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Original Article

Patient outcomes following transfer between intensive care units during the COVID-19 pandemic

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Summary

Transferring critically ill patients between intensive care units (ICU) is often required in the UK, particularly during the COVID-19 pandemic. However, there is a paucity of data examining clinical outcomes following transfer of patients with COVID-19 and whether this strategy affects their acute physiology or outcome. We investigated all transfers of critically ill patients with COVID-19 between three different hospital ICUs, between March 2020 and March 2021. We focused on inter-hospital ICU transfers (those patients transferred between ICUs from different hospitals) and compared this cohort with intra-hospital ICU transfers (patients moved between different ICUs within the same hospital). A total of 507 transfers were assessed, of which 137 met the inclusion criteria. Forty-five patients underwent inter-hospital transfers compared with 92 intra-hospital transfers. There was no significant change in median compliance 6 h pre-transfer, immediately post-transfer and 24 h post-transfer in patients who underwent either intra-hospital or inter-hospital transfers. For inter-hospital transfers, there was an initial drop in median PaO_2/F_IO_2 ratio: from median (IQR [range]) 25.1 (17.8–33.7 [12.1–78.0]) kPa 6 h pre-transfer to 19.5 (14.6–28.9 [9.8–52.0]) kPa immediately post-transfer ($p < 0.05$). However, this had resolved at 24 h post-transfer: 25.4 (16.2–32.9 [9.4–51.9]) kPa. For intra-hospital transfers, there was no significant change in PaO_2/F_IO_2 ratio. We also found no meaningful difference in pH; $PaCO_2$; base excess; bicarbonate; or norepinephrine requirements. Our data demonstrate that patients with COVID-19 undergoing mechanical ventilation of the lungs may have short-term physiological deterioration when transferred between nearby hospitals but this resolves within 24 h. This finding is relevant to the UK critical care strategy in the face of unprecedented demand during the COVID-19 pandemic.

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Introduction

Inter-hospital transfer of critically ill patients is often required within the National Health Service (NHS) in the UK, with over 11,000 critically ill patient transfers per year [1]. This may occur for several reasons including transfer to a specialist centre for specific clinical management, repatriation and capacity reasons. Before 2017, the latter accounted for only a small proportion (4.4%) of transfers overall in the South West England Critical Care Network [2].

COVID-19, caused by SARS-CoV-2 infection, has caused a high incidence of acute respiratory and multi-

organ failure requiring organ support and admission to an intensive care unit (ICU) [3, 4]. In the UK, there have been several surges of patients with COVID-19 resulting in high numbers of hospital and, subsequently, ICU admissions [5], creating pressure on bed capacity. During these periods, a high number of inter-hospital ICU to ICU transfers took place to relieve pressure on beds, preventing units becoming overwhelmed, and to create capacity for admissions from the Emergency Department. Indeed, nationally, 2793 patients were transferred between ICUs between September 2020 and March 2021, of which 2320 were for comparable clinical care, rather than for specialist management, and, in London, 20% of ICU admissions were due to transfers from other hospitals [6].

The North West London Critical Care Network is a collaboration of five NHS Trusts (10 hospital sites), covering 1.8 million patients [7]. In order to manage the increased ICU demand during the first peak of the COVID-19 pandemic in 2020, a high number of ICU transfers occurred within this network [8]. However, there is a paucity of data examining clinical outcomes following transfer of patients and whether this strategy affects patients' physiology or outcome. This is a particularly pertinent issue since transfers of critically ill patients can be associated with complications or difficulties in up to two-thirds of cases [9]. Understandably, therefore, careful patient selection is advised to mitigate these risks [10].

We investigated all critically ill COVID-19 patient transfers between three different hospital sites over a 1-y period (March 2020 to March 2021). We evaluated whether any physiological deterioration occurred following an ICU transfer and the success of ICU transfers as a strategy to compensate for increased ICU demand.

Methods

Ethical approval was not required as this study was carried out as a service evaluation within the NHS and recorded under the auspices of the clinical audit office at Imperial College Healthcare NHS Trust. This comprises four hospitals 5–6 km apart, three of which had multiple ICUs during the COVID-19 pandemic (Charing Cross, Hammersmith and St. Mary's). We retrospectively evaluated all adult patients with COVID-19 undergoing mechanical pulmonary ventilation transferred between the three hospital sites. Inter-hospital transfers were included if the patient tested positive for SARS-CoV-2 infection and their lungs were mechanically ventilated for at least 6 h preceding transfer to at least 24 h after. Transfers were excluded if the patient was spontaneously breathing, non-invasively ventilated during transfer or if the transfer involved an ICU-to-ward stepdown or 'discharge' due to death (Fig. 1). As controls, we compared this patient cohort with those moved between different ICUs within the same hospital (intra-hospital transfers).

