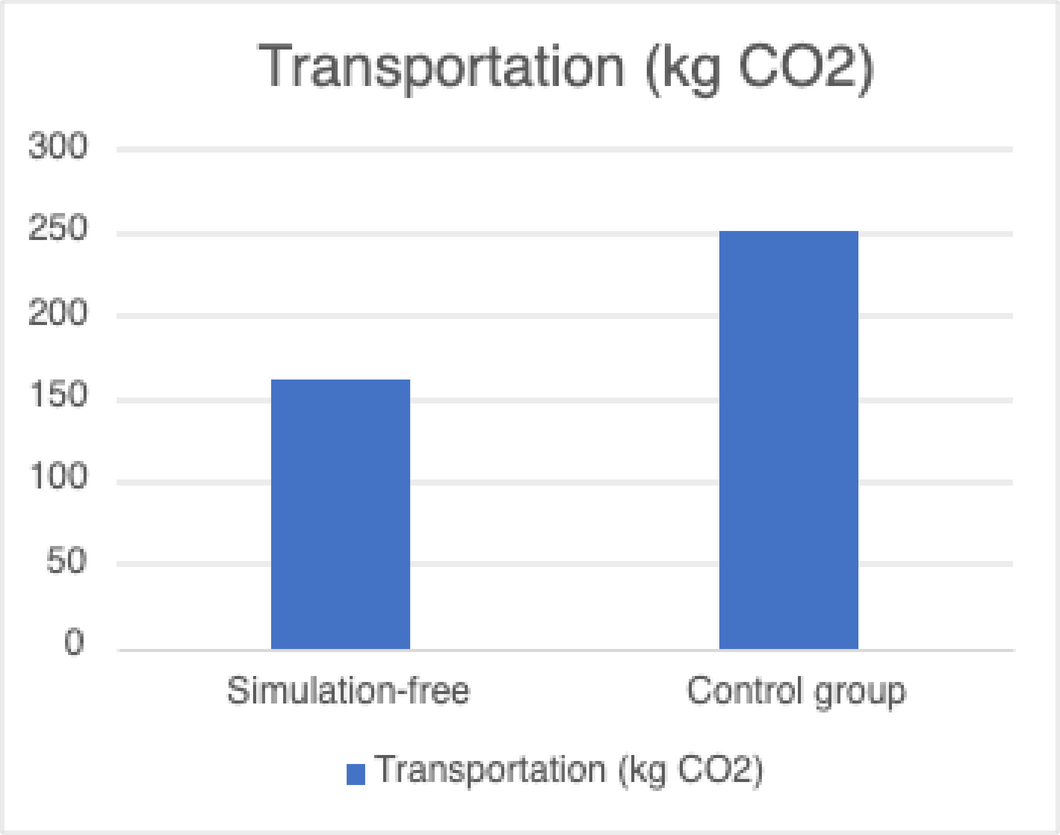
Control Distances



Mean distance: 21.6 km; **Total: 306 km**

Transportation

- **Thirteen** control patients made an additional trip to hospital for simulation CT prior to treatment
    - Three patients had simulation CT taken same day as treatment
- **~35.28%** less CO2 emissions in simulation-free treatment group
    - Sim-free 162.2268 kg CO2
    - Control 250.614 kg CO2



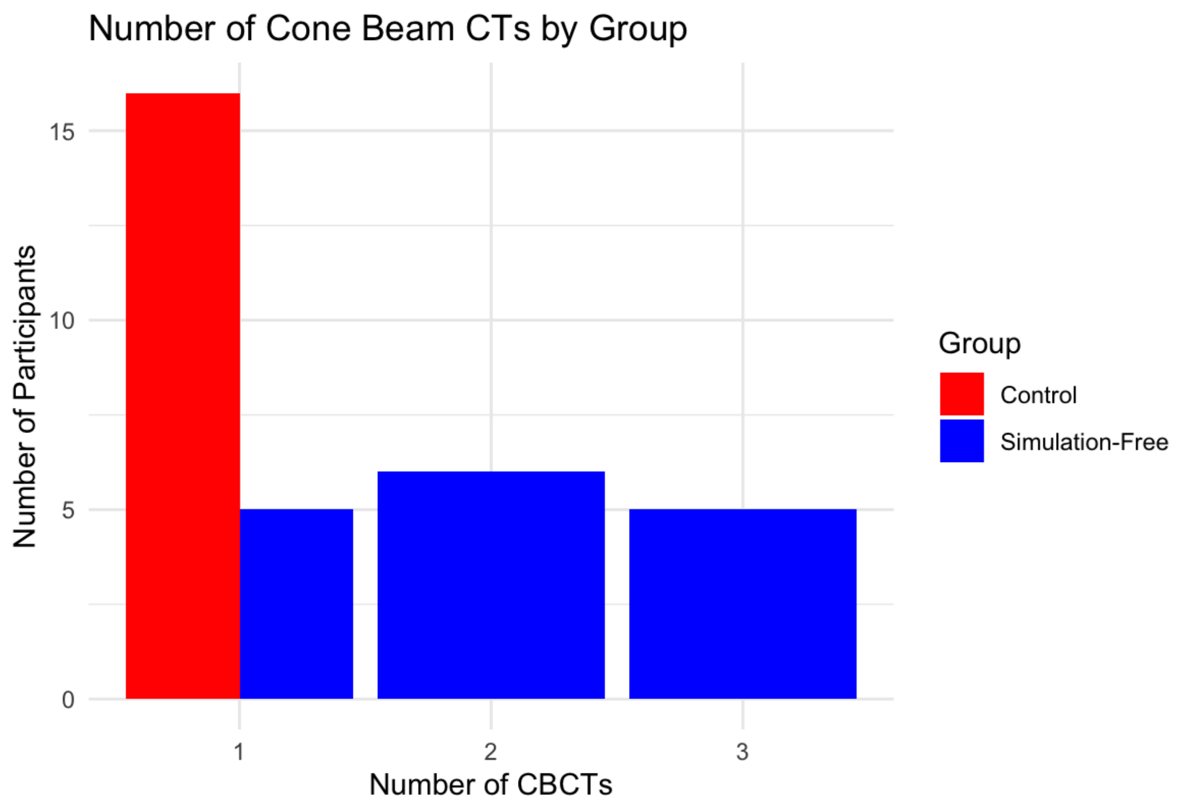
Simulation CT

- Control group patients underwent simulation CT
  - Additional **0.594 kg CO_2** emitted
  - Calculated using estimated CO_2 emissions for various imaging protocols from Heye, Knoerl, Wehrle, and colleagues (2020)

Area scanned approximated to radiology scan regions	#
Abdomen-pelvis	1
Neck-chest-abdomen-pelvis	3
Chest-abdomen-pelvis	4
Extremities	1
Chest	2
Pelvis	5

Heye T, Knoerl R, Wehrle T, et al. The Energy Consumption of Radiology: Energy- and Cost-saving Opportunities for CT and MRI Operation. Radiology. 2020;295(3):593-605. doi:10.1148/radiol.2020192084

