Insights on the carbon footprint of radiotherapy in France

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To cite this version:

HAL Id: hal-04299747
https://hal.science/hal-04299747
Submitted on 22 Nov 2023

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Cancer / Radiotherapie
Insights on the carbon footprint of radiotherapy
--Manuscript Draft--

Manuscript Number:

Article Type: Article original/Original article

Section/Category: Submission for the SFRO's annual meeting / Article pour le congrès de la S.F.R.O.

Keywords: Radiotherapy, carbon footprint, fractionation, environmental impact, mitigation strategies

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Abstract:
The French healthcare system is responsible for 8% of the national footprint. Achieving a net zero emissions scenario will require a 4-5 fold decrease of carbon emissions in the coming years. The carbon footprint of radiation therapy has not been specifically studied to date.
In this review we summarize the content of the carbon footprint dedicated session in the SFRO congress. We discuss the French healthcare system carbon footprint and its major drivers and our work on the estimation of the carbon footprint of external beam radiation therapy in the French setting. We developed a dedicated methodology to estimate the carbon footprint related to radiation therapy treatments, and describe the main drivers of emissions based on a single center as an example, namely patient’s rides, accelerators acquisition and maintenance and data storage. Based on the carbon footprint calculated in our centers, we propose mitigation strategies and an estimation of their respective potential. Our results may be extrapolated to other occidental settings by adapting emission factors (kgCO2/item or euro) to other national settings.
EBRT has a major carbon footprint that may be mitigated in many ways that may impact how radiation therapy treatments are delivered, as well as the national organization of the radiotherapy sector. This needs to be taken into account when thinking about the future of radiotherapy.
Credit Author Statement

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Figure 1 : Detailed carbon footprint of French hospitals, excluding medication and medical devices, at the national scale as estimated by The shift Project. Report can be downloaded at https://theshiftproject.org/wp-content/uploads/2023/04/180423-TSP-PTEF-Rapport-final-Sante_v2.pdf
Insights on the carbon footprint of radiotherapy

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Titre court : Insights on the carbon footprint of radiotherapy

Conflicts of interest
M.P.: Has shares and scientific advisor for Everzom, Evora bioscience, Therafast-Bio, D.A.: conceptor of DCD, other authors: NA.

**Contribution of the authors**

M.P. conceived the study, elaborated the methodology, wrote and validated the work.

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M.E., M.K. reviewed the manuscript.

A.A., C.M., S.R. and J.V. participated to the writing.

D.A. analyzed the data and participated to the writing.

G.D., S.S. coordinated the writing of the manuscript.

**Fundings**

This work was not supported by specific public or private fundings.

Ce travail n’a bénéficié d’aucune subvention spécifique émanant d’organismes de financement publics, commerciaux ou à but non lucratif.

**Acknowledgments**

We thank the workers of Bourg en Bresse, Lyon Sud, Versailles and ICO Saint-Herblain radiotherapy units for their precious support.

**Mots clés**

Radiothérapie, empreinte carbone, fractionnement, impact environnemental, stratégies de diminution

**Keywords**

Radiotherapy, carbon footprint, fractionation, environmental impact, mitigation strategies
Résumé
Le système de santé français est responsable de 8% de l’empreinte carbone nationale. La réalisation d'un scénario neutre en émission nécessiterait de diviser par 4 ou 5 les émissions carbonées actuelles dans les années à venir. Cependant l’empreinte carbone de la radiothérapie n’a pas été spécifiquement étudiée à ce jour.
Dans cette revue, nous résumons le contenu de la session du congrès de la SFRO dédiée à la sobriété énergétique et à l’empreinte carbone de la radiothérapie. Nous discutons de l’empreinte carbone du système de santé français et de nos travaux sur l’estimation de l’empreinte carbone de la radiothérapie externe. Nous avons développé une méthodologie dédiée pour estimer l’empreinte carbone liée aux traitements de radiothérapie et ainsi estimé les principales sources d’émissions, à savoir les trajets des patients et des personnels, la fabrication et la maintenance des accélérateurs et le stockage des données. Sur la base de l’empreinte carbone calculée dans nos centres, nous proposons des stratégies de réduction et une estimation de leur potentiel respectif. Nos résultats peuvent être extrapolés à d'autres paramètres internationaux en adaptant les facteurs d'émission (kgCO2/article ou euro) à d'autres paramètres nationaux.
La radiothérapie externe a une empreinte carbone majeure qui peut être diminuée de plusieurs manières, notamment en modifiant le fractionnement des traitements. Ces modifications auraient un impact important sur la manière dont les traitements de radiothérapie sont dispensés, ainsi que sur l’organisation des soins en radiothérapie. Il faut donc en tenir compte dans la réflexion sur l’avenir de la radiothérapie.

Achieving a net zero emissions scenario will require a 4-5 fold decrease of carbon emissions in the coming years. The carbon footprint of radiation therapy has not been specifically studied to date.

