	Critical care transfers and COVID-19: managing capacity challenges through critical care networks
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Abstract :	The intensive care units in North West London are part of one of the oldest critical care networks in the UK, forming a mature and established strategic alliance to share resources, experience and knowledge for the benefit of its patients. North West London saw an early surge in COVID-19 admissions, which urgently threatened the capacity of some of its intensive care units even before the UK government announced lockdown. The pre-existing relationships and culture within the network allowed its members to unite and work rapidly to develop agile and innovative solutions, protecting any individual unit from becoming overwhelmed, and ultimately protecting its patients. Within a short 50-day period 223 patients were transferred within the network to distribute pressures. This unprecedented number of critical care transfers, combined with the creation of extra capacity and new pathways, allowed the region to continue to offer timely and unrationed access to critical care for all patients who would benefit from admission. This extraordinary response is a testament to the power and benefits of a regionally networked approach to critical care, and the lessons learned may benefit other healthcare providers, managers and policy makers, especially in regions currently facing new outbreaks of COVID-19.
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Introduction

COVID-19 hit North West London very early, with COVID hospital admissions soaring even before the United Kingdom entered lockdown. This was particularly marked in outer North West London, which is densely populated and home to a high-risk population. This placed unprecedented demand on the capacity and resources of Intensive Care Units (ICUs) in the region, leading to the highest frequency of critical care transfers that have ever been, and may ever be, carried out in North West London.

The North West London Critical Care Network (NWLCCN) is a strategic alliance of acute hospitals, health commissioning groups and the London Ambulance Service (LAS), covering a population of 2·4 million with approximately 186 commissioned critical care beds.[1] As one of the first-generation adult critical care networks in the UK, NWLCCN has extensive experience in emergency and winter surge planning, and was pivotal in the creation of CRITCON, a tool for ICU surge reporting and management in response to 2009 H1N1 influenza.[2,3]

Critical care transfers are highly complex. They necessitate caring for physiologically vulnerable patients in an isolated environment, incurring the stress of acceleration/deceleration and risking accidental discontinuity in treatment, life support or monitoring. With an incidence of serious adverse events of up to 8·9%, critical care transfers should only be undertaken when there is a strong clinical indication with clear benefit to the patient.[4] Ordinarily, these risks are mitigated across NWLCCN by extensive transfer training, use of protocols and dedicated mobile application, adherence to national guidelines and standardised transfer equipment, and close collaboration with LAS, a member organisation of the NWLCCN.[5]

The COVID-19 pandemic posed an unrivalled challenge. NWLCCN was tasked with delivering a coordinated and innovative response to enable the sustained decompression of critical care admission surges across multiple sites over many weeks. The strength of the collegiate culture and working relationships within NWLCCN was a key enabler, distributing and dissipating the pressures of the pandemic and preventing any individual unit from becoming overwhelmed.

This article presents some of the strategies, pathways and solutions developed within NWLCCN to manage the pandemic from three viewpoints: first, Northwick Park Hospital (NPH), NWLCCN's busiest acute surge hospital; second, the NWLCCN Transfer Hub Team, set up in response to the pandemic; and third, Royal Brompton and Harefield NHS Foundation Trust (RBHT), the biggest recipient of critically ill patients within NWLCCN. We believe our front-line experience is a testament to the power of collaborative working and a regionally-networked approach. We hope this may benefit other healthcare providers, managers and policy makers, especially in regions currently facing new outbreaks.[6]

Transferring the critically ill from one of London's hardest hit hospitals

Northwick Park Hospital was one of United Kingdom's hardest hit hospitals for ICU COVID-19 admissions, relative to baseline critical care capacity.[7] NPH is a large district general hospital situated near Heathrow Airport in North West London, serving a diverse population of approximately one million; where Black, Asian and Minority Ethnic (BAME) communities, who are at an increased risk of COVID-19[8], predominate. It houses a tertiary Infectious Diseases service and one of London's busiest emergency departments. These were all ingredients for what followed.

