Climate change and neurology: time to talk and to act

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The global average temperature has risen by 1.2°C since the end of the 19th century. The nine warmest years on record have all occurred within the past ten years.[1] This temperature increase has been accompanied by significantly more extreme weather events. On May 17, 2023, the World Meteorological Association raised "the alarm that we will breach the 1·5°C level on a temporary basis with increasing frequency", even between now and 2027.[2] Climate change is here and will change every aspect of our lives, including health. People in the most vulnerable categories—the poorest, the youngest, the oldest, and those with chronic conditions—will be affected first and worst. People with neurological diseases are typically among the most vulnerable for many reasons, such as underlying disease biology, compromised thermoregulation, and disordered cognitive, memory, sensorimotor and autonomic systems. Neurological diseases are already the most burdensome in the world and comprise the second leading cause of death.[3] It is imperative that the neurological community thinks about climate change.

On May 18, 2023, *The Hot Brain*,[4] to my knowledge the world's first conference on climate change and neuroscience, was held at University College London (UCL, UK), bringing together people with lived experience, neuroscientists, climate and built environment scientists, clinicians, and leaders of sustainability efforts, with aims of raising awareness, fostering discussion, and promoting action about climate change and neurological diseases. No one flew to attend the meeting.

The Lancet Countdown series[5] has already reported on the serious current and projected consequences of climate change on population health, as related by Marina Romanello (UCL, UK), but has not systematically considered individual disease areas. The first three sessions began with personal testimony from individuals affected by neurological diseases about their experiences related to heatwaves in the UK, which are expected to occur more regularly as temperatures continue to rise. Galia Wilson, mother of a child with Dravet syndrome and chair of Dravet Syndrome UK,[6] and Katherine Behl, mother of a child with alternating hemiplegia of childhood and vice-chair of Alternating Hemiplegia of Childhood UK[7], related additional limitations imposed on affected children, their families, and support networks from life-threatening symptom aggravation by weather extremes and rapid temperature changes. Reports from the organisations they represent suggest a heightened risk of mortality during heatwaves, and we know little about the effects of long-term exposures to higher temperatures. In multiple sclerosis, heat is well-known to aggravate symptoms, for which detailed individual management strategies were discussed by Patrick Burke, who has progressive multiple sclerosis. Such personal consequences lie behind well-documented population-level impacts of climate change, and reflect added anxieties of many people who are already at the edge of coping.

Angel Aledo-Serrano (Vithas Madrid La Milagrosa University Hospital, Spain) and Bernadette Macrohon (Zamboanga City Medical Center, Philippines) reported their experience practising adult and paediatric neurology, respectively. Even in the heat-adapted Spanish capital, aggravation of symptoms in people with epilepsies, Parkinson's disease, and Alzheimer's disease showed the breadth of adverse health outcomes, often mediated by multiple factors, including pollution, disrupted sleep or daily routines, dehydration, medication-related disordered thermoregulation, and anxiety. Madrid has a heat-health alert system for vulnerable individuals; this system could be widely applicable if, for example, disease registries could be linked to weather forecasting systems, perhaps focusing on individuals already identified as vulnerable during the COVID-19 pandemic. In the southern Philippines, many families are already struggling to afford essential medications. Unusual high temperatures and flooding add to these existing burdens, compromising supply chains. Adaptation is already underway, for example with wider implementation of telemedicine, but for many families here, climate change is an added concern.

In addition to aggravation of established disease, climate change may also raise disease incidence, particularly for infections, especially when coupled with multiple interacting upstream drivers, such as altered land use and biodiversity, creating 'infection engines', as described by Kris Murray (London School of Hygiene and Tropical Medicine, UK). Most known human infections can be aggravated by climate change,[9] with over 1,000 unique pathways by which climatic hazards influence pathogenic diseases. As vector ranges expand, regions at risk for infection by neurotropic viruses such as dengue and Zika will extend.

James D. Mills and Nathanael O'Neill (UCL) explored the fundamental biological consequences of altered, especially higher, temperatures in several experimental systems ranging from human fetal astrocytes, through various tissue- and whole-animal models, to functioning organoids of reprogrammed human stem cells. Temperature manipulations cause widespread alterations in transcriptomic profiles, cellular pathway activities, and network dysfunction, underpinning the necessity of both controlling and reporting temperature variables in experimental studies. Human thermoregulatory control requires multiple actors in the nervous system, and multiple effectors, such as cutaneous vasodilation and sweat glands, as Michael Tipton (University of Portsmouth, UK) explained, rendering it vulnerable to neurological disorders such as autonomic diseases and spinal cord injury. Moreover, heat-related illnesses (eg, hyperthermia and heat stroke) are often marked by acute or permanent neurological impairments. Extensive existing knowledge of acclimatisation physiology, derived for example from studies of elite sportspeople, could be applied to help protect those with disease-related compromised thermoregulation. David Henshall (Royal College of Surgeons in Ireland) provided data from animal models, such as rodents in which elevation of temperature can provoke seizures. These models reveal the complexity of thermoregulation, permitting detailed analysis of, for example, central control (eg, by the pre-optic area of the hypothalamus) and receptor and effector mechanisms (eg, by transient receptor potential channels), whilst allowing dissection of the neurological consequences of heat stress and potentially providing countermeasures to adverse effects of extreme temperatures in humans.