Cone Beam CT

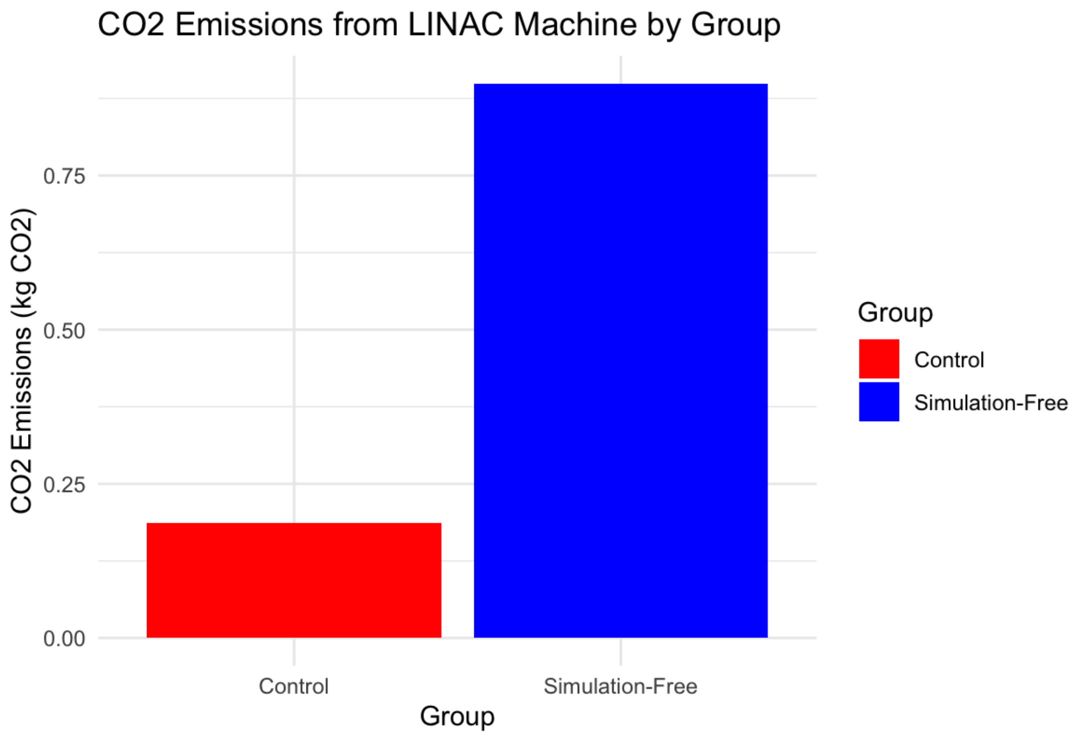


- Simulation-free patients underwent more cone beam CTs than control patients

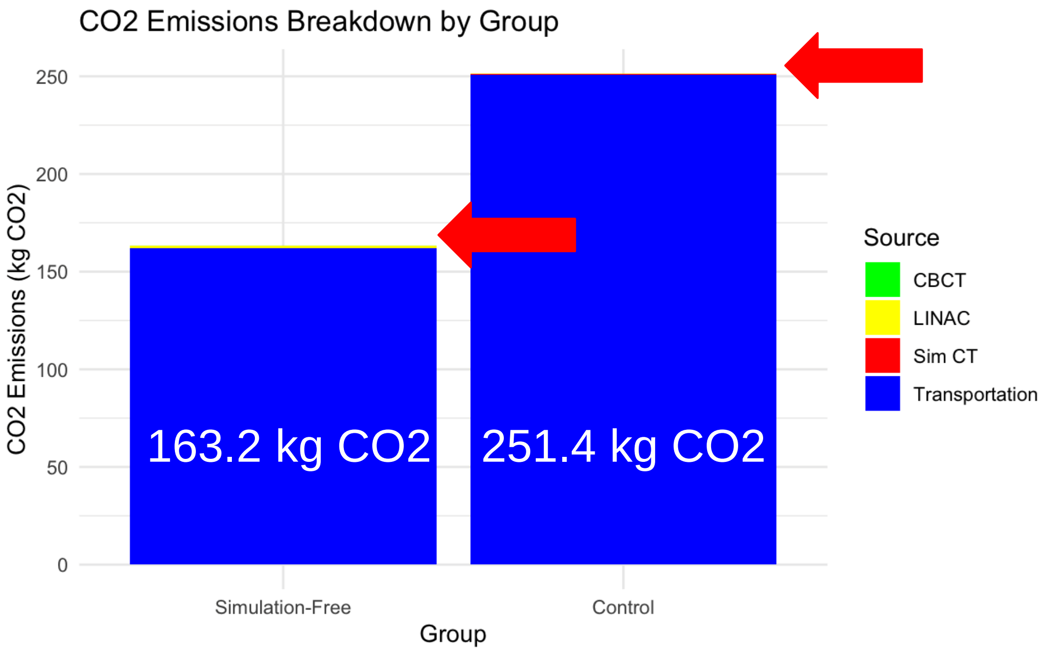
Linear Accelerator

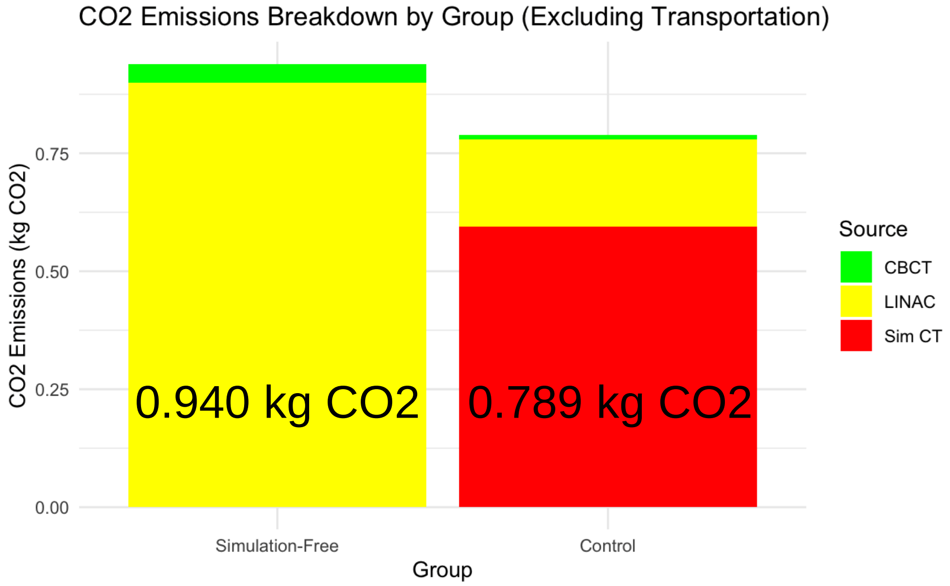
Machine units:

- Simulation-free: 35747.08 MUs
- Control: 16741.30 MUs



Overall Environmental Impact of Each Workflow





- Simulation-free group produces **less** CO2 emissions than control group
- Transportation makes up the **majority** of the carbon dioxide production
  - If we exclude transportation, simulation-free workflow produces slightly more CO2 than control

Conclusion

- Omitting simulation CT resulted in more cone beam CTs
  - Energy consumption from cone beam CTs is relatively small
  - However, simulation-free workflow takes longer with unpredictable amount of time due to repeat imaging and positioning
- Simulation-free treatment workflow is an effective method of reducing carbon dioxide production for eligible patients
  - Transportation is the greatest contributor to carbon dioxide emissions!

Other Points for Discussion

Same-day simulation CT and radiation treatment appointments

- Patients often wait a long time between the appointments, which makes the experience inconvenient for them
- Requires sufficient planning team resources for same-day radiation plan creation and verification
- Certain treatments (ex: SBRT) cannot be completed same day due to extensive dose calculation, will likely be limited to simple 8 in 1 treatments

Patient comfort and ability to tolerate treatments

- Simulation CTs allow us to test whether patient can remain in certain position reliably for treatment