NPH acted early and pre-emptively. After the first COVID-19 case arrived in the UK on 31 January 2020, we initiated training and simulation to develop pathways for triage, safe intubation, and transfer to ICU for suspected COVID-19 patients under strict personal protective equipment (PPE) and infection control precautions. On 3 March, these preparations were put to the test as we admitted one of the first intubated COVID-19 positive patients in the country to ICU. We were then among the first to see the rapid, devastating impact of COVID-19 spreading through our local communities, with demand for critical care capacity surging rapidly. Critical care capacity was increased in planned phases, with operating theatres, post-surgical recovery, and finally medical wards being converted into ICU beds. However, both the onset and rate of admissions at NPH were outliers within London and nationally, and these beds filled up as quickly as they were opened (Figure 1).
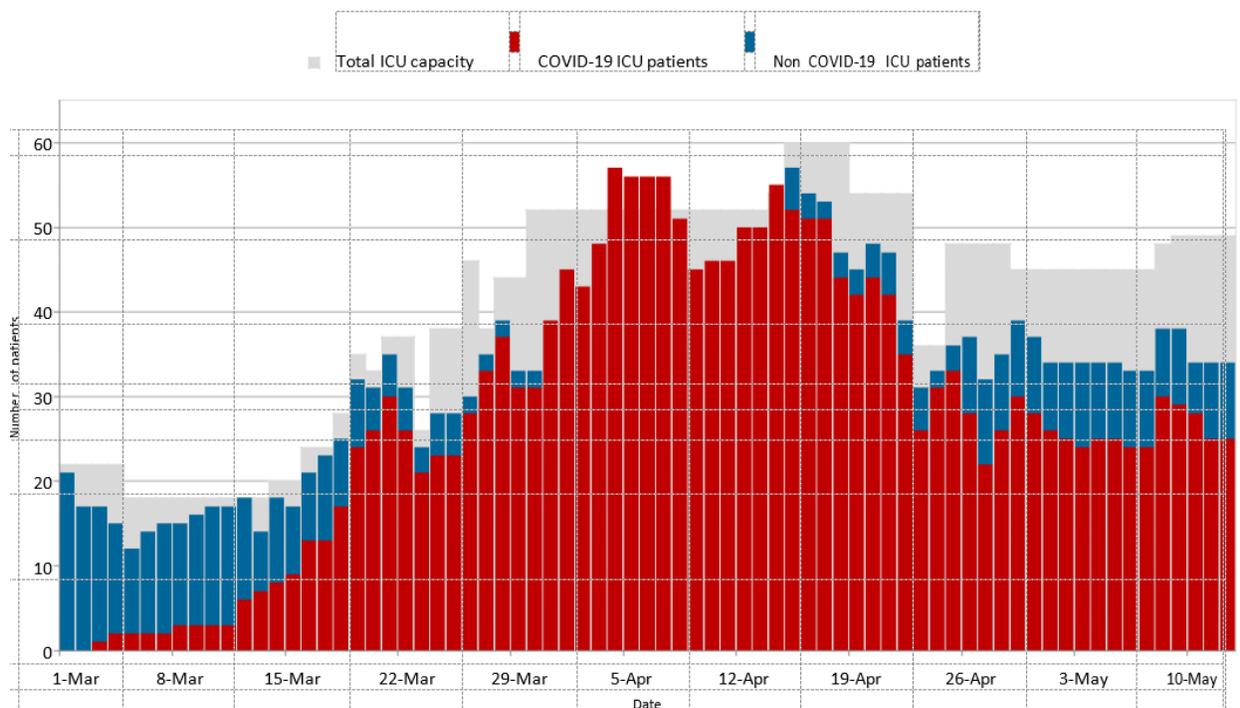

Figure 1. Northwick Park Hospital's daily ICU bed capacity, COVID-19 and non-COVID-19 bed occupancy.