In many high-income countries, people spend most of their lives indoors, and this is even more likely for people with neurological diseases. Anna Mavrogianni (UCL) discussed how residential circumstances can modulate – and typically worsen – climate change effects. For example, sustained elevation of indoor night-time temperatures might preclude essential relief from heat stress and can disrupt sleep, and after a heatwave, indoor temperatures can remain elevated for days. Results from the ClimaCare project[9] examining thermal behaviour of residential care facilities highlight complexities needing consideration, such as the dilemma that one building is both a resident's home and a carer's workplace: comfortable temperatures for the former may be excessive for the latter. Aggregations of buildings, including homes, bring further complications, for example through the urban heat island effect (which can aggravate nocturnal overheating). Different cities across the world can have their own local issues and their own local adaptations, as Michael Davies (UCL) explained through work in the Complex Urban Systems for Sustainability and Health (CUSSH) programme.[10] CUSHH and similar efforts may provide tools that enable vulnerable individuals, including those with neurological disorders, to make their own adaptations. Importantly, systems thinking is essential so that adaptations to optimise domestic thermal performance does not have inadvertent downsides, such as increasing indoor radon concentrations.

Health systems embody the weighty paradox that whilst they will increasingly need to manage climate-related health impacts, they are also significant producers of greenhouse gases. The UK NHS accounts for almost 5% of the entire national greenhouse gas emissions, and in some parts of the world, the carbon footprint of healthcare systems is rising. Natalia Kurek (NHS, UK) explained actions

being taken through the Greener NHS programme,[11] establishing not only where emissions arise, but also the actions the NHS is now legally committed to take to become a net-zero organisation for its own emissions by 2040 and those including all its suppliers by 2045. The plans are ambitious, but also practical, often driven by clinicians themselves. For example, the anaesthetic desflurane, a greenhouse gas 2,500 more potent than carbon dioxide, will shortly become the first drug to be removed from the NHS for the protection of the climate.

Many important themes emerged across the day. One is the complexity of climate change effects at every level, from disease pathophysiology to the built environment and healthcare system sustainability. Urgent, but carefully considered, responses, are needed and are particularly important if we are to avoid additional harms resulting from adaptation, such as exacerbating pre-existing inequalities generated by neurological diseases.

Mitigation against climate change remains possible: Mark Maslin (UCL, UK) suggested elevation limited to the internationally agreed ceiling of 1.5˚C global warming is still feasible – but only just. So perhaps the most important theme was what the neurology community should do. We need first to act to mitigate climate change, building a world that is more just and healthier for all, with resulting significant financial savings if we act now. Governmental and international action is essential but individuals can also make a difference. Engaging individuals is challenging, but Kris de Meyer (UCL, UK) outlined potentially successful approaches, based on action: taking action, making those actions visible, and promoting sustainable actions as preferred and easier options. Action helps manage climate anxiety, which can manifest when the gravity of the situation hits home. Healthcare professionals, as widely trusted individuals, can help build awareness, making health impacts of climate change part of societal and professional conversation, engaging their own spheres of influence, and developing solutions in their own specialties. The power of healthcare professionals and organisations was emphasised by Richard Smith from the UK Health Alliance on Climate Change,[12] who asked us to imagine what net-zero neurology might look like. Most importantly, we must engage people with neurological diseases in these conversations, to understand their vulnerabilities and needs, to advise about climate change, and together create a safer, healthier future in a fundamentally changing world.

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1 For more on the warmest years see https://www.noaa.gov/news/2022-was-worlds-6th-warmest-year-on-record

2 For more on The World Meteorological Association update see WMO Global Annual to Decadal Climate Update (Target years: 2023-2027)

3 For more on the burden of neurological diseases, see https://www.thelancet.com/journals/laneur/article/PIIS1474-4422(19)30411-9/fulltext

4 For more on The Hot Brain meeting see https://www.ucl.ac.uk/ion/events/2023/may/hot-brain-climate-change-and-neuroscience

5 For The Lancet Countdown see https://www.lancetcountdown.org/

6 For more on Dravet syndrome UK see https://www.dravet.org.uk/

7 For more on Alternating Hemiplegia of Childhood UK see https://www.ahcuk.org/

8 For more on the effects of climate change on infections see *Nat Clim Chang* 2022; 12, 869–75 https://doi.org/10.1038/s41558-022-01426-1

9 For more on the ClimaCare project see https://www.ukclimateresilience.org/projects/climacare-climate-resilience-of-care-settings/

10 For more on CUSSH see https://www.ucl.ac.uk/complex-urban-systems/cussh

11 For more on the Greener NHS programme see https://www.england.nhs.uk/greenernhs/

12 For more on the UK Health Alliance on Climate Change see https://ukhealthalliance.org/