Limitations

01 Differences between groups

02 Various assumptions for calculations

03 Limited sample size (N=16)

University Medical Imaging Toronto

UNIVERSITY OF TORONTO

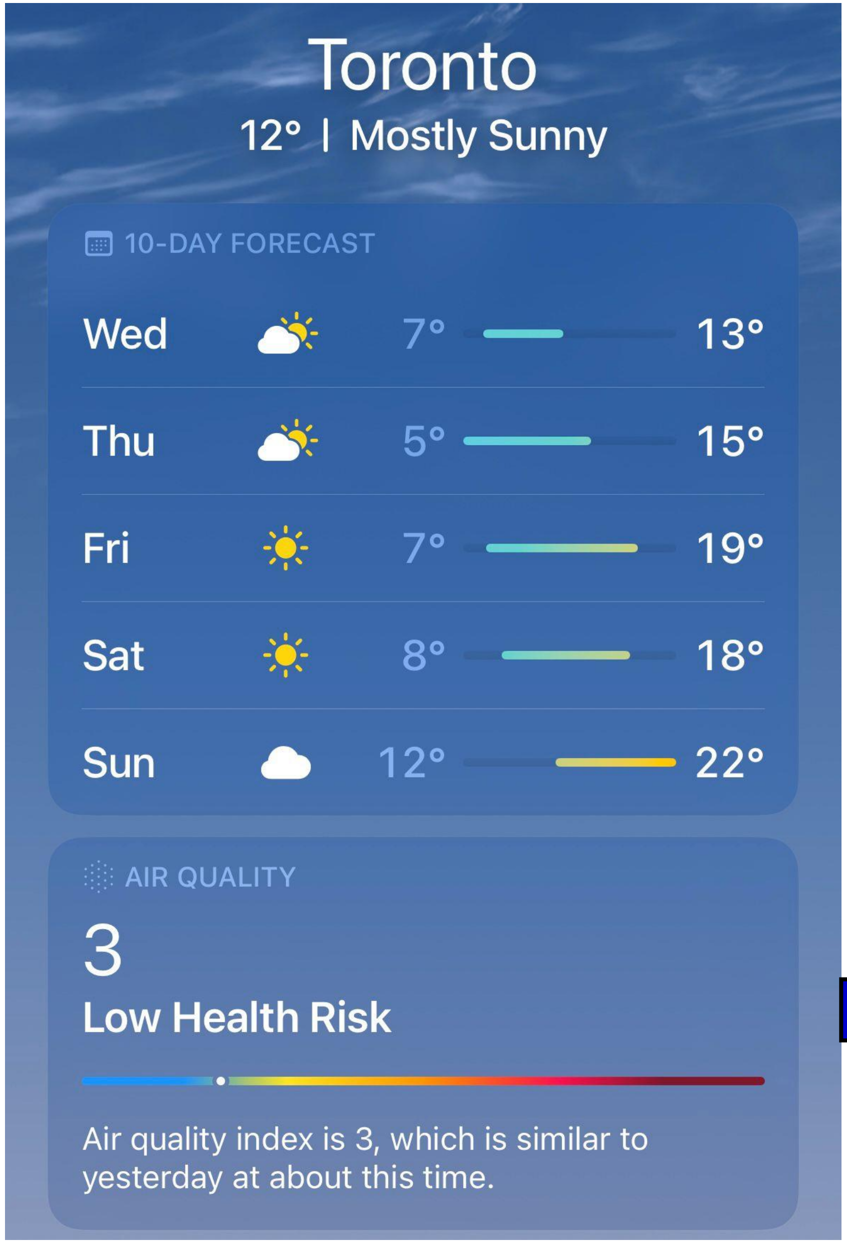
UHN Peter Munk Cardiac Centre

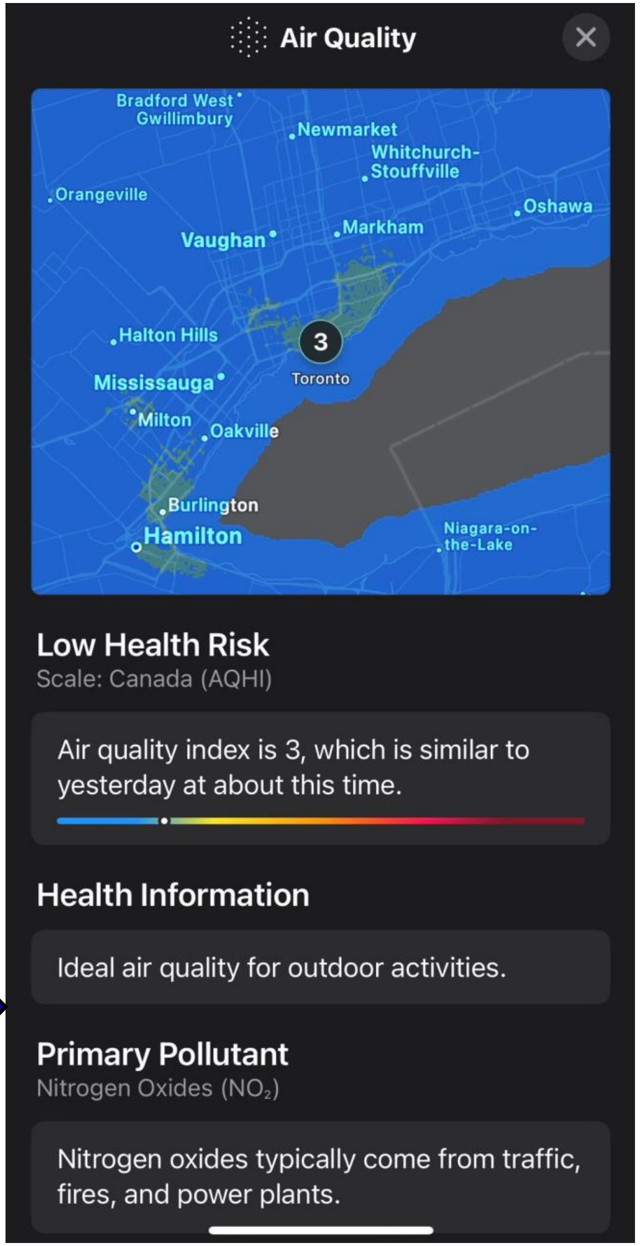
Association between Long-Term Ambient Air Pollution and Myocardial Fibrosis Assessed by MRI

Jacques du Plessis MD, Chloe DesRoche MD MSc, Scott Delaney ScD JD MPH, Rachel C. Nethery PhD, Rachel Hong BSc, Paaladinesh Thavendiranathan MD SM, Heather Ross MD MHSc, Kate Hanneman MD MPH

Financial Disclosures

- Neither of the authors have a financial relationship with a commercial organization that may have a direct or indirect interest in the content


Toronto
12° | Mostly Sunny
10-DAY FORECAST
Wed 7° 13°
Thu 5° 15°
Fri 7° 19°
Sat 8° 18°
Sun 12° 22°
AIR QUALITY
3
Low Health Risk
Air quality index is 3, which is similar to yesterday at about this time.


Air Quality
Bradford West Gwillimbury
Newmarket
Whitchurch-Stouffville
Orangeville
Oshawa
Vaughan
Markham
Halton Hills
3
Toronto
Mississauga
Milton
Oakville
Burlington
Hamilton
Niagara-on-the-Lake
Low Health Risk
Scale: Canada (AQHI)
Air quality index is 3, which is similar to yesterday at about this time.
Health Information
Ideal air quality for outdoor activities.
Primary Pollutant
Nitrogen Oxides (NO_2)
Nitrogen oxides typically come from traffic, fires, and power plants.

Background

- Air pollution is a leading environmental health hazard contributing to excess in morbidity and mortality
- In 2019, 99% of the world’s population lived in places where the WHO air quality guidelines were not met
- Health damages associated with air pollution are estimated at US$8.1 trillion

Background

- Fine particulate matter with ≤2.5 µm aerodynamic diameter ($PM_{2.5}$) is the most studied component of air pollution and is associated with cardiovascular disease
- 31% of cardiovascular disease is related to environmental factors, of which air pollution is regarded as the most important

⇹

Background

- Animal studies and autopsy data suggest that myocardial fibrosis could mediate the adverse cardiovascular effects of air pollution
- Myocardial fibrosis is associated with adverse outcomes and can precede development of heart failure
- Can be assessed non-invasively using cardiac MRI

Background

- Long-term air pollution is associated with ventricular remodeling in patients without CVD
- Myocardial fibrosis could explain some of the variability in heart failure progression, which is not explained by traditional risk factors

Purpose

- To evaluate the relationship between long-term exposure to ambient $PM_{2.5}$ and and the extent of myocardial fibrosis in patients with cardiovascular disease

Methods

- Single-center retrospective cohort study
- Inclusion: Patient with dilated cardiomyopathy (DCM) referred for CMR between 2018–2022 with clinical follow-up
- Exclusion: Prior myocardial infarction and severe valve disease

Methods

- Primary outcome: Cardiac MRI native T1 z-score (marker of diffuse myocardial fibrosis)
- Secondary outcomes:
  - Late gadolinium enhancement (replacement fibrosis)
  - Left ventricular ejection fraction (LVEF)
  - Left ventricular end-diastolic volume
  - Native T2 z-score (marker of edema)

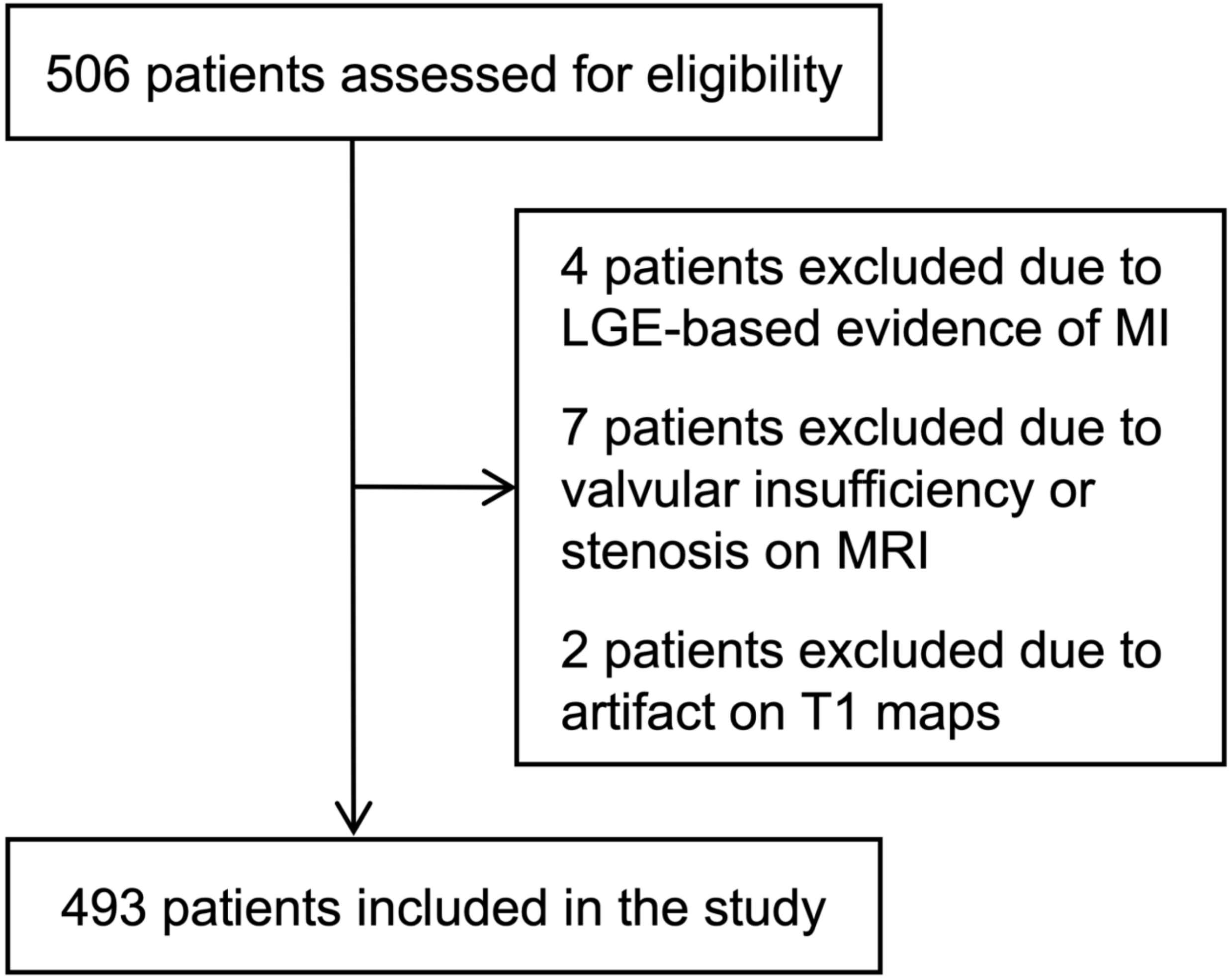
Methods

- Exposure: One-year mean concentration of daily ambient $PM_{2.5}$ ($\mu g/m^3$) from the closet monitoring station to each patient’s residential address prior to cardiac MRI