On 19 March, NPH declared a 'critical incident', as the number of ventilated COVID-19 patients exceeded available critical care beds and the rate of simultaneous new admissions exceeded staffing resources.[9] This occurred before the UK entered lockdown on 23 March, and the publication of clinical guidelines for the management of surge during the pandemic on 12 April (Figure 2). Capacity-driven inter-hospital transfers were already taking place, but the numbers of new cases warranted urgent escalation. We therefore requested assistance from NWLCCN to alleviate pressures on capacity by coordinating transfers of critically ill COVID-19 patients to other hospitals within the sector.
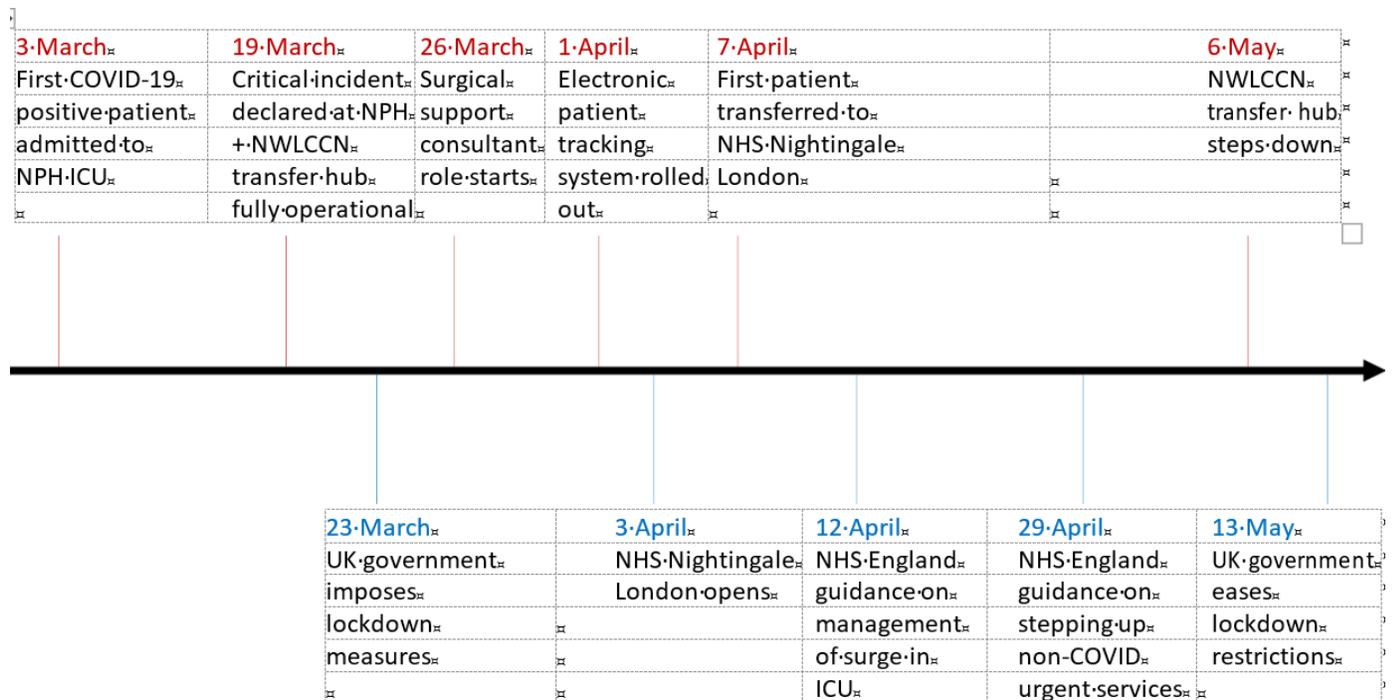
3·March	19·March	26·March	1·April	7·April		6·May
First·COVID-19 positive·patient admitted·to NPH·ICU	Critical·incident declared·at·NPH +·NWLCCN transfer·hub fully·operational	Surgical support consultant role·starts	Electronic patient tracking system·rolled out	First·patient transferred·to NHS·Nightingale London		NWLCCN transfer· hub steps·down

23·March		3·April	12·April	29·April	13·May
UK·government imposes lockdown measures		NHS·Nightingale London·opens	NHS·England guidance·on management of·surge·in ICU	NHS·England guidance·on stepping·up non-COVID urgent·services	UK·government eases lockdown restrictions

Figure 2. Timeline of events in Northwick Park Hospital (red) and UK (blue).

