REVIEW

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Diagnostic Excellence in the Context of Climate Change: A Review

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ABSTRACT

Climate change is leading to a rise in heat-related illnesses, vector-borne diseases, and numerous negative impacts on patients' physical and mental health outcomes. Concurrently, healthcare contributes about 4.6% of global greenhouse gas emissions. Low-value care, such as overtesting and overdiagnosis, contributes to unnecessary emissions. In this review, we describe diagnostic excellence in the context of climate change and focus on two topics. First, climate change is affecting health, leading to the emergence of certain diseases, some of which are new, while others are increasing in prevalence and/or becoming more widespread. These conditions will require timely and accurate diagnosis by clinicians who may not be used to diagnosing them. Second, diagnostic quality issues, such as overtesting and overdiagnosis, contribute to climate change through unnecessary emissions and waste and should be targeted for interventions. We also highlight implications for clinical practice, research, and policy. Our findings call for efforts to engage healthcare professionals and policymakers in understanding the urgent implications for diagnosis in the context of climate change and reducing global greenhouse gas emissions to enhance both patient and planetary outcomes.

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INTRODUCTION

Climate change is having a profound impact on health and healthcare with the emergence of heat-related illnesses,[1] epidemiological shifts in vector-borne diseases,[2] and numerous negative impacts on patients' physical and mental health outcomes.[3] The health sector also contributes to climate change with its share of 4.6% of global greenhouse gas emissions.[3] Additionally, health damages from US healthcare pollution resulted in approximately 388,000 disability-adjusted life years lost in 2018, a disease burden reported by the study as comparable in magnitude to deaths caused by preventable medical errors.[4]

Most healthcare emissions indirectly result from delivering healthcare and relate to the production, transport, and use of pharmaceuticals and chemicals, medical devices, medical supplies, food, and waste.[4] Low-value care thus contributes to unnecessary emissions.[5,6] For example,

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inefficient diagnostic processes, over-testing, and overuse of diagnostic resources are not only costly but also consume energy resources and generate excessive greenhouse gas emissions. A single computed tomography (CT) or magnetic resonance imaging (MRI) examination can consume up to 30 kWh of energy, equivalent to the average daily consumption of a typical single-family home in the US.[7]

Diagnostic excellence involves not only making a correct and timely diagnosis but also doing so using the fewest possible resources.[8] As the effects of climate change intensify, clinicians will need to diagnose and treat emerging illnesses related to climate change while achieving high-value care and reducing waste.[9] In this article, we review the literature to describe diagnostic excellence in the context of climate change and focus on two areas. First, climate change is affecting health, leading to the emergence of certain diseases, some of which are new, while others are increasing in prevalence and/or becoming more widespread. These conditions will require timely and accurate diagnosis by clinicians who may not be used to diagnosing them. Second, several diagnostic quality issues, such as overtesting and overdiagnosis, contribute to climate change through unnecessary emissions and waste and should be targeted for interventions. We also describe the implications of these two focus areas for clinical practice, research, and policy.

CLINICAL SIGNIFICANCE

- Diagnostic excellence involves not only making a correct and timely diagnosis but also doing so using the fewest possible resources.
- Low-value care, such as overtesting and overdiagnosis, contributes to unnecessary greenhouse gas emissions.
- As the effects of climate change intensify, clinicians should develop knowledge and skills needed for timely recognition and accurate diagnosis of emerging illnesses related to climate change while achieving high-value care and reducing waste.

ACHIEVING ACCURATE AND TIMELY DIAGNOSIS IN THE CONTEXT OF CLIMATE CHANGE

A recent study reports that 218 of the 375 infectious diseases that have impacted humanity have been aggravated by climate change at some point.[10] Over the past several years, healthcare has faced major public health concerns or emergencies, including a pandemic and outbreaks related to Ebola, monkeypox, and measles—to name just a few. Recognition of new and emerging or re-emerging diseases related to climate change is likely to pose diagnostic challenges. Future pandemics with new pathogens will impact diagnosis of not only the new disease but also diagnosis of other conditions, similar to what was observed during the COVID pandemic.[11] Accurate and timely diagnosis also remains relevant for early recognition of emerging climate-related illnesses, such as heat-related illnesses, vector-borne diseases, respiratory conditions, and cancer.[12-14] Many of these conditions are known to be at risk for delayed or incorrect diagnosis,[13,15] warranting targeted efforts to improve their early recognition. Below, we discuss implications for the diagnosis of selected emerging diseases in the context of climate change.