Methods

- Linear and logistic regression models
- Adjusted for: age, sex (sex assigned at birth), body surface area, local ambient temperature, distance to nearest monitoring station, urban versus rural residence location, MRI field strength, year, cardiac risk factors and socioeconomic status

Results



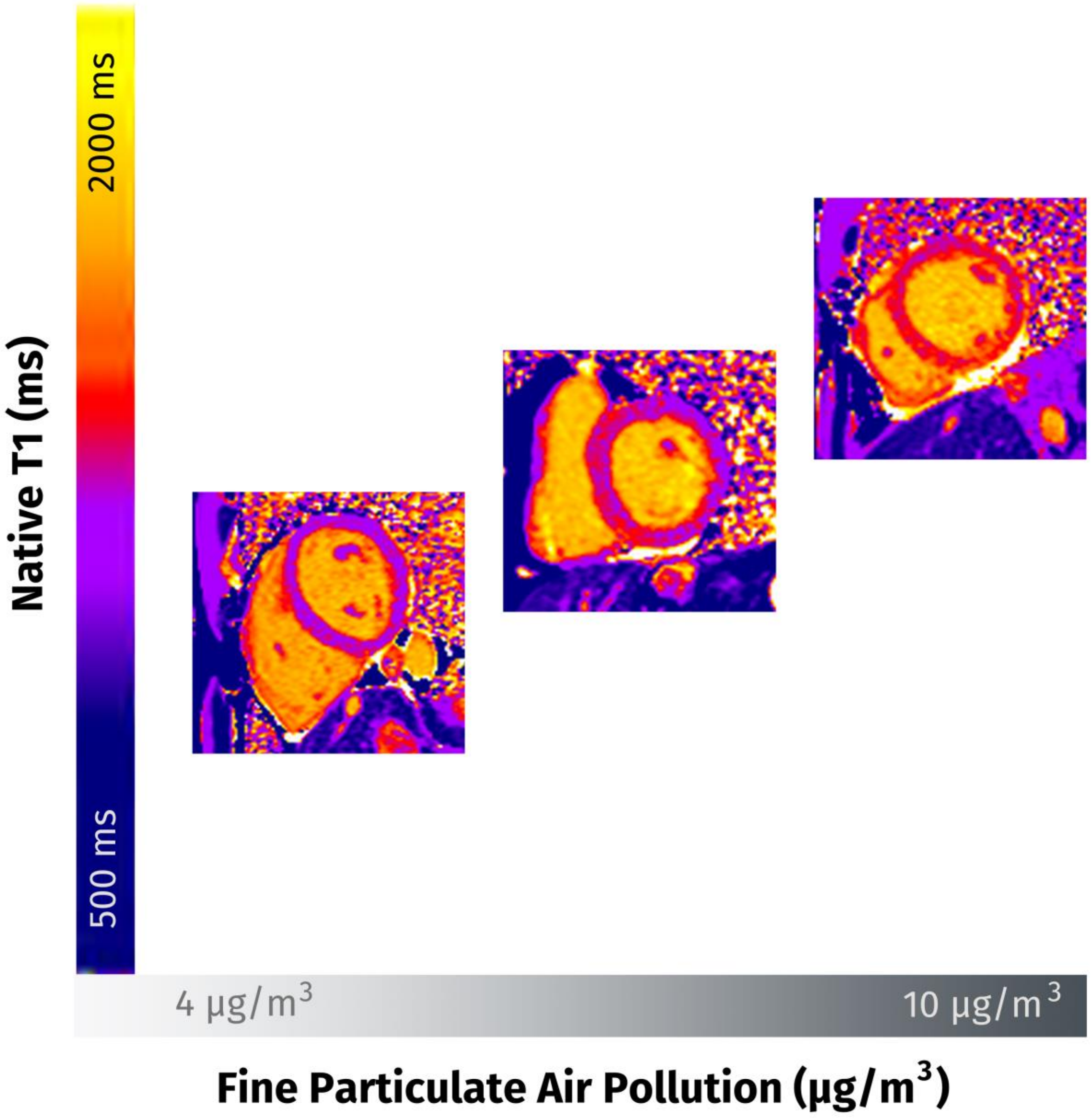
Median one-year $PM_{2.5}$ = 7.8 $\mu g/m^3$ (IQR 7.4, 8.1)

	All Patients n=493	Low $PM_{2.5}$ Tertile (4.3-7.6 µg/m^3) n=165	Medium $PM_{2.5}$ Tertile (7.6-8.0 µg/m^3) n=164	High $PM_{2.5}$ Tertile (8.0-9.8 µg/m^3) n=164	p-value
Age, year [a]	48 ± 16	46 ± 15	48 ± 17	50 ± 16	.09
Male (%)	350 (71)	120 (73)	116 (71)	114 (70)	.52
Female (%)	143 (29)	45 (27)	48 (29)	50 (30)	.52
Height, cm [a]	174 ± 15	175 ± 10	174 ± 21	174 ± 10	.57
Weight, kg [a]	82 ± 20	82 ± 19	81 ± 22	81 ± 20	.41
BSA, m^2 [a]	1.98 ± 0.27	2.00 ± 0.26	1.97 ± 0.28	1.97 ± 0.27	.32
Distance to nearest station (km) [b]	6.6 (3.5, 9.9)	6.6 (3.5, 14.1)	6.7 (4.1, 8.4)	6.3 (3.5, 9.5)	.19
Urban residence (%)	450 (91)	139 (84)	158 (96)	153 (93)	.004
Hypertension (%)	148 (30)	44 (27)	53 (32)	51 (31)	.38
Hyperlipidemia (%)	86 (17)	26 (16)	31 (19)	29 (18)	.65
Smoking history (%)	105 (21)	39 (24)	38 (23)	28 (17)	.15
Diabetes (%)	55 (11)	14 (8)	22 (13)	19 (12)	.37
Neighborhood median annual household income ($)[b]	42,400 (36,800, 51,200)	42,400 (36,800, 48,800)	40,400 (35,200, 51,800)	43,600 (37,200, 52,000)	.27
Neighborhood education level (diploma or higher) (%)	73 ± 11	72 ± 12	73 ± 11	73 ± 11	.17