Throughout this first peak, we frequently reviewed over 20 patients each day for ICU admission, and intubated an average of 7·5 patients daily for several weeks. Every day, we admitted enough patients to fill a medium-sized district general hospital ICU. Inter-hospital transfers were our only means of controlling capacity and ensuring provision of safe, high quality critical care (Figure 3). This bought us time to expand, and ultimately triple, our baseline ICU bed capacity. To support the high number of patients and inter-hospital transfers we adapted our processes; reorganising space, staffing, equipment, and training.[10] We upskilled non-intensive-care-trained health professionals, and deployed them into ICU. Hospital COVID-19 guidelines and standard operating procedures (SOPs) were rapidly created, with multidisciplinary collaboration from hospital management, ICU and infection control teams. An electronic patient tracking system was developed, allowing real-time monitoring of patient flow within the hospital.
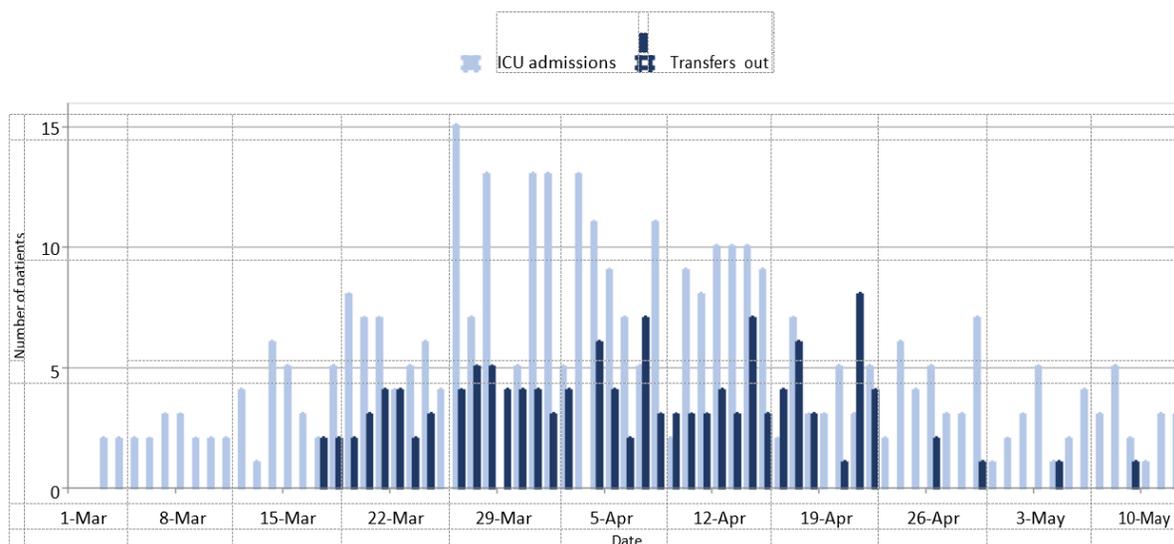
Figure 3. Daily admissions to and transfers out from Northwick Park Hospital ICU.

Anaesthetists were assigned to dedicated intubating teams, and the entire multi-professional ICU team was providing hands-on care to critically unwell patients in line with national guidance. With elective surgery cancelled, consultant surgeons joined a new role as Surgical Support Consultants,[11] providing logistical support for expanding ICU capacity and organising the flow of patients in and out of ICU. Appropriate patients for inter-hospital transfers were identified and prepared nightly, and communicated to NWLCCN in the morning. Transfer teams, often arriving in full PPE, were met at the hospital entrance and chaperoned to ICU for patient handover, with prepared drugs and equipment ready for transfer. We saw these seemingly small measures yielding substantial improvements in transfer efficiency and safety. On one occasion, four simultaneous transfer teams were accommodated at NPH. During our busiest month, an average of 3·5 patients were transferred each day.