Diagnosis of Heat-Related Health Emergencies

Recognizing heat-related illnesses will be critical, particularly with increasing patient volume, busy emergency rooms, and changing illness patterns.[1,16] Heat-related illnesses have worsened with rising temperatures and are estimated to contribute, in combination with malnutrition, malaria, and diarrhea, to an increase of 250,000 deaths per year between 2030 and 2050,[17] with associated healthcare costs of approximately $2-$4 billion dollars per year.[17] Impacts include emergencies (eg, heatstroke, heat exhaustion) and various complications, including electrolyte imbalance, neurological impairments, failure of vital organ systems, kidney stones, preterm birth, and fetal health impacts.[1,16,18] An analysis of cause-specific hospitalization rates in the US during heat waves revealed elevated admission rates for 11 medical diagnoses, including heat-related illnesses, fluid and electrolyte disorders, acute kidney failure, and urinary tract infections.[19] Heat waves worsen existing medical conditions, disproportionately affecting certain populations, such as older adults,[19] infants, and children.[20] In 2023, a retrospective study of the Veterans Affairs electronic health record data over 18 years identified approximately 33,000 documented heat-related illnesses (eg, cramps, exhaustion, and stroke) caused by the body's inability to self-regulate in high temperatures.[1] Death rates are observed to rise during and after heat waves due to heat-related illnesses and severe complications.[1]

Implications for Diagnosis with Rising Prevalence of Chronic Disease

Climate change heightens the risk of chronic illnesses such as cancer and respiratory diseases.[12,21,22] Overall, cancer incidence is rising due to increased environmental exposure to carcinogens—for example, the prevalence of lung cancer is expected to rise in part from climate change-induced air pollution, skin cancer from growing exposure to ultraviolet radiation, and gastrointestinal cancers from industrial pollutants, water supply deterioration, and food insecurity; the latter is also impacted by climate change.[23,24] Nearly a third of patients with various types of cancer already experience diagnostic errors,[25] and the frequency of these errors may also rise.

Respiratory morbidity and mortality rates are rising among individuals with chronic lung diseases (ie, asthma

and chronic obstructive pulmonary disease), aggravated by exposure to new climate-induced risk factors (ie, air pollution, air pollen, and aeroallergens).[22,26,27] The rising prevalence of these conditions place additional diagnostic and treatment burdens on healthcare systems and has implications for wait times for procedures and diagnostic evaluation. An increasing number of patients will require both long-term care management and immediate intensive care,[28] contributing additional strain on the diagnostic capacity of healthcare systems.[28-30]

Spread of Diseases and Increasing Complexity of Diagnosis

Weather directly influences vector biology (eg, lifespan, survival), and extreme weather significantly affects human society and natural ecosystems.[31] Floods and droughts, for example, create more suitable environments for larval development and raise the risk of malaria, dengue fever, and Chikungunya.[32] There is both rise and spread of new infectious diseases alongside the emergence of existing diseases encountered in locations not seen before.[33] Vector ranges are extending due to the changing climate, and these epidemiological shifts in disease transmission patterns have profound implications for public health and clinical diagnosis.[2]

Several studies have demonstrated the effect of climate change on transmission dynamics, geographic distribution, and the re-emergence of vector-borne diseases in both human and nonhuman hosts.[10,34,35] Heat waves and flooding have expanded the geographical range of mosquitos, vectors of infectious diseases (eg, dengue, malaria, yellow fever, West Nile fever, Zika), to geographic regions once considered low-risk (eg, US, Europe).[33] Further, the World Health Organization recently warned of historic dengue levels globally due to the expanding geographic spread of mosquitoes driven by global warming.[36] These changes are context-specific and disease-dependent and will require clinicians to consider rare or emerging diagnoses that may not have previously existed within their direct environments but are related to emerging epidemiological disease shifts.[2] There is also a surge of antibiotic-resistant infections. A study found a 10°C rise in temperature across geographic regions correlated with increases in antibiotic resistance rates for common pathogens (eg, *Escherichia coli* 4.2%, *Klebsiella pneumoniae* 2.2%, and *Staphylococcus aureus* 2.7%).[37] In addition to training and preparing clinicians, diagnostic services and testing for emerging conditions will need to adapt and expand.

USING DIAGNOSTIC RESOURCES APPROPRIATELY

Unnecessary tests and overdiagnosis contribute significantly to increased resource consumption, and thereby emissions,[38] underscoring the environmental imperative for high-quality diagnostic processes. Responsible and appropriate use of diagnostic resources can lower emissions and should be prioritized in the context of climate change.

Impact of Early Diagnosis

Early diagnosis can halt disease progression and reduce the likelihood of downstream tests, treatments, and hospitalizations.[9] In theory, reduced consumption of healthcare resources from early diagnosis of certain conditions can reduce healthcare-related emissions.[4,39] Hospitals are significant contributors to the carbon footprint within the healthcare sector. Early and more timely diagnosis and disease management in prehospital and preventative care settings could avoid unnecessary or prolonged hospitalizations.