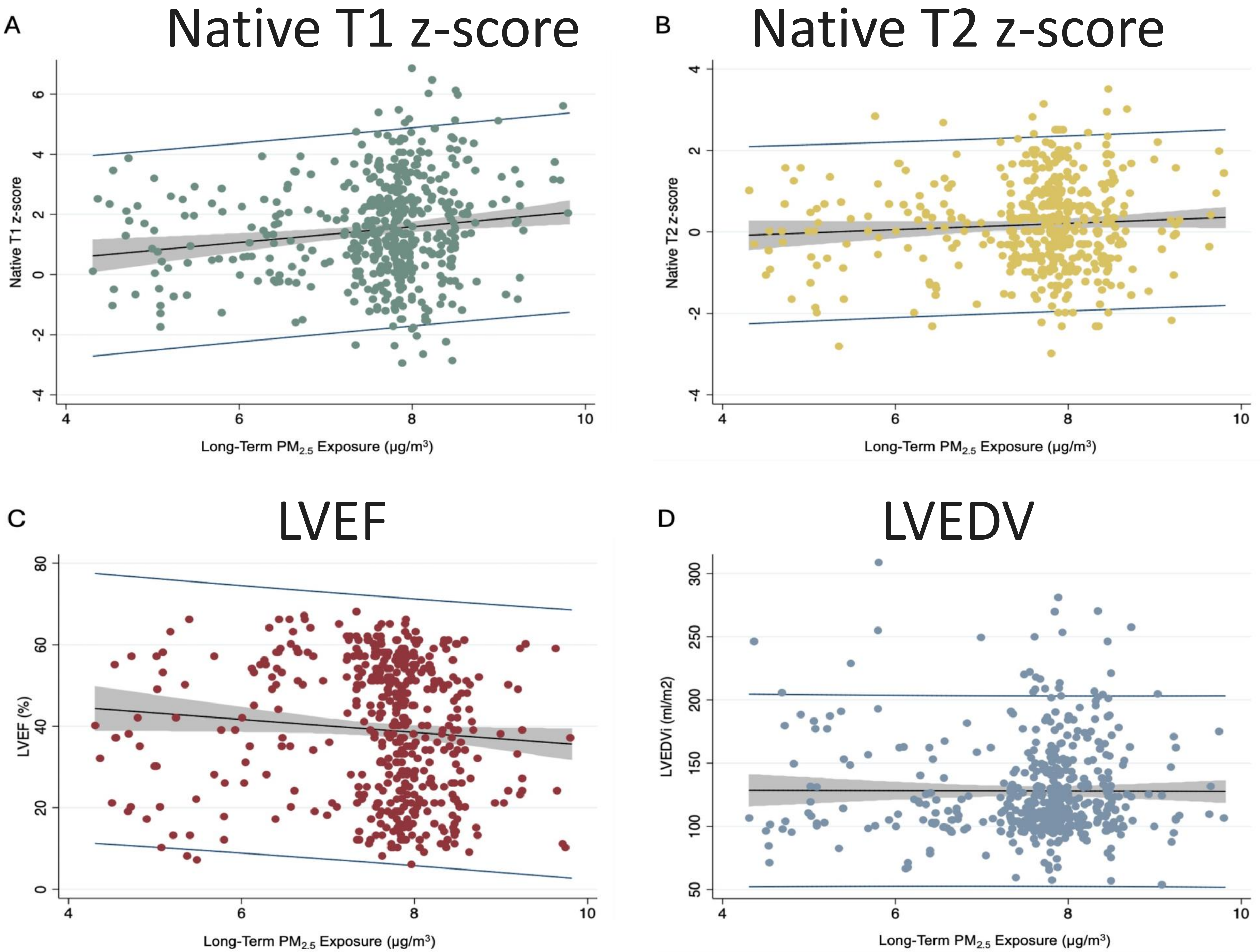
Results

Cardiac MRI Findings by Tertiles of One-Year Mean $PM_{2.5}$ Exposure

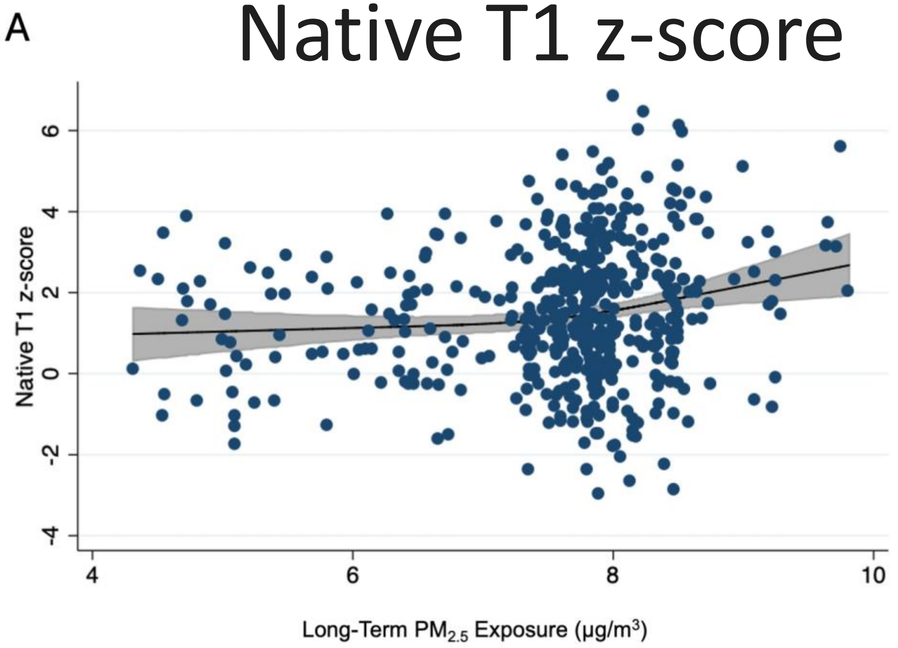
	All Patients n=493	Low $PM_{2.5}$ Tertile (4.3-7.6 µg/m³) n=165	Medium $PM_{2.5}$ Tertile (7.6-8.0 µg/m³) n=164	High $PM_{2.5}$ Tertile (8.0-9.8 µg/m³) n=164	p-value
Native T1 *z*-score	1.4 (0.4, 2.5)	1.1 (0.1, 2.2)	1.4 (0.4, 2.5)	1.7 (0.5, 3.1)	.005
T2 *z*-score	0.2 (-0.6, 0.9)	0.1 (-0.6, 0.7)	0.3 (-0.6, 1.0)	0.0 (-0.7, 0.8)	.85
LVEDVI, ml/m^2	116 (103, 146)	111 (102, 138)	116 (105, 144)	122 (105, 152)	.01
LVEF, %	40 (24, 54)	49 (28, 57)	41 (25, 54)	35 (21, 51)	.001
LGE presence (%)[a,b]	322 (67)	92 (58)	112 (70)	118 (72)	.005



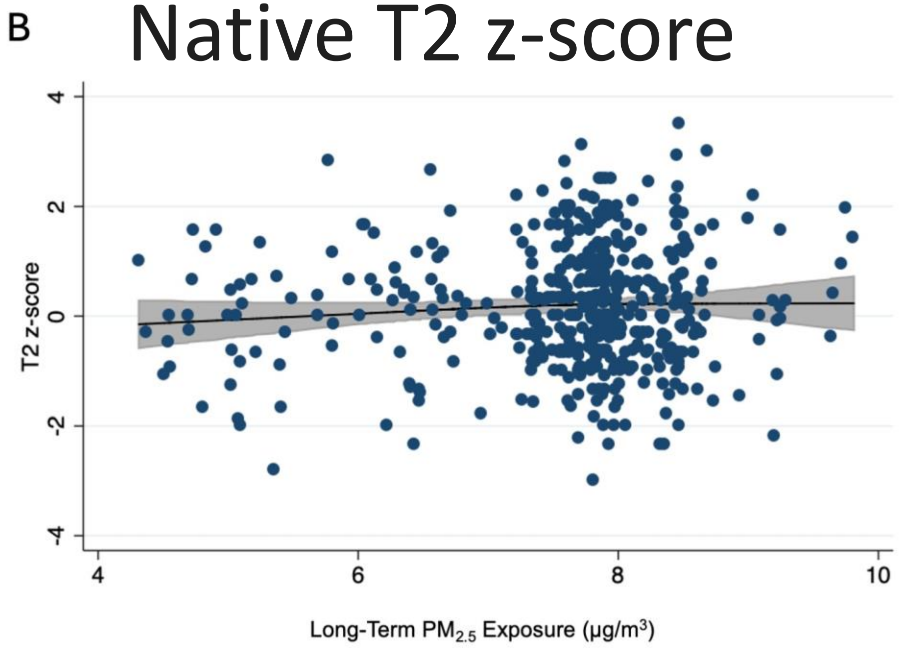
In fully adjusted multivariable model, one-year ambient $PM_{2.5}$ exposure was associated with a 0.28 higher native T1 z-score per 1 µg/m^3


A
Native T1 z-score
Native T1 z-score
Long-Term PM2.5 Exposure (μg/m3)
B
Native T2 z-score
Native T2 z-score
Long-Term PM2.5 Exposure (μg/m3)
C
LVEF
LVEF (%)
Long-Term PM2.5 Exposure (μg/m3)
D
LVEDV
LVEDVi (ml/m2)
Long-Term PM2.5 Exposure (μg/m3)