From 1 March to 12 May, when the first steps were taken to ease national lockdown, we transferred 136 of 365 (37%) total patients admitted to ICU in NPH. Many patients owe their survival to the close collaboration and aid from NWLCCN and receiving hospitals.

Creating and coordinating NWLCCN Transfer Hub

On 17 March 2020 the NWLCCN quarterly planning meeting was in session when NPH first reached out for urgent external support; COVID-19 admissions were rising, and NPH required mutual aid to maintain capacity within its ICU. With COVID-19 admissions forecast to increase exponentially across the region, it became clear that NWLCCN would need to unite to deliver a sustained and high volume of patient transfers over the coming weeks to distribute patient volumes and manage capacity at NPH and other NWLCCN ICUs (Figure 4).
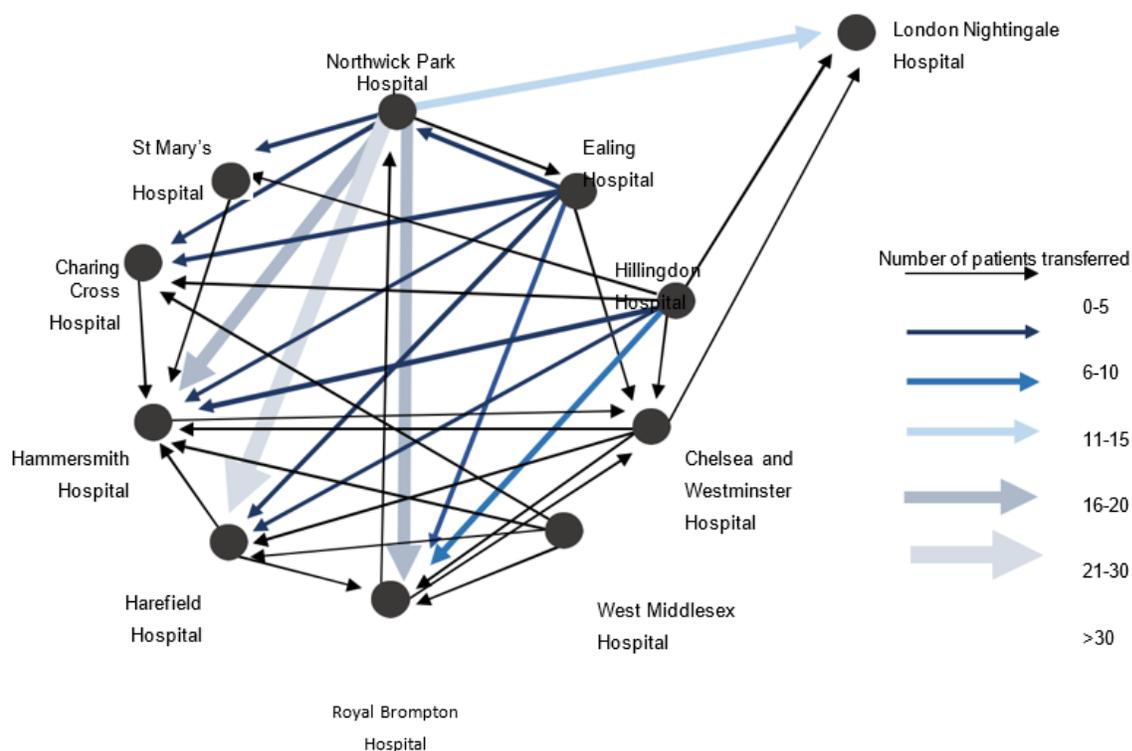
Figure 4. Transfers by location and volume within NWLCCN from 17th March to 6th May 2020.