Data were collected from the IntelliSpace Critical Care and Anaesthesia critical care information system (Koninklijke Philips N.V., Amsterdam, the Netherlands) and we recorded: age; sex; date of transfer; time of transfer; type of transfer (either inter- or intra-hospital); ICU length of stay pre- and post-transfer; and number of days ventilated pre- and post-transfer. The following data on investigations were collected 6 h pre-, immediately post- and 24 h post-transfer: fraction of inspired oxygen (F_IO_2); partial pressure of oxygen (PaO_2); partial pressure of carbon dioxide ($PaCO_2$); pH; base excess; serum lactate concentration; tidal volume; peak airway pressure; positive end-expiratory pressure; and norepinephrine requirement. PaO_2/F_IO_2 (P/F) ratios and dynamic pulmonary compliance were collected at 6 h pre-, immediately post- and 24 h post-transfer for each patient.

Primary endpoints were change in P/F ratio and change in compliance from 6 h pre-transfer to immediately post-transfer and to 24 h post-transfer (for all inter-hospital and intra-hospital ICU transfers). Secondary endpoints were change in pH, $PaCO_2$, lactate, base excess and norepinephrine requirement over the same time-points.

The Shapiro–Wilk normality test was carried out and comparison between the groups for non-continuous data was performed using Friedman's test corrected for multiple comparisons. All data were anonymised and analysed blind using GraphPad Prism (v8.0; GraphPad Software, San Diego, CA, USA). A p value of < 0.05 was defined as the minimum threshold for significance.

Results

During the study period, there were a total of 504 critically ill patients transferred within Imperial College Healthcare NHS Trust, of which 137 met our inclusion criteria (Table 1). The overall study cohort had a mean (SD) age of 62 (11) y with a male predominance (66%). Median (IQR [range]) dynamic compliance 6 h pre-transfer was 25.3 (20.2–36.9 [10.2–113.0]) ml.cmH_2O. Median P/F ratio at 6 h pre-transfer was 22.0 (17.0–29.1 [10.1–78.0]) kPa. Twenty-nine (21%) patients had mild acute respiratory distress syndrome (ARDS), 77 (56%) had moderate ARDS and 13 (9%) had severe ARDS as defined by the Berlin criteria [11]. Of the overall cohort, there were 23 (17%) deaths and 114 (83%) patients remained alive. All 23 deaths occurred >24 h post-transfer. Forty-five patients underwent inter-hospital transfer compared with 92 who were moved between ICUs within the same hospital. Table 1 summarises the baseline