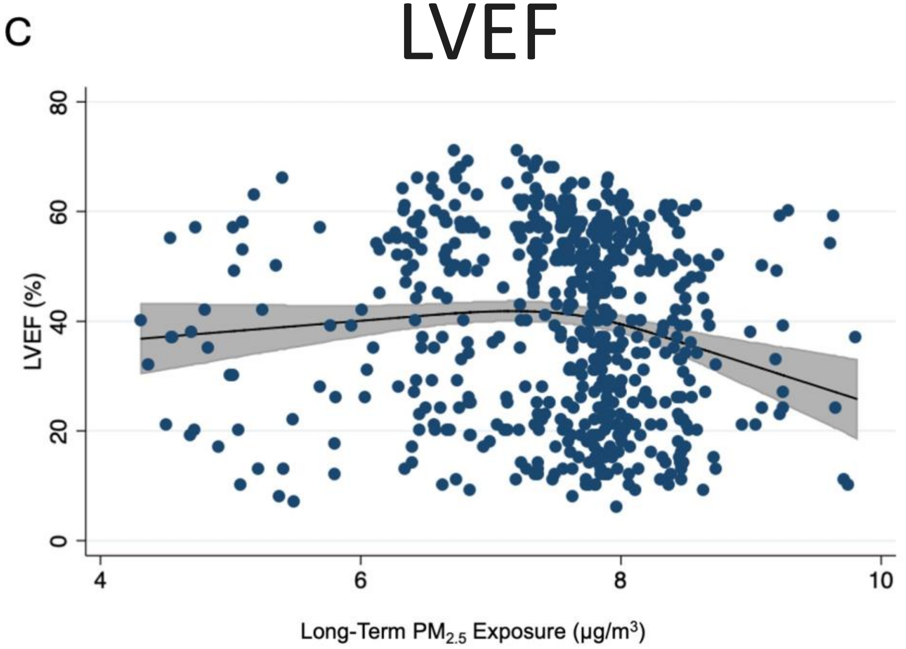
Native T1 z-score



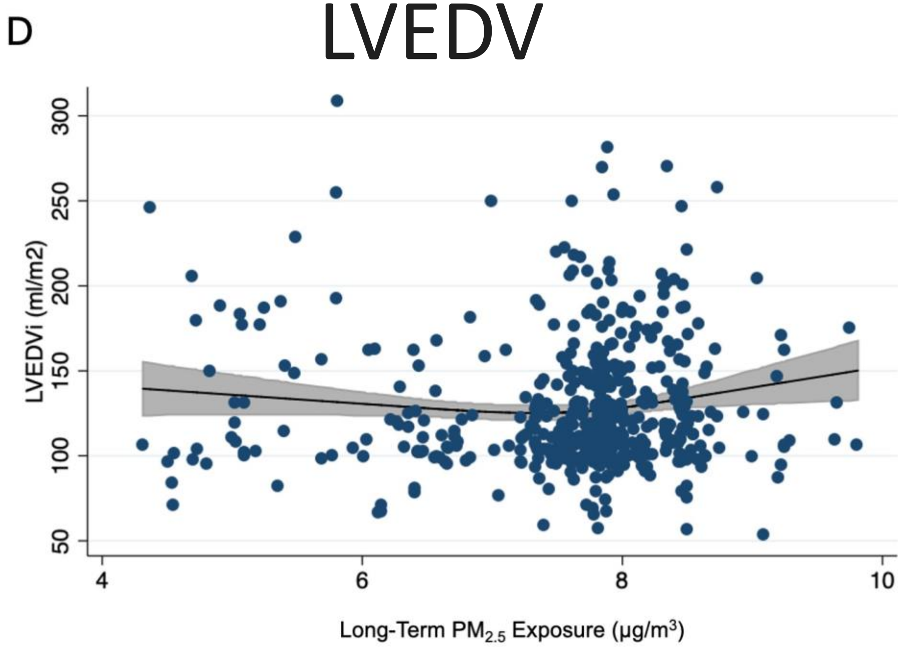
Native T2 z-score



LVEF



LVEDV



	Linear Regression			Logistic Regression	
	B-coefficient [a] (95%CI)	*P* value		*Odds Ratio* [b] (95%CI)	*P* value
UNIVARIABLE MODELS					
Native T1 *z*-score	0.26 (0.11, 0.42)	.001		-	-
T2 *z*-score	0.08 (-0.02, 0.18)	.13		-	-
LVEDVI, ml/m^2	1.4 (-2.4, 5.2)	.48		-	-
LVEF, %	-1.6 (-3.1, -0.3)	.045		-	-
LGE presence (%)	≈	.		1.22 (1.02, 1.47)	.034
MULTIVARIABLE MODELS [c]					
Native T1 *z*-score	0.28 (0.11, 0.45)	.001		-	-
T2 *z*-score	0.05 (-0.06, 0.16)	.37		-	-
LVEDVI, ml/m^2	2.6 (-1.4, 6.6)	.20		-	-
LVEF, %	-1.2 (-2.8, 0.3)	.11		-	-
LGE presence (%)	≈			1.25 (1.01, 1.56)	.041

Results

- In fully adjusted multivariable model the increase in native T1 z-score (per 1 $\mu g/m^3$) were
  - 0.40 in women compared to 0.23 in men
  - 0.45 in smokers compared to 0.24 to non-smokers
  - 0.37 in hypertensive patients compared to 0.26 in non-hypertensive patients
- Adjusted effect estimates for long-term $PM_{2.5}$ exposure on native T1 z-scores were similar for patients <50 and ≥50 years of age

Limitations

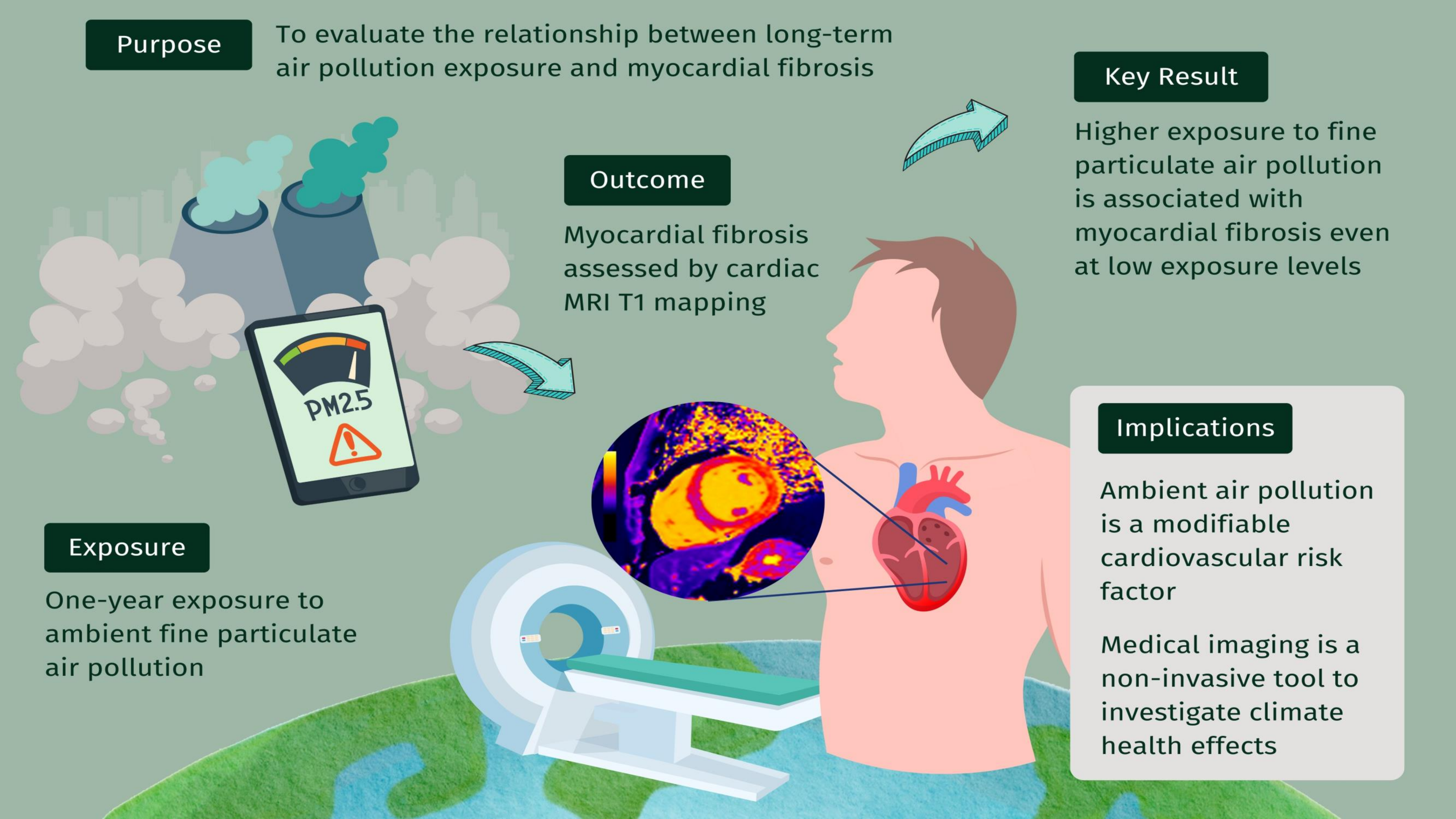
- Single center study
- Potential for unknown and unmeasured confounders
- No histological confirmation
- Only evaluated ambient $PM_{2.5}$ exposure and did not account for indoor exposure or exposure to other air pollutants

Conclusion

- Higher past $PM_{2.5}$ exposure was associated with increased native T1, a marker of diffuse myocardial fibrosis
- Myocardial fibrosis could mediate the adverse cardiovascular effects of air pollution, even at exposures below current air quality guidelines

Conclusion

- Air pollution is ubiquitous, although the risks are not equal
- Certain subgroups are more vulnerable, with a larger effect observed in women, smokers, and hypertensive patients
- Medical imaging can be used as a non-invasive tool to assess underlying mechanisms of climate-related disease


Purpose
To evaluate the relationship between long-term air pollution exposure and myocardial fibrosis
Key Result
Higher exposure to fine particulate air pollution is associated with myocardial fibrosis even at low exposure levels
Outcome
Myocardial fibrosis assessed by cardiac MRI T1 mapping
PM2.5
Implications
Ambient air pollution is a modifiable cardiovascular risk factor
Medical imaging is a non-invasive tool to investigate climate health effects
Exposure
One-year exposure to ambient fine particulate air pollution

University Medical Imaging Toronto

Jacques.Duplessis@sunnybrook.ca

kate.hanneman@uhn.ca

@KateHanneman

Conducting Sustainable Health Research in the Anthropocene

Jeff D'Souza

COI

I have no conflicts of interest to declare

Disclaimers

- The views expressed in this presentation are my own and do not express the views or opinions of my employer
- Ethicist & ~ Climate Scientist

Research ethics, climate change, & human health

RESEARCH ETHICS

CLIMATE CHANGE

HUMAN HEALTH

What makes research ethical?