A NWLCCN COVID-19 Transfer Hub was rapidly mobilised to manage the strategy and logistics of decompression. This was coordinated by three doctors, seconded to the role full time and armed with a dedicated phone line and email address to act as a single point of contact for NWLCCN's transfer work. We joined video conferences each morning with medical directors from across all hospitals within North West London, where their ICU bed status was declared and anticipated staffing or equipment issues raised. We continued to communicate closely throughout the day with ICU leads to get real-time updates on the fluctuating operational and clinical pressures on the ground. Our minute-to-minute oversight of demand and capacity allowed us to tactically plan the volume and destinations of patient transfers. Over the coming weeks, this constant dialogue with ICUs formed the backbone of a close, collaborative relationship between the Hub and each of the clinical leads.

The organisation and logistics of transferring critically unwell patients during the COVID-19 crisis posed extra challenges to an already highly complex task fraught with inherent risk.[4] Our first challenge concerned the staffing of transfer teams. In England, save for specialised services, e.g. Extra Corporeal Membrane Oxygenation (ECMO) transfers, adult critical care transfers are generally performed by referring hospital teams (often a critical care nurse and ICU or anaesthetic doctor).[12] This contrasts with the use of dedicated regionalised transfer teams in Scotland and

Wales, and in paediatric practice. However, with ICUs undergoing rapid expansion and high rates of staff sickness and self-isolation, there were concerns that taking staff from already stretched ICUs could limit the volume and speed of transfers, and compromise care in the rest of the unit. Whilst receiving ICUs could frequently send transfer teams to retrieve patients, we recognised the need for a staffing safety-net to ensure that vital transfer work could continue reliably in all circumstances.

We therefore established an emergency bank of stand-by transfer volunteers consisting of critical care nurses, intensive care doctors and anaesthetists from the region that we could draw upon. A prerequisite to joining the bank was evidence of formal training in transferring critically ill patients. At its peak, the bank had 69 members. The number of professionals volunteering to work when off-duty is a testament to the culture within NWLCCN, and also a legacy of the NWLCCN's previous work on transfer training, education and transfer safety.[13,14] To support operations, we adopted an app-based framework to manage the bank. This allowed volunteers to schedule shifts according to their availability, and facilitated the automatic distribution of SOPs developed by the Hub for the transfer of COVID-19 ICU patients and other essential information to our volunteers. In total, 36% of transfers were performed by retrieval teams from the receiving unit, 14% by sending teams from the decompressing units, and 26% by transfer volunteers, with the remaining 24% performed by LAS and out-of-sector teams. This patchwork approach allowed us to flex resources up or down on a daily basis to meet fluctuating demand for patient transfer.

Another challenge concerned transfer vehicles. As the degree of strain that COVID-19 would impose on LAS was uncertain, we secured the services of an additional four independent ambulances. Two were equipped with transfer equipment including ventilators, thus ensuring that decompressing hospitals were not without vital equipment (e.g. for intra-hospital transfers or ad hoc additional bed capacity). We retained centralised control of the deployment of these vehicles, enabling them to be dispatched according to a real-time holistic appraisal of capacity and equipment pressures within the Network. Overall, the Hub's independent ambulances performed 71% of ICU transfers.

To the extent possible, we sought to anticipate transfer demand in advance, and pre-positioned ambulances at expected sending or retrieving hospitals at the start of each day. However, there were inherent limitations on our ability to pre-plan the transfer of specific COVID-19 patients due to rapid deteriorations in patient condition, and constant changes in ICU capacity at potential receiving hospitals. This continuous state of flux heightened the importance of clear communication in order to provide ICU consultants with immediate intelligence on sector-wide bed availability for mutual aid.