In this review we summarize the content of the carbon footprint dedicated session in the SFRO congress. We discuss the French healthcare system carbon footprint and its major drivers and our work on the estimation of the carbon footprint of external beam radiation therapy in the French setting. We developed a dedicated methodology to estimate the carbon footprint related to radiation therapy treatments, and describe the main drivers of emissions based on a single center as an example, namely patient’s rides, accelerators acquisition and maintenance and data storage. Based on the carbon footprint calculated in our centers, we propose mitigation strategies and an estimation of their respective potential. Our results may be extrapolated to other occidental settings by adapting emission factors (kgCO2/item or euro) to other national settings.

EBRT has a major carbon footprint that may be mitigated in many ways that may impact how radiation therapy treatments are delivered, as well as the national organization of the radiotherapy sector. This needs to be taken into account when thinking about the future of radiotherapy.

Abstract
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Introduction
Limiting warming to 2°C requires global greenhouse gas (GHG) emissions to be around 20 GtCO2e/year around 2050 (or “net zero”). With an estimated world population of about 10 billion people this would represent 2 tCO2e/year/person. Current French carbon footprint is around 9 tCO2e/year/person meaning that French emission per capita should be reduced by a factor 4 to 5 during the next 30 years. Since there is no debate in the scientific community to state that climate change can be attributed to human activities, all sectors of the society are concerned and must initiate major changes in their organizations, including healthcare.

In a 2021 study, updated in 2023, the think tank The Shift Project estimated the carbon footprint of the French healthcare system to be 49 MtCO2e/year, accounting for approximately 8% of the nation's greenhouse gas emissions. The study also highlighted that these emissions are predominantly driven by the procurement of medications and medical devices, which collectively contribute to slightly less than half of the sector's emissions. The study encompassed various components of the healthcare system, including primary care, hospitals, services for the elderly and disabled, public administration, and health insurance providers.

The medical community has started to work on the relevancy of care pathways to achieve better cost efficacy, but not yet for carbon efficacy. In order to do so, we need to better understand the carbon footprint of health products, medicine and medical devices.

The carbon footprint of radiation therapy has not been specifically and deeply studied to date. Only a few articles were published on this topic with a focus on electrical consumption or transport.

The number of radiotherapy centers is limited to about 180 in France, implying sometimes long distance travels for patients and staff. In addition, external beam radiation therapy (EBRT) relies
on the use of a heavy technical platform, with linear accelerators installed in thick concrete vaults and a huge amount of imaging data to store for decades. Thus, extrapolation of available data from other healthcare settings to the EBRT context seems difficult. However, reducing GHG emissions to achieve net zero emissions in 2050 requires a better understanding of the carbon emissions main drivers. A dedicated carbon footprint methodology has been developed in order to estimate the CO2 emissions impact of a radiotherapy center. It takes into account energy consumption, products and services use and patient trips (among other) to estimate carbon emissions of the center. We determine the most impactful domains in terms of carbon emissions in radiotherapy centers. Finally, we discuss ways to reduce the carbon footprint of EBRT.

The carbon footprint of hospitals in France
For hospitals specifically, emissions excluding medications and medical devices were estimated at 9.1 MtCO2e/year. Of this total, 23% were attributed to assets, including building construction, IT systems, furniture, machinery, and vehicles (Figure 1). Furthermore, 22% of emissions resulted from the consumption of fossil fuels for purposes such as heating, air conditioning, and hot water. Additionally, 16% of emissions were attributed to catering services, and 14% were associated with the travel of healthcare professionals, as well as patients and visitors. Each year, the distance covered by patients traveling to hospitals in France was estimated to be 5.5 billion kilometers, which is equivalent to more than 7,000 round trips between Earth and the Moon. Although for methodological reasons and data availability, the carbon footprint associated with hospital purchases of healthcare products has not been estimated, it is likely to account for a significant proportion of total emissions.

Figure 1 : Detailed carbon footprint of French hospitals, excluding medication and medical devices, at the national scale as estimated by The shift Project. Report can be downloaded at https://theshiftproject.org/wp-content/uploads/2023/04/180423-TSP-PTEF-Rapport-final-Sante_v2.pdf
Methodological aspect on the evaluation of carbon footprint of French radiotherapy center

A full methodologic guide will be published elsewhere. Briefly, a specific methodology for estimating the carbon footprint of French radiation therapy centers has been developed on the basis of ISO 14064-2018 (ISO norm for carbon accounting), the GHG protocol (an international multi-stakeholder partnership for carbon accounting) and the Bilan Carbone® methodology version 8 (a French NGO for carbon accounting). At the French level, we mostly relied on the Base Empreinte® database and the ADEME (Agence De l’Environnement et de Maîtrise de l’Energie) sectoral guide for French Healthcare sector and the report from the Shift Project (a French NGO) on the french health sector.

Organizational perimeter

We concentrated our evaluation on EBRT, excluding brachytherapy and hospitalization. We included the full scope 1 (direct CO2 emissions like fuel consumption), scope 2 (indirect consumption like electricity), and almost all of the upstream scope 3 (medical devices, drugs, machines, etc) and some of the downstream scope 3 (waste, etc). Specifically, only the carbon footprint of prescribed care (drugs, radiology, biology) related to radiotherapy has been taken into account and potential others excluded.