Avoiding Misdiagnosis

An inaccurate diagnosis can result in treatments detrimental to patient health and the environment. For example, asthma is not only increasing in prevalence but a condition where misdiagnosis may lead to unnecessary and environmentally harmful interventions.[22,26] A significant proportion of asthma diagnoses may be incorrect, leading to unnecessary treatments and missed opportunities for addressing the actual underlying conditions.[40] The propellant used in metered-dose inhalers for treating asthma has a substantial environmental impact, possessing 1000 times the global warming potential of carbon dioxide.[26,41] While alternatives such as dry-powder inhalers exist, metered-dose inhalers are prescribed more frequently, constituting nearly three-quarters of all inhalers prescribed in the US.

Reducing Unnecessary Tests and Overdiagnosis

Over-testing increases healthcare costs and can subject patients to unnecessary harm.[42] Many potentially unnecessary procedures in healthcare consume single-use devices that contain plastic from fossil fuels.[38,43] Optimizing the diagnostic process by reducing unnecessary tests and procedures can enhance patient outcomes, reduce cost, and contribute to environmental sustainability.[44] Some examples of over-testing that have been shown to contribute to increased emissions include:

- ***Vitamin D testing:*** In measuring the health, financial, and environmental impacts of healthcare activities, evidence illustrates how unnecessary vitamin D testing leads to avoidable carbon dioxide (CO_2) emissions and healthcare costs.[38,45] In a 2022 study that measured emissions related to plastic and electricity required to run vitamin D tests, approximately 4.5 million government-funded vitamin D tests were performed in Australia, with an estimated 76% providing no net health benefit.[45] This cost taxpayers more than $87 million, resulting in a carbon footprint estimated at 28-42K kg of CO_2, equivalent to driving approximately 99-140K miles in a standard passenger car.[38,45]
- ***Medical imaging:*** Medical imaging significantly contributes to CO_2 emissions[46] and given that there is substantial

overuse of medical imaging in selected areas, this is an area ripe for interventions. For instance, in one study, over half of lumbar spine MRI requests (55.7%) were either inappropriate (28.5%) or of uncertain value (27.2%).[47] Another study evaluated CO_2 emissions attributable to unwarranted variation in the use of MRI and CT scans and found that among seven developed countries, unwarranted variation caused significant emissions of CO_2, with the US having the highest use.[48] Among common cardiac imaging techniques, CO_2 emissions increased 10-fold for cardiac CT angiography and 100-fold for cardiac MRI in less than a decade.[46] An estimate from 10 billion medical examinations per year worldwide suggests that medical imaging alone might account for approximately 1% of the overall carbon footprint.[46]

IMPLICATIONS AND NEXT STEPS

We identify several implications at the intersection of climate change and clinical diagnosis. While the evidence base is still emerging at this intersection, our findings suggest several considerations for clinical practice, research, and policy.

Clinical Practice

Findings from our review underscore the need for improving diagnostic accuracy and timeliness not just from a quality and health system perspective but also from an environmental one.[49] Unfamiliar scenarios stress healthcare professionals who must adapt to changing risk factors and disease patterns.[2,49] There is a need to develop novel assessment and treatment approaches to support clinicians in diagnosing emerging climate-related conditions. New climate-related competencies and tailored training programs focusing on specific climate-related conditions will be required to enhance diagnostic excellence.[49]

Interventions are needed to train and prepare clinicians for improving the diagnosis of emerging climate-related illnesses. For instance, a 2023 study in Pakistan assessed the effectiveness of such an educational intervention, Heat Emergency Awareness and Treatment, in the emergency departments of four hospitals. Results showed statistically significant improvements in diagnostic capabilities and treatment measures. Specifically, the rate of climate-related diagnoses increased from 3% to 7.5%, temperature monitoring rose from 0.9% to 13%, and the application of external cooling measures, such as water sponging, escalated from 1.3% to 3.4%.[16]

Clinical decision support tools can promote appropriate testing and discourage unnecessary procedures.[50] The Choosing Wisely campaign recommends that clinicians and patients decide whether tests and treatments may be unnecessary or harmful.[51] Recently, Choosing Wisely Canada released climate-conscious recommendations aimed at improving planetary health.[52]

Clinicians should play leading roles in their organizations and communities to address the health risks of climate change. They should partner with national societies to develop diagnostic excellence resources and professional guidelines.

Research

Increased funding is imperative for health services research on improving diagnosis in the context of climate change. This includes developing and testing new tools and techniques to better recognize emerging climate-related illnesses. Additional research is needed to develop and evaluate interventions that simultaneously promote diagnostic quality and reduce emissions.