Favorable risk-benefit ratio

- Risks **to participants** are minimized;
- Potential benefits to **participants and society** are maximized;
- Risks/harms **to participants** are proportionate to the potential benefits to **participants and society**.

Special Communication

May 24/31, 2000

What Makes Clinical Research Ethical?

Ezekiel J. Emanuel, MD, PhD; David Wendler, PhD; Christine Grady, PhD

Author Affiliations

Table 2. Seven Requirements for Determining Whether a Research Trial Is Ethical*

Requirement	Explanation	Justifying Ethical Values	Expertise for Evaluation
Social or scientific value	Evaluation of a treatment, intervention, or theory that will improve health and well-being or increase knowledge	Scarce resources and nonexploitation	Scientific knowledge; citizen's understanding of social priorities
Scientific validity	Use of accepted scientific principles and methods, including statistical techniques, to produce reliable and valid data	Scarce resources and nonexploitation	Scientific and statistical knowledge; knowledge of condition and population to assess feasibility
Fair subject selection	Selection of subjects so that stigmatized and vulnerable individuals are not targeted for risky research and the rich and socially powerful not favored for potentially beneficial research	Justice	Scientific knowledge; ethical and legal knowledge
Favorable risk-benefit ratio	Minimization of risks; enhancement of potential benefits; risks to the subject are proportionate to the benefits to the subject and society	Nonmaleficence, beneficence, and nonexploitation	Scientific knowledge; citizen's understanding of social values
Independent review	Review of the design of the research trial, its proposed subject population, and risk-benefit ratio by individuals unaffiliated with the research	Public accountability; minimizing influence of potential conflicts of interest	Intellectual, financial, and otherwise independent researchers; scientific and ethical knowledge
Informed consent	Provision of information to subjects about purpose of the research, its procedures, potential risks, benefits, and alternatives, so that the individual understands this information and can make a voluntary decision whether to enroll and continue to participate	Respect for subject autonomy	Scientific knowledge; ethical and legal knowledge
Respect for potential and enrolled subjects	Respect for subjects by (1) permitting withdrawal from the research; (2) protecting privacy through	Respect for subject autonomy and welfare	Scientific knowledge; ethical and legal knowledge; knowledge of particular subject population

Peculiarity: A risk-benefit fallacy?

Potential **risks** focus on the **individual**

Vs.

Potential **benefits** focus on **more than just the individual**

Central ethical inquiry

Do the potential harms/risks of a research study to non-participants (e.g., society, future generations, etc.) matter?

Where beneficence, we should find non-maleficence

- Insofar as we stand in moral relation to a group, we cannot arbitrarily decide what it is that we owe them

- If we have a general duty of beneficence, we have at the very least an equal duty of non-maleficence toward them

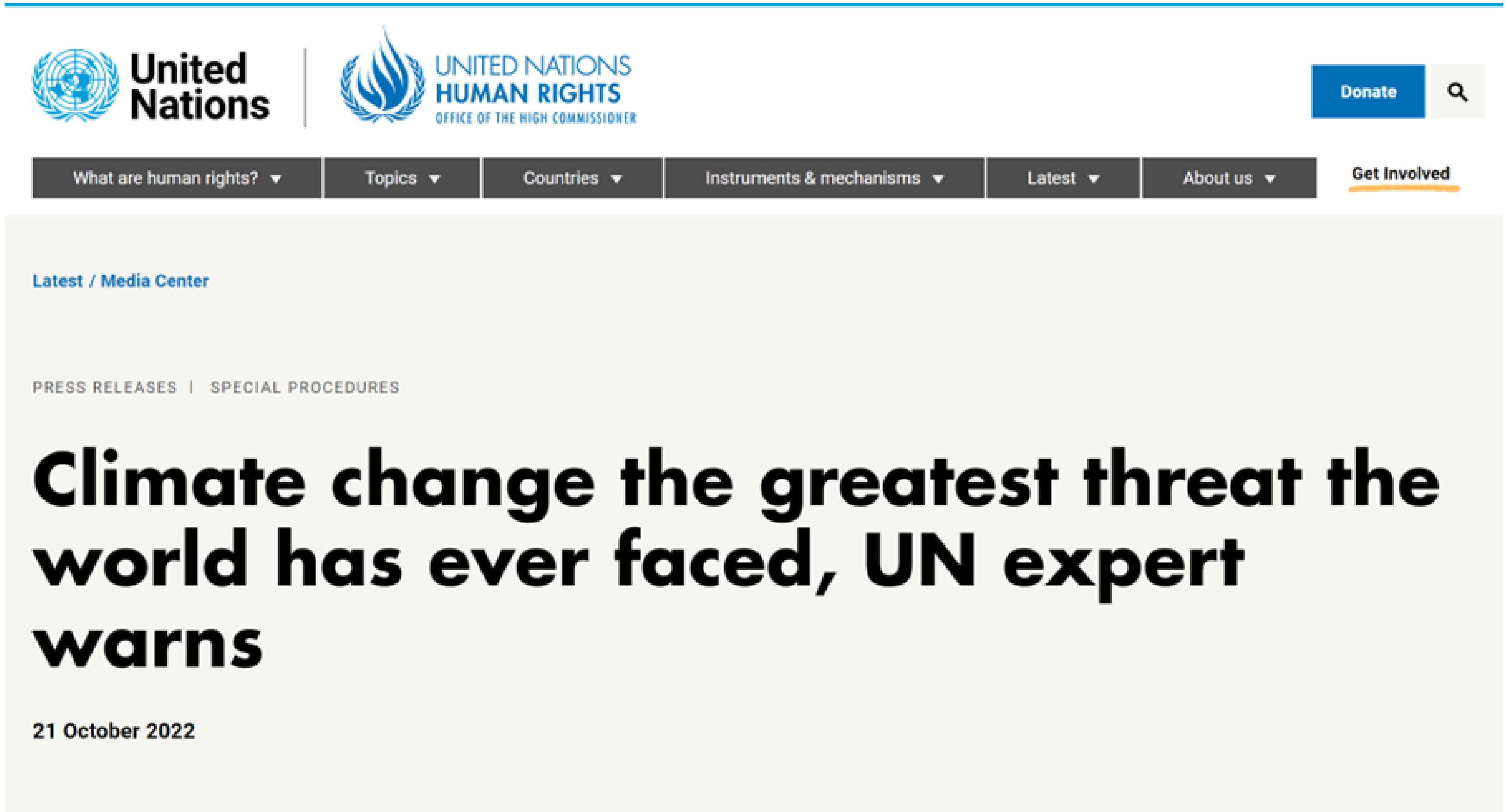
Indirect harms and risks to society matter

Such indirect risks and harms include how health interventions may:

(1) Broaden health inequities
(2) Exploit lands, resources, humans, and non-human animals,
(3) Destroy natural habitats, and
(4) Contribute to anthropogenic climate change through the carbon footprint of health research

Research ethics & climate change

Major Problem: Ignores the greatest threat to our species, non-human animals, plants, natural ecosystems, and our planet: climate change



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Climate change the greatest threat the world has ever faced, UN expert warns

21 October 2022

Health research not insignificant contributor

- Based on 350 000 trials on ClinicalTrials.gov. by the Sustainable Clinical Trials Group, we get an estimated 27.5 million tones of carbon emission (1/3 of the total annual carbon emissions of Bangladesh, a country of 163 million people)