During the 50-day period from 17 March to 6 May 2020, the Hub oversaw the transfer of 238 patients (Table 1), at its peak coordinating 13 patient transfers in a single day, into seven different receiving ICUs. Over the Hub's busiest seven-day period (commencing 4 April), we averaged 9 transfers per day. Critical care transfers are usually driven by clinical escalation, and only very rarely by capacity; however, during these 50-days alone, we performed 223 capacity-driven transfers, which is nearly 10 times the annual average from the last 3 years. Over 95% of patients

transferred were (or were suspected to be) COVID-19 positive. While equipment and logistical challenges were occasionally reported, no incidents of death or serious clinical deterioration occurred during transfer.

Table 1. Critical Care Transfers from North West London Hospitals.

	COVID-19 response emergency (17/03/20 - 06/05/20)	Equivalent 50-day period in 2019	Annual average numbers (2017-20)
Total number critical care transfers	238	106	682
Indication for transfer:	..	..	..
ICU capacity transfers	223 (94.5%)	0 (0%)	25 (3.6%)
Clinical	7 (3%)	83 (78.3%)	529 (77.5%)
Repatriation	8 (3.5%)	23 (21.7%)	129 (18.9%)
Level of transfer:	..	..	..
Mechanically ventilated	232 (97%)	49 (46.2%)	325 (47.6%)
Not mechanically ventilated	6 (3%)	57 (53.8%)	357 (52.4%)

A centralised Hub for transfer coordination was an essential enabler for optimising mutual aid delivery within NWLCCN. The Hub served as a real-time arbiter of ICU capacity pressures across NWLCCN, facilitating the rapid and resource-efficient delivery of a high volume of transfers. Centralising transfer coordination also reduced the associated organisational and logistical demands placed on ICU clinicians, allowing them to focus on clinical needs and patient care.

Streamlining transfers to receiving hospitals within the critical care network

RBHT is a specialist cardiothoracic centre. Its two campuses within North West London, The Royal Brompton Hospital and The Harefield Hospital, provide tertiary and quaternary care to a wide region of the country, and RBHT is the ECMO provider for South West England. During the pandemic, The Harefield Hospital was the designated cardiac surgical centre for West London and a COVID-19 Heart Attack Centre, and The Royal Brompton Hospital continued to provide veno-venous ECMO services to the South West of England. While maintaining receiving capabilities for these specialist clinical pathways, between them these two centres provided the greatest mutual aid to other ICUs within North West London.

There were a number of enabling factors that contributed to this ability. Firstly, as neither hospital has an emergency department, we received no direct COVID-19-related admissions. Moreover, we have

substantial baseline ICU capacity, given our specialist surgical centre status. We could therefore restructure normal hospital operations to create dedicated ICUs for mutual aid within NWLCCN. At our peak, we surged to 32 ventilated COVID-19 beds at The Harefield Hospital and just under 80 at The Royal Brompton Hospital.

Secondly, we quickly recognised the importance of using a dedicated retrieval team. As an ECMO provider, we are experienced in the retrieval of patients presenting with severe acute respiratory failure. However, it became clear that transferring patients in large numbers during the pandemic posed significant challenges. Our transfers were initially conducted on a transfer-by-transfer basis, using the staff and equipment that were available. This was inefficient, and limited our daily transfer capacity. We therefore introduced a dedicated retrieval rota, which allocated a critical care consultant, registrar and nurse from each hospital to retrievals each day. This provided an invaluable staffing resource to the Transfer Hub coordinators who could draw upon our retrieval capability and capacity; of the 104 patients received by RBHT from NWLCCN, 64% were retrieved using RBHT transfer teams. The clinical expertise and resources of our hospitals allowed us to transfer some of the sickest COVID-19 patients, including in the prone position when necessary.