Functional unit

In order to ensure comparability, the total carbon footprint of an entity must be divided by a production unit. We propose to use one EBRT treatment as this denominator and to calculate the carbon footprint of one EBRT treatment. Alternatively, the carbon footprint related to the delivery of one fraction was used as a secondary functional unit.

Reports

On top of the classical sources in national and international guidelines, we propose to specifically report the following sources. Correspondence with international classification are in brackets.

- Fuel (Direct energy consumption - mobile sources with thermal motor - part 2)
- Gas (Direct energy consumption - fixed source of combustion - part 1)
- Collective heating (part 7)
- SF6 (fugitive emissions - part 4)
- Desk material (part 10),
- Medical material (part 10)
- Heating, Ventilation, and Air Conditioning (HVAC) system construction (part 10),
- Buildings & bunkers (part 10)
- Accelerators & CT scanners (part 10)
- IT material (part 10)
- Patients transportation (part 16)
- Workers transportation (part 13 and 22)
- Servers (part 9 if externalized, 10 otherwise)
- Waste (part 11)
We searched the literature for specific emission factors (in kgCO2/euro) or value per item (in kgCO2/unit) to account for each of these subparts. We established a methodology to estimate the carbon footprint of radiotherapy centers. For accelerators, CT scanners and their maintenance, we used an emission factor (kgCO2/euro) proposed by manufacturers, in good agreement with emission factors proposed by ADEME, taking amortization into account. Large, small material and information technology was accounted for using adapted emission factors or the estimated best carbon footprint when available taking into account amortization. Distance and mode of transport of patients and workers were collected and transformed in carbon footprint using emission factors per kilometer for each transport method. Medical device and drugs carbon footprint was estimated using the total expenses spent in the RT facility as well as the one associated with the patient care pathway multiplied by the adapted reported emission factor of the medical device or drug industry (ADEME).

**Evaluation of carbon footprint of a French radiotherapy center**

As an example, we report the relative carbon footprint of the Versailles radiotherapy center in 2022 using this methodology. Patients' trips were the most emissive subpart (about 30%), followed by accelerators & scanners construction, maintenance and disposal. The less CO2 intensive subparts in order of importance were servers, medical material, HVAC, buildings and bunkers and workers transportation. Direct and indirect energy consumption was limited to electricity which accounted for 2 - 3% of the total carbon footprint. Detailed results will be presented during the SFRO congress.

Of note, our multicentric study limits are that (i) it is limited to the French setting at the moment and will discuss how our estimation may be extrapolated to other countries and what are the key factors to take into account, (ii) is limited to EBRT and (iii) that a substantial uncertainty surrounds the value of carbon emission estimated per treatment strategy.

**Mitigations strategies**

Mitigation strategies should preferentially target the most emissive subparts of the footprint.

*a) Evaluation of the impact/benefit ratio of new machines*

Complex accelerators result in larger GHG emissions. The clinical benefit of these costly machines should be thoroughly evaluated and carefully weighted against their environmental impact before being used in clinical routine.

*b) Hypofractionation*
A classical treatment comprises an initial consultation, a planning CT scanner and a set-up, followed by 1 to 40 fractions. Patients' ride emissions are almost linearly linked to the number of fractions. Moreover, hypofractionation also reduces the number of accelerators needed to perform a given amount of treatments, lowering accelerators, bunkers and workers needed among others. Therefore, hypofractionation is a very effective mitigation strategy.

c) Geographical appropriateness
Patients are not always treated in the closest radiotherapy center available, including for palliative treatments. Geographical appropriateness when clinically possible, i.e. treating the patients in the closest center from where they live, could lead to significant reduction in patient transportation distance.

d) Transport mode appropriateness
Use of public transportation when clinically possible could lead to significant reduction in patients' transportation emissions. Similarly, use of normal vehicles versus ambulances limits carbon emissions, as well as use of personal vehicles that limit the number of kilometers traveled. The organization of shared travels could make it possible to reduce this impact.

e) Data deletion policy
Data storage in servers is the third most emissive subpart. Moreover, data storage per treatment is rising over time as resolution increases. From a purely mathematical point of view, with no change in data deletion policy, the amount of stored data will continue to rise exponentially. An updated data deletion policy is needed to achieve stabilization in data storage volume in the coming years.

f) Communication with patients and workers
Most of the previously described mitigations strategies will require both patient and workers collaboration. Awareness about the climate change impact of radiotherapy treatments as well as the most emissive parts of it needs to be better understood by these two populations in order to obtain these collaborations.

The potential reductions associated with the discussed mitigations strategies a) to f) have been quantified using Versailles 2022 carbon and activity report and will be presented during the congress.

Conclusion

Radiotherapy has a role to play in carbon emission mitigation. EBRT has a major carbon footprint that may be mitigated in many ways like hypofractionation, careful evaluation of the impact of new accelerators before their large dissemination and new data deletion policies among others. The accelerator industry also should engage deeper into this decarbonation approach of the sector. All these mitigation strategies may impact how radiation therapy treatments are delivered, as well as the national organization of the radiotherapy sector. This needs to be taken into account when thinking about the future of radiotherapy.
References


