that vaccine-derived poliovirus can emerge in such settings and underline the importance of implementing effective environmental surveillance in countries where it is not currently in place. The genomic data will underpin tracking of the emergence of genetically linked vaccine-derived poliovirus in Israel and New York, and could guide future control measures. The methods described are also relevant to countries where environmental surveillance is used to monitor existing vaccine-derived poliovirus outbreaks in the context of oral polio vaccine use and low vaccination coverage. Although requiring further validation, the technique described for direct detection by nanopore sequencing could offer a means of more rapid identification of polioviruses in wastewater, enabling faster public health interventions.

There are limitations to this work. Although large-scale environmental surveillance has enabled localisation of poliovirus transmission to several areas of London, it does not identify transmission in small communities or on an individual basis. Thus, it is unclear whether virus transmission is being sustained by unvaccinated or under-vaccinated individuals, or whether transmission is also occurring between vaccinated individuals. The age cohort involved in these transmission events is also unknown. Although the extent of circulation implied by these results suggests that transmission between vaccinated individuals might be occurring, stool surveys would be required to confirm this.

These important results highlight the crucial role of environmental surveillance in identifying and understanding poliovirus transmission, and guiding appropriate and timely responses. Ongoing surveillance will be essential to determine if the intervention in London works or whether further escalation is needed. Important as these findings are to the local public health response, they also starkly highlight wider deficiencies in surveillance, emphasising that today we are in the dark about what is happening across most of the planet.

AJP is the Chair of the Department of Health and Social Care's Joint Committee on Vaccination and Immunisation (JCVI) and was a member of WHO's Strategic Advisory Group of Experts on Immunization (SAGE) until Jan 1, 2022. AJP does not participate in the JCVI COVID-19 committee. Oxford University has entered into a partnership with AstraZeneca on COVID-19 vaccines. AJP has advised Shionogi on COVID-19. MH declares no competing interests.

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Plugging the medical brain drain

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More than a decade since the publication of *The Lancet's* Commission on education of health professionals for the 21st century,[1] Julio Frenk and colleagues now examine the challenges and opportunities for educating health professionals after the COVID-19 pandemic in a new Health Policy paper in *The Lancet*.[2] Their analysis includes discussion of chronic shortages of health-care workers globally. Frenk and colleagues report that in the past 10 years globally, the annual number of medical graduates has almost doubled and the annual number of nursing graduates has tripled,[2] contributing to a current global health workforce estimated at 65·1 million.[2–4] This increase in medical and nursing graduates has helped reduce the global health workforce shortage, but the gap remains substantial and was estimated at 15 million in 2020 and is expected to be 10 million in 2030.[3,4] Yet the improvement in the number of medical and nursing graduates masks the maldistribution of the workforce. There are more graduates from high-income countries (HICs) than from low-income and middle-income countries (LMICs) and a persistent 6·5-fold difference in the density of the health workforce between HICs and LMICs.[2,4] Furthermore, recent gains in the numbers of medical and nursing graduates might be offset by the great resignation associated with the COVID-19 pandemic in both HICs and LMICs.[5] Additionally, the economic, social, and political instability in many LMICs has prompted further migration waves, compounding the pressure on already overstretched health systems in LMICs.

The movement of health-care professionals from LMICs to HICs, and internally from the public to the private health sector, jeopardises health systems. The fourth round of reporting on the WHO Code of Practice on the International Recruitment of Health Personnel indicates that about 15% of health and care workers globally are working outside their country of birth or first professional qualification.[6] In Mozambique, for example, the annual incidence of physician migration was estimated to be 3·7% in 2012, but internal migration accounted for more cases of physician loss than external migration.[7] Internal migration in Malaysia, for instance, has resulted in 36% of specialists working in the private health sector providing care for 30% of the population.[8] Physician migration not only threatens health systems and patient safety and exacerbates inequitable access to quality care, but also weakens health profession education and perpetuates a cycle that prevents the expansion of a high-quality and effective health workforce. This problem is severe for some countries and regions. For example, in Nigeria an estimated 2000 physicians leave the country annually, further widening the existing physician-to-patient ratio of four doctors per 10 000 population.[9] In a study documenting physician migration over 25 years, India and Pakistan had an estimated 88 000 and 26 500 physician emigrants in 2014 compared with 46 000 and 7752, respectively, in 1990.[10] This increase partly reflects the UK National Health Service's historical and continuing reliance on doctors from these two countries.[10] The situation is likely to worsen with the intensifying health workforce shortage in the UK and the resultant recruitment of doctors from LMICs.[11]