Thirdly, we streamlined our logistics processes. We bought our own ambulance trolley and installed a footbridge, ventilator bracket, oxygen cylinder tray and high-quality fluid and equipment poles. RBHT retrieval teams would check their equipment each morning and liaise with the Transfer Hub, who would then allocate an ambulance and provide a list of patients and locations

7

for the day. We directed referring hospitals to send referral letters to a single designated RBHT email address. We treated equipment as contaminated for the day once it had entered the red zone at any referring hospital, requiring all subsequent ambulance journeys to be undertaken in PPE. COVID-19 patients were brought in through a designated entrance, and kept wholly separate from non-COVID areas of the hospital. Any necessary imaging could be performed upon entry to the hospital. All equipment was cleaned and stored in a designated clean area of the ICU after the final retrieval of each day.

Finally, we built on our expertise in managing mechanically ventilated patients undergoing tracheostomy weaning by establishing a dedicated COVID-19 tracheostomy weaning unit at The Royal Brompton Hospital. Our bespoke pathway accepted referrals and transfers from across NWLCCN of patients appropriate for a tracheostomy or who already had one. We worked closely with surgeons, specialist respiratory physicians and physiotherapists, enabling us to share our specific expertise in this field for the mutual benefit of all patients in NWLCCN.

Conclusion

Although the UK's baseline critical care capacity lies beneath the European average (6·6 critical care beds per 100,000 population in the UK vs. 11·5 per 100,000 European average)[15], critical care transfers are rarely capacity-driven, and normally undertaken for clinical escalation. Our experience has demonstrated that such transfers can be an effective crisis management tool for distributing regional demand in a major conurbation, where demand at individual sites can show significant variation and where demand may outstrip capacity at individual sites despite extensive, city-wide capacity expansion.

Longer-range mass critical care transfer processes have been utilised internationally during the COVID-19 pandemic, including high-speed rail-based transfers from Paris to Bordeaux,[16] and military-operated aero-medical transfers of critically ill patients from Bergamo, Italy to Germany.[17]

Co-ordinated, clinician-led mutual aid and interhospital transfers were essential to North West London's ability to cope with pandemic-induced regional critical care demand. Alongside the creation of extra capacity, this ensured timely and unrationed access to critical care for all patients who would benefit from admission. Our experience, both during and prior to the pandemic, is informing discussions about developing a more formalised transfer service for critical care patients across London.

However, the benefits of distributing demand across a region must be balanced against clinical transfer risks. Within the context of NWLCCN, a mature multi-organisation regional critical care network, we believe we successfully minimised these risks through rapid regional innovation, including by establishing a central coordinating hub and developing standard operating procedures for distribution via an app-based framework. NWLCCN's established collaborative learning and governance program provided not only operational and clinical harmonisation, but also longstanding pre-pandemic working relationships with mutual familiarity and patterns of

support. This enabled an unprecedented joint effort by the NWLCCN team and clinicians across all NWLCCN sites to support patients in hospitals other than their own.

Quality improvement literature has discussed potential benefits of networks over other structures, given that networks have a flatter hierarchy and thus facilitate crisis learning.[18] Unlike many other critical care networks in the UK, NWLCCN is not structured around a large single tertiary centre fed by district hospitals, but instead comprises a complex array of academic centres and large or medium-sized general hospitals. It therefore operates on a point-to-point, rather than hub-and-spoke, model. This exacerbates the logistical complexities of transfers, which must deliver patients to multiple sites within a network, as opposed to a single focal receiving site. However, our experience demonstrates that with shared learning, rapid coordination, and regional innovation, critical care transfers can be successfully coordinated across such a network. This suggests that local networks may have structural advantages over national centralised structures, in being more agile and able to respond to local challenges. However, network-initiated and volunteer-based transfer services may not be sufficiently robust to cope in the face of unrelenting demand and when formalising these services in the future, one challenge will be to ensure that this does not become a limiting factor.

The COVID-19 pandemic was tremendously challenging for North West London, whose pattern of population and disease would undoubtedly have resulted in critical care demand exceeding supply at individual sites without a coordinated response. Surviving this crisis has given us an unique opportunity for learning, development and growth.

Authors' Contributions
All authors worked collaboratively and contributed equally to the content and writing of this article.

Declaration of interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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