Net Neutral: a modest proposal

1. Calculate and disclose the associated carbon footprint of their research; &

2. Develop a reduction/mitigation plan to ensure that study achieves net-zero carbon emissions

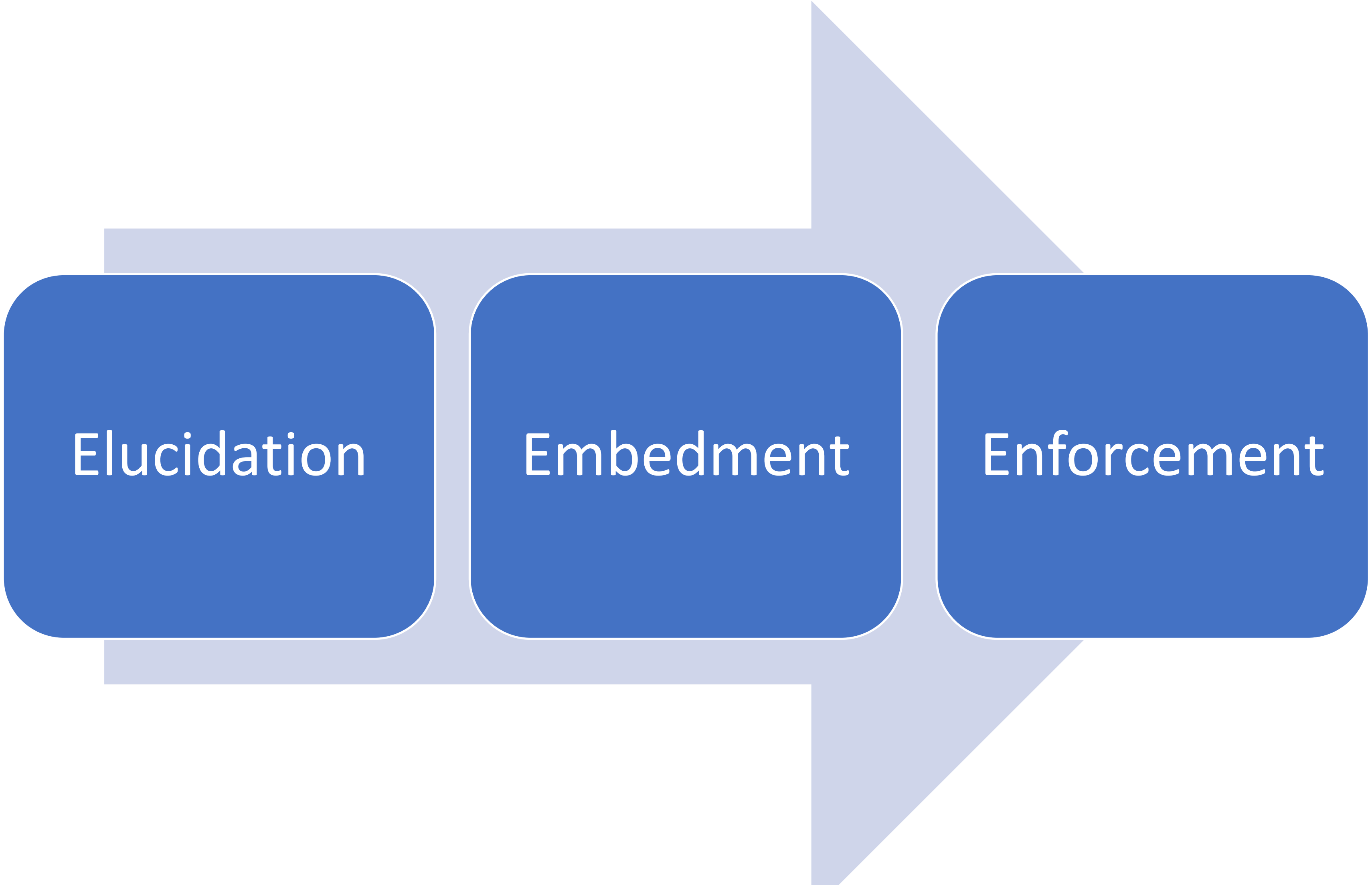
On this account, *mutatis mutandis*, research that cannot achieve net-zero carbon emissions would, *prima facie*, be deemed ethically unacceptable

Moral Justification

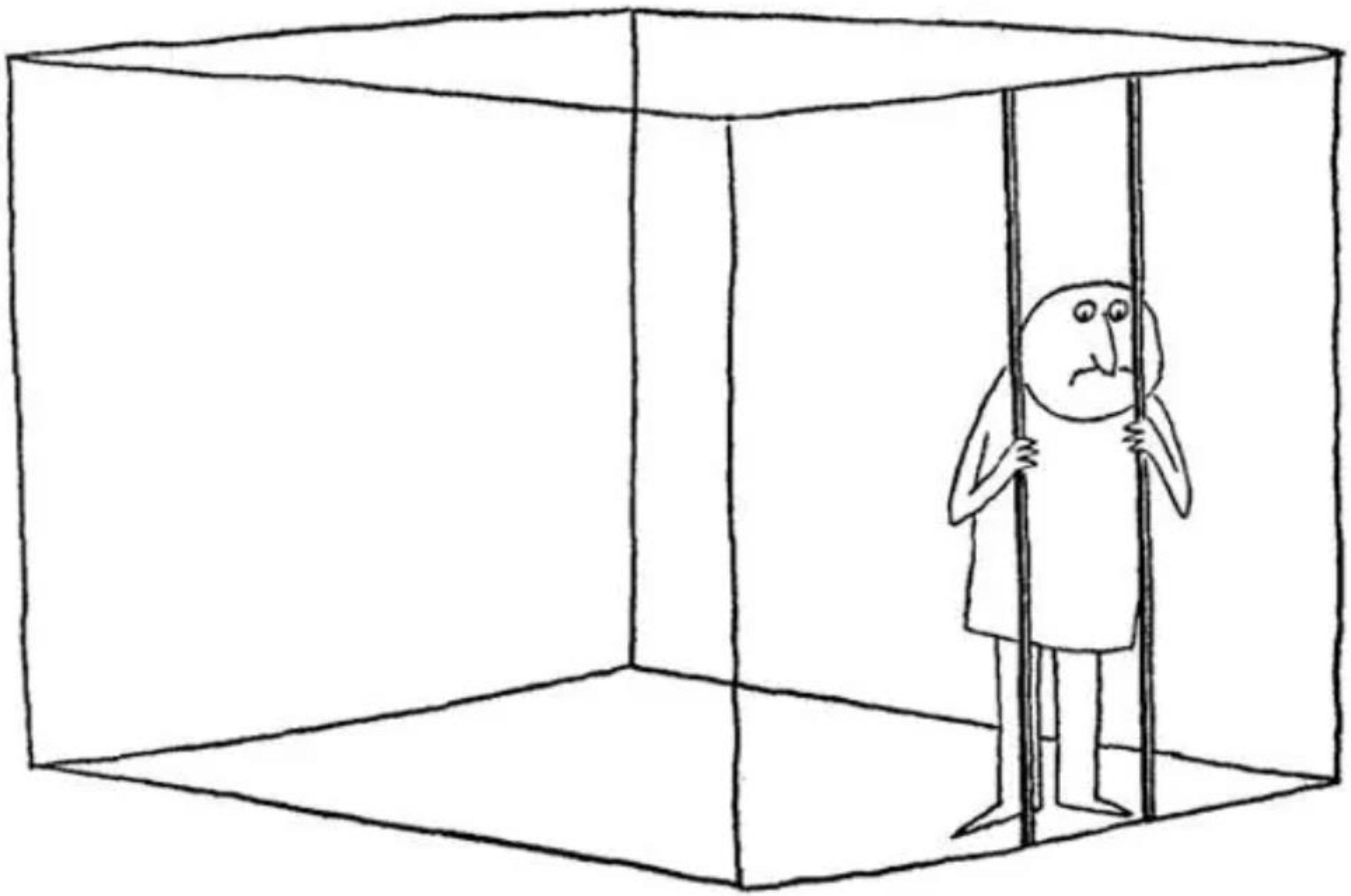
- How do we ground a "new requirement" Vs. making an already existent moral requirement explicit?
- Risk-benefit ratio principle
  - Respect for persons
  - Environmentalism

Principle 11: "Medical research should be conducted in a manner that that avoids or minimizes ~~possible~~ harm to the environment [and strives for environmental sustainability]"

Elucidation, Embedment & Enforcement



Barrier?



Informative Vs. Uninformative Research

“As the system encourages poor research it is the system that should be changed. We need less research, better research, and research done for the right reasons” (Altman, 1994)

Viewpoint

July 25, 2019

Harms From Uninformative Clinical Trials

Deborah A. Zarin, MD[1]; Steven N. Goodman, MD, MHS, PhD[2]; Jonathan Kimmelman, PhD[3]

Author Affiliations

JAMA. 2019;322(9):813-814. doi:10.1001/jama.2019.9892

Individuals who enroll in clinical trials do so with the belief that their participation will help to advance medical science. However, many trials are designed, conducted, and reported in ways that stymie this objective, a problem that can be called “uninformativeness.” From the perspective of rese a form of research inefficiency.[1] But from the perspective of participants, preventable uni ness is a serious breach of trust and a violation of research ethics.

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Home / Ideas / “Uninformative research” is the global health crisis you've never heard of

“Uninformative research” is the global health crisis you’ve never heard of

To put it bluntly: Three out of four [U.S. clinical trials] were a waste of time and money.

Research Industrial complex?

- Perverse research motivations?
- More is better?

"We are stealing from the future, selling it to the present, and calling it GDP"-Paul Hawken

Do your part!

We need researchers, funders, sponsors and the research industrial complex to do their fair share with respect to their carbon footprint

D'Souza & Samuel (2023)

Viewpoint | Climate Change and Health

November 27, 2023

Clinical Research Risks, Climate Change, and Human Health

Jeff D'Souza, PhD[1,2]; Gabrielle Samuel, PhD[3]

Author Affiliations

JAMA. 2023;330(23):2247-2248. doi:10.1001/jama.2023.23724

Chapter 13: "Have We Been Miscalculating the Potential Benefits and Risks of Research All Along?: A Closer Look at the Interconnectedness of Research Ethics, Climate Change & Global Health" in *Handbook of Environmental Bioethics*, Oxford University Press, (2025)

Summary

(1) We need to revise how we calculate the risks and benefits of health research to include those indirect harms related to climate change
(2) We should advocate for change across the research ethics ecosystem
(3) We need to do so in a fair and just way that does not exacerbate existing health inequities & opportunities

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