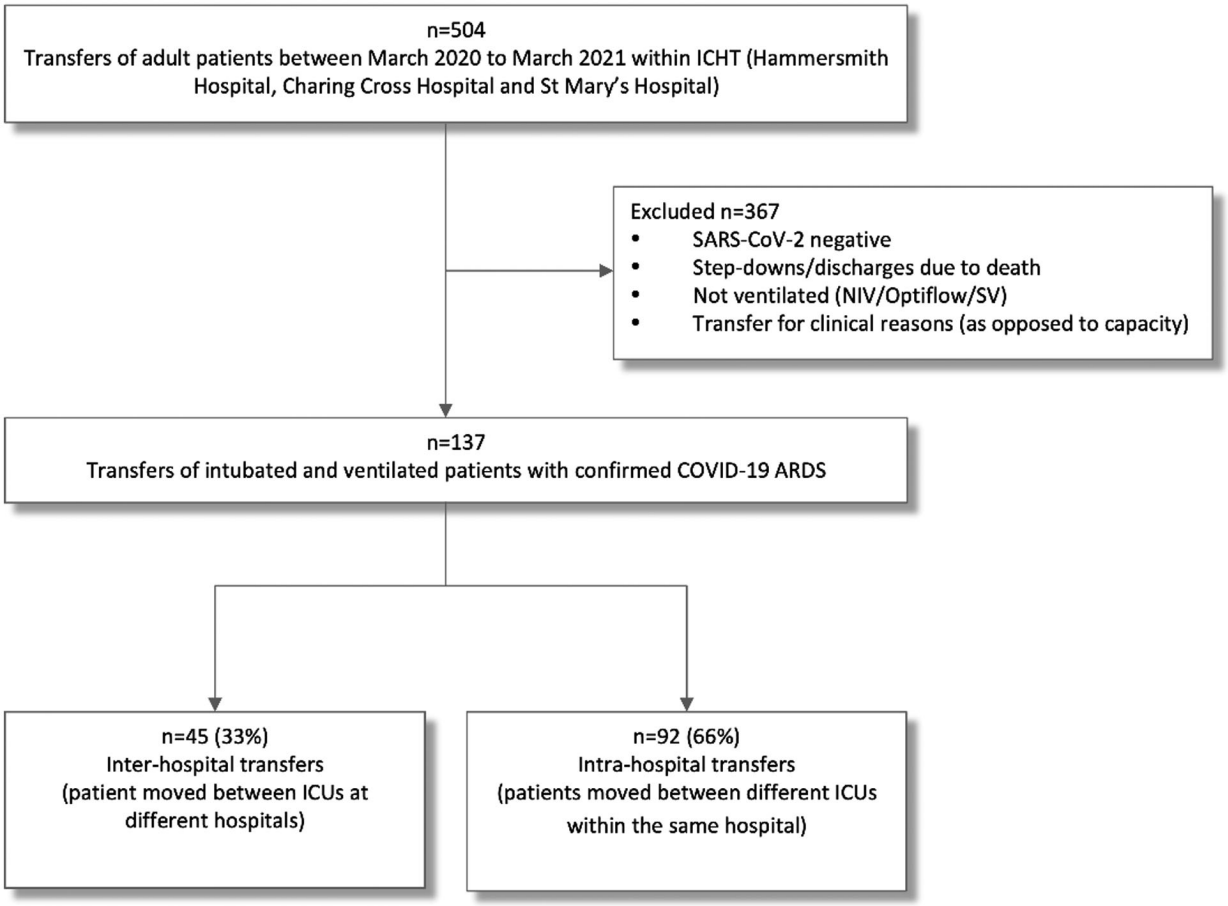

Figure 1 Patient recruitment and the hospitals involved.

characteristics of inter- and intra-hospital ICU transfers and key differences between these groups. There was no increase in mortality in inter-hospital transfers compared with intra-hospital transfers.

Inter-hospital transfers involved a transfer team, connection to a portable ventilator, an ambulance journey to a new hospital site and ICU, and then synchronisation to another ventilator following arrival. Intra-hospital transfers were less cumbersome, shorter and did not involve an ambulance journey. Therefore, as expected, patients chosen for inter-hospital transfer were suitably selected, with less deranged physiological parameters (e.g. P/F ratios) compared with those who underwent intra-hospital transfers (Tables 1 and 2).

In the cohort of patients who underwent inter-hospital transfer, there was no significant change in dynamic compliance: 25.8 (20.2–38.1 [14.3–59.6]) ml.cmH_2O 6 h pre-transfer, 23.1 (19.0–37.5 [10.8–78.8]) ml.cmH_2O immediately post-transfer and 25.8 (19.9–46.4 [10.5–77.5]) ml.cmH_2O 24 h post-transfer (Fig. 2). Similarly, following intra-hospital transfers, there was also no significant change in median compliance: 25.1 (20.1–36.6 [10.2–113.0) ml.cmH_2O 6 h pre-transfer, 25.1 (19.2–40.9 [11.6–81.2]) ml.cmH_2O immediately post-transfer and 29.2 (19.1–42.5 [6.2–111.4]) ml.cmH_2O 24 h post-transfer. For inter-hospital transfers, there was an initial significant drop in median P/F ratio from 25.1 (17.8–33.7 [12.1–78.0]) kPa 6 h pre-transfer to 19.5 (14.6–28.9 [9.8–52.0]) kPa immediately post-transfer ($p < 0.05$). However, this had resolved by 24 h post-transfer: 25.4 (16.2–32.9 [9.4–51.9]) kPa (Fig. 3a). For intra-hospital transfers, there was no significant change in median P/F ratio: 20.5 (15.9–27.3 [10.1–50.9]) kPa 6 h pre-transfer, 20.0 (13.8–28.5 [8.2–61.1]) kPa immediately post-transfer and 20.0 (13.8–29.8 [7.1–51.3]) kPa 24 h post-transfer (Fig. 3b). Due to these results, we closely assessed which groups of patients, based on the severity of ARDS, were most at risk of deterioration in P/F ratio. As demonstrated in Fig. 3c–f, a deterioration in P/F ratio was most pronounced in those whose ARDS had resolved (baseline P/F ratio > 39.9 kPa), but this recovered within 24 h post-

Table 1 Baseline characteristics of the study population. Values are mean (SD) or number (proportion).