While the new NIH Climate Change and Health Initiative is focusing on health impacts, there is a need for healthcare delivery system-focused research that can include topics such as quantifying existing gaps in diagnostic care for climate-related illnesses[49] development, refinement, and implementation of clinical decision-making tools to support clinicians in making environmentally friendly choices; testing strategies to better communicate and engage with patients and families on how they can help recognize and improve diagnosis for these illnesses; improving diagnostic skills and capabilities at individual, team, and system-based levels[41]; and developing novel interventions to prevent overtesting and overdiagnosis. Preventing harm from climate change requires multidisciplinary research and implementation activities, and this research can build on recent scientific advances in patient safety and diagnostic excellence. Research is needed to discover solutions and innovations to identify and manage climate-related health conditions more effectively and to safeguard patients from potential harm associated with diagnostic errors and delays.

Policy Implications

Achieving diagnostic excellence in the context of climate change requires a public health system informed by accurate diagnosis-related documentation and robust data capture mechanisms to quantify the disease burden and impact of climate-related illnesses. National and local public health systems gather existing data, perform surveillance, and implement warning systems for health systems and clinicians. These warning systems can inform health systems and clinicians about new risks and galvanize local and regional efforts to rapidly design processes to recognize, evaluate, and manage new conditions. However, there remains a concerning trend of underreporting climate change linkages for certain climate-related conditions.[53-55] Australia's national mortality records from 2006 to 2017 exemplify this significant underreporting, where less than 0.1% of 13.7 million deaths were directly or indirectly linked to extreme natural heat, with recent research indicating a 50-fold underestimation.[56,57] A lack of reliable national and global data on climate-caused diagnoses and

health outcomes hinders comprehension of the true magnitude of this crisis.[53-55]

Both globally and within the US, developing partnerships and collaborations focused on improving data collection and sharing around climate-related diagnoses and health outcomes is critical to addressing climate change.[49] Capturing the diagnosis of climate illnesses accurately could also lead to better resource allocation and a more resilient public health infrastructure that is well-prepared and has the adaptive capacity to tackle climate change. Partnerships between public health, healthcare systems, and care delivery stakeholders are needed to address the challenges of inadequate documentation of environmental causes of clinical encounters in medical records.[29,58] For example, patients impacted by air and water pollution-related illnesses incurred considerable healthcare costs[29,58] but these expenses are likely underestimations and do not capture the entire burden of climate-caused diseases due to inadequate medical record documentation.[58] A 2012 analysis of 10 climate-sensitive events in the US estimated health-related costs of $10 billion, where mortality costs surpassed the combined costs of illnesses and lost wages.[29] Despite clear links to climate, climate-sensitive events such as a homeless person with pavement burns during a heat event, a pregnant migrant woman with heat stroke, and a child wheezing from wildfire smoke, are often recorded in medical records using vague terms,[54] thus making it more challenging to identify these events and their cascading effects on health and cost outcomes. Poverty, inadequate housing, malnutrition, poor environmental conditions, and limited access to quality health services exacerbate climate change's effects on health[2] and require targeted efforts to identify and mitigate inequities.

To measure the health-related burden of climate change, particularly the worsening burdens on socially and economically vulnerable populations and communities, it is important to identify and label these health outcomes as "climate-caused" or "climate-sensitive" for accuracy.[57] New reporting standards and climate-specific ICD codes, such as "sequela from heatwave" and "exposure to wildfire smoke," are needed for more comprehensive, accurate, and timely diagnostic tracking.[54,59] Well-designed, coordinated methods to capture this data can enhance climate-related links to clinical diagnoses and provide better estimates of the substantial impact of the climate crisis.[53,60,61]

Policies should support enhanced surveillance systems to monitor the prevalence and distribution of climate-related illnesses as well as the appropriate allocation of resources to health systems and clinicians for improving diagnosis and managing climate-related conditions. Additionally, policies could incentivize clinicians and healthcare organizations to adopt practices to reduce low-value diagnostic care[41,45] and support national and local programs to train clinicians[49] on climate-related documentation and diagnostic excellence.

CONCLUSION

Several implications arise for diagnostic excellence in the context of climate change, including accurate and timely diagnoses of new and emerging conditions and appropriate use of diagnostic resources to reduce greenhouse gas emissions. Efforts are needed to engage clinicians in understanding the urgent health effects of climate change and enhance both patient and planetary outcomes while promoting high-quality, equitable healthcare and reducing global greenhouse gas emissions. Research and policy efforts can advance the understanding of climate-related diagnostic excellence and help develop strategies to address challenges described herein. Our review can promote collaborative efforts involving clinicians, health systems, policymakers, and researchers to help improve outcomes for patients, healthcare professionals, and our planet.

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