Apart from the impact on the health system, at an average cost for medical and nursing education in 2018 of US$114 000 per physician and $32 000 per nurse, the financial price of physician and nursing migration to the health workers' country of origin has been enormous.[2] Previous reported total estimated loss of returns from investment for doctors' education ranged from $2·16 million for Malawi to $1·41 billion for South Africa.[12] More recently, Saluja and colleagues conducted a modelling estimate of the added cost of excess mortality associated with physician migration to HICs and reported an annual loss of $15·86 billion to LMICs, with the greatest total costs incurred by India, Nigeria, Pakistan, and South Africa.[13] This modelling analysis, however, may not represent the true cost to the health system, given the scale of the problem and the large burden of diseases in these countries.

The migration of health professionals results from multiple push and pull factors, including poor working conditions, low salary, insufficient training and career opportunities, inadequate research investment and infrastructure, and political instability.[14] Health professional migration is also strongly affected by the economic characteristics of origin and destination countries. Many affected countries have attempted programmes designed to retain or attract their health-care workers with varying degrees of success. Malaysia ensures that medical trainees on government scholarships sent to the UK and Australia return by having legal contracts and guaranteeing that there are jobs to return to. In Mozambique, the government-level cooperation agreements for training linked to specific health-sector development programmes motivate high rates of return to the country. Taiwan and South Korea have "reverse brain drain" programmes that encourage professionals to return from HICs, such as the USA, through investment in building excellence in research and technology made possible by economic growth in both countries.[14] However, such programmes may not be replicable elsewhere.[15]

Several successful North–South partnership models have also emerged, such as the US-funded Medical Education Partnership Initiative (MEPI) that involves 13 medical schools in 12 sub-Saharan African countries.[16] The MEPI included as a specific goal measures to retain graduates within their countries.[16] The initiative saw an expansion to more than 60 other medical schools in Africa and stimulated the establishment of ten new medical schools. However, sustaining the MEPI after the substantial grant from the US Government ended after 5 years became a major challenge. This programme has been transformative for medical education and research in the participating countries, but the long-term outcome of retention of health-care workers and scientists remains to be seen.[17] Rwanda similarly embarked on a Human Resource for Health programme by partnering with 23 US institutions of medicine, nursing, health management, and oral health.[18] The US institutions provide full-time faculty members who are paired with Rwandan faculty staff and students to ensure knowledge transfer and upgrading of clinical and didactic skills.

One of the counter arguments to the negativity surrounding medical brain drain is the potential to harness the experience and skills of expatriate health-care workers and diaspora to their country of origin. Additionally, advances in digital technologies have led to increasing opportunities for information-technology facilitated medical education in LMICs. The accelerated adoption of such medical education and improved digital connectivity and the development of global collaborative networks, which have accelerated during the COVID-19 pandemic, will provide transnational paths for the expansion of medical education even to rural areas, such as Project ECHO which is now implemented in many countries around the world and is showing promising impacts on patient and community health outcomes.[19]

Although these North–South partnerships are necessary and beneficial, to sustainably stem the medical brain drain from LMICs, policy makers in source countries must address the underlying social and economic issues that prompt individuals to leave in the first place. Investing in and strengthening domestic health care, providing career opportunities and attractive remuneration, and investment in research and development in a context of political stability are necessary ingredients to attract and retain health workers. All too often, policy makers see medical education, supporting the health workforce, and strengthening the health system as a cost and not as an investment. Investment in a high-quality health workforce and a strengthened health system not only saves lives, but is also a crucial investment in the overall economy and is necessary for prosperity. Without such support for health systems and the health workforce, the continuing exodus of health-care workers from LMICs to HICs and internally to the private health sector will ultimately cost lives and money.

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