	Overall transfer cohort n = 137	Inter-hospital ICU transfers n = 45	Intra-hospital ICU transfers n = 92
Age; y	62 (11)	65 (9)	61 (12)
Sex; male	90 (66%)	30 (67%)	60 (65%)
ARDS severity			
Severe (P/F < 13.3 kPa)	13 (9%)	1 (2%)	12 (13%)
Moderate (P/F < 26.6 kPa)	77 (56%)	23 (51%)	54 (59%)
Mild (P/F < 39.9 kPa)	29 (21%)	14 (31%)	15 (16%)
Resolved (P/F > 39.9 kPa)	15 (11%)	5 (11%)	10 (11%)
Died	23 (17%)	6 (13%)	17 (18%)
Date			
First wave: Mar–Oct 2020	25 (18%)	3 (7%)	22 (24%)
Secnd wave: Nov 2020–Mar 2021	112 (82%)	42 (93%)	70 (76%)
Time			
In-hours (08:00–17:00)	58 (42%)	23 (51%)	35 (38%)
Out of hours (17:01–07:59)	79 (58%)	22 (49%)	57 (62%)
Hospitals (intra-hospital)			
St Mary's			54 (59%)
Hammersmith			32 (35%)
Charing Cross			6 (6%)
Hospitals (inter-hospital)			
Charing Cross → Hammersmith		16 (36%)	
Hammersmith → St. Mary's		2 (4%)	
St. Mary's → Charing Cross		9 (20%)	
St. Mary's → Hammersmith		18 (40%)	

ARDS, acute respiratory distress syndrome; ICU, intensive care unit.

Table 2 Comparison of physiological variables between inter- and intra-hospital transfers. Values are median (IQR [range]).

	Inter-hospital transfer			Intra-hospital transfer		
	6 h pre-transfer n = 45	Immediately post-transfer	24 h post-transfer	6 h pre-transfer n = 92	Immediately post-transfer	24 h post-transfer
Noradrenaline dose; $\mu g.kg.min^{-1}$	0.014 (0–0.015 [0–0.150])	0.016 (0–0.020 [0–0.160])	0.019 (0–0.025 [0–0.120])	0.038 (0–0.040 [0–0.410])	0.049 (0–0.050 [0–0.800])	0.028 (0–0.040 [0–0.340])
Lactate	5.4 (2.6–7.3 [0–17.9])	1.2 (0.8–1.4 [0.5–2.0])	1.4 (0.9–1.6 [0–6.0])	1.4 (0.9–1.6 [0.5–9.0])	1.4 (0.9–1.6 [0.5–4.1])	1.3 (0.9–1.7 [0.5–2.3])
Base excess	4.43 (1.05–7.30 [−4.50–17.9])	5.29 (0.60–9.30 [−5.60–17.90])	5.17 (1.10–9.95 [−5.60–15.90])	4.15 (−0.08–7.85 [−7.40–20.40])	4.80 (0.33–8.28 [−4.30–26.0])	5.03 (0.98–20.10 [−6.80–20.10])
pH	7.42 (7.36–7.48 [7.25–7.56])	7.42 (7.38–7.47 [7.20–7.56])	7.42 (7.38–7.45 [7.24–7.54])	7.41 (7.38–7.46 [7.09–7.53])	7.40 (7.36–7.45 [7.19–7.52])	7.39 (7.34–7.44 [7.13–7.53])
PCO_2	5.97 (4.90–6.60 [3.90–9.50])	6.20 (5.30–7.10 [3.90–9.10])	6.22 (5.40–7.10 [4.10–12.40])	6.20 (5.10–6.93 [3.40–12.90])	6.47 (5.20–7.23 [3.30–11.70])	6.94 (5.38–7.63 [3.80–18.50])

transfer. We also found no meaningful difference in pH, $PaCO_2$, base excess, bicarbonate or norepinephrine requirements between either inter- or intra-hospital ICU transfers (Table 2).

Discussion

We were reassured to find that, although there was some short-term decline, none of the parameters investigated in this study demonstrated significant deterioration from a

