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The environmental burden of melanoma: a national stage-specific carbon footprint analysis

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Teaser Text

This is the first population level England-based stage-specific estimates of the carbon footprint associated with

melanoma care.

Dear Editor, Healthcare delivery contributes approximately 4–5% of global greenhouse gas emissions.¹ Advanced stages of melanoma are associated with increased morbidity, mortality, and escalating healthcare costs² driven by the need for more intensive interventions including imaging, systemic therapies, and hospital-based care. Despite growing emphasis on sustainable healthcare,^{3,4} the environmental impact of melanoma care remains poorly quantified. While previous studies have evaluated the carbon footprint of melanoma follow-up pathways, these analyses are limited to specific components of care.⁵ Therefore, a critical gap in understanding the stage-specific environmental burden exists across the melanoma disease spectrum. Quantifying this burden may provide important evidence as to whether prevention and early detection can reduce not only the clinical and economic impact, but also the environmental burden of melanoma care.

Our study aimed to estimate the projected stage-specific carbon footprint of melanoma care in England using a prevalence-based cost modelling approach.

Using published stage-specific melanoma treatment costs for England (2023) alongside NHS reference cost and prevalence data (2022), we conducted a cost-based modelling study.⁶ Average healthcare costs for melanoma stages I–IV were calculated to represent resource utilization across diagnostic, therapeutic and stage-specific surveillance pathways over five years from diagnosis. These included inpatient and outpatient procedures, systemic therapy, relapse and supportive care. The analysis did not include the wider resource use associated with early-detection activities, including skin checks, opportunistic screening and population-level screening. Costs were converted to estimated carbon emissions using a published UK-specific healthcare carbon intensity factor (0.1558) derived from environmentally extended input–output (EEIO) analysis.⁷ These estimates should be interpreted as indicative of the scale and pattern of emissions rather than definitive carbon footprint measurements. To estimate population-level carbon burden, stage-specific per-patient carbon footprints were multiplied by 5-year melanoma prevalence in England (2022), using National Disease Registration Service (NDRS) data.⁸ This approach estimates emissions from healthcare costs when detailed life cycle assessment (LCA) data are unavailable.

Per-patient treatment costs increased substantially with advancing melanoma stage: £9,512 for stage I, £77,813 for stage II, £179,274 for stage III, and £213,801 for stage IV disease (Table 1).

Corresponding carbon emissions rose from approximately 1,482 kgCO₂e per patient for stage I to 33,310 kgCO₂e for stage IV melanoma, representing an absolute increase of 31,828 kgCO₂e and a 22.5-fold rise between early and advanced stages. At the population level despite representing the largest proportion of prevalent cases (n=41,052, 71.2%), stage I melanoma contributed a relatively modest carbon burden (60,829 tCO₂e). In contrast, Stage II (n=11,066, 19.2%), Stage III (n=4,564, 7.9%) and Stage IV melanoma (n=978, 1.7%) contributed 134,168 tCO₂e, 127,473 tCO₂e and 32,577 tCO₂e, respectively.

This national analysis provides, to our knowledge, the first England-based stage-specific carbon estimates associated with melanoma care. Our findings demonstrate a pronounced increase in carbon emissions with advancing melanoma stage at individual and population levels. This escalation reflects increasing reliance on imaging, systemic therapies, and prolonged follow-up. Although emissions per case rise with advancing stage, overall environmental impact also depends on disease prevalence. Consequently, stages II–III contribute the greatest carbon burden, underscoring the importance of early melanoma diagnosis and timely intervention not only for improving patient outcomes and reducing healthcare costs, but also for promoting environmental sustainability. Earlier diagnosis may improve clinical outcomes and be associated with lower healthcare-related carbon emissions; however, further evaluation is required to establish this relationship.

This study provides a structured approach to estimating the carbon footprint of melanoma care across disease stages, laying the groundwork for consensus-based, standardised methods for carbon footprint assessment in healthcare. Building on pragmatic, system-level modelling, our study may support future integration of environmental impact into clinical guidelines and treatment decision-making.

However, this study has limitations. Barriers include reliance on cost-based estimates and limited availability of detailed LCA data. Using healthcare costs as a proxy for carbon emissions is a crude approximation and may not reflect true environmental impact, given the complex relationship between resource use and carbon emissions. Furthermore, changes in healthcare costs over time may alter cost-derived carbon estimates without corresponding

changes in actual emissions. The cost-based approach does not fully capture emissions associated with specific components of melanoma care, such as patient travel, which may contribute disproportionately to emissions independent of cost. Our study reflects UK-based cost data and may not be generalisable to other healthcare systems. As a prevalence-based model, this analysis does not account for time since diagnosis and may overestimate the projected burden for recently diagnosed patients. Stage-specific costs were based on stage at diagnosis without independently modelling subsequent disease progression. The evolving melanoma treatment landscape, including increasing use of adjuvant systemic therapy in stage II disease, may alter future stage-specific costs and associated carbon estimates. Also, the analysis does not capture emissions associated with benign lesion assessment and excision, which may increase healthcare utilisation and environmental burden through increased awareness and potential overdiagnosis. Addressing these gaps will be essential to advance robust, standardised approaches to evaluating and reducing the environmental impact of melanoma care.

The study findings demonstrated increased carbon emissions with advancing melanoma stage. This national study lays the foundation for ongoing discussions on environmentally sustainable melanoma care pathways.

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Table 1 Summary of stage-specific 5-year melanoma prevalence in England (2022) and corresponding estimated population-level carbon burden (tCO₂e)

Melanoma Stage	Average Cost per Patient (£)	Estimated Emissions per Patient (kgCO ₂ e)	Prevalence cases (England, 2022)	Population-level healthcare cost (£ million)	Total carbon burden (tCO ₂ e)
Stage I	9,512	1,482	41,052	391	60, 839
Stage II	77,813	12,123	11,066	861	134,153

Stage III	179,274	27,931	4,564	818	127, 477
Stage IV	213,801	33,310	978	209	32, 577

kgCO₂e, kilograms of carbon dioxide equivalent. Carbon footprints were estimated using the environmentally extended input–output analysis method (where life cycle analysis data were not available) based on the National Institute for Health and Care Excellence Environmental Impact Report, which estimates a carbon intensity of 0.1558 kg CO₂e per £1 spent on pharmaceuticals (≈0.181 kg CO₂e per €1).⁷ A consistent conversion method was applied across all stages to enable direct comparison. For illustration purposes, UK average petrol car emissions factor is 0.23kgCO₂e/kilometre. Thus, carbon footprint of stage 1 disease per patient approximates a driving distance of 6,500km; stage 2 is 52,700km; stage 3 is 121,000km; and stage 4 is 145,000km. An EEIO-based approach was adopted due to the limited availability of granular resource-level data across the melanoma care pathway. While suitable for system-level estimation, this method assumes proportionality between costs and emissions and does not capture variation in carbon intensity across specific components of melanoma care (e.g. imaging, radiotherapy, and patient travel), some of which may contribute disproportionately to emissions independent of cost. Total carbon burden (tCO₂e) was calculated by multiplying stage-specific per-patient emissions (kgCO₂e) by the number of melanoma cases in England and converting to tonnes, where 1 tonne (tCO₂e) = 1,000 kgCO₂e. Cases recorded as stage unknown or stage not published were excluded from the stage-specific analysis. UK-derived cost estimates were applied to England-specific prevalence data, assuming comparable patterns of healthcare delivery and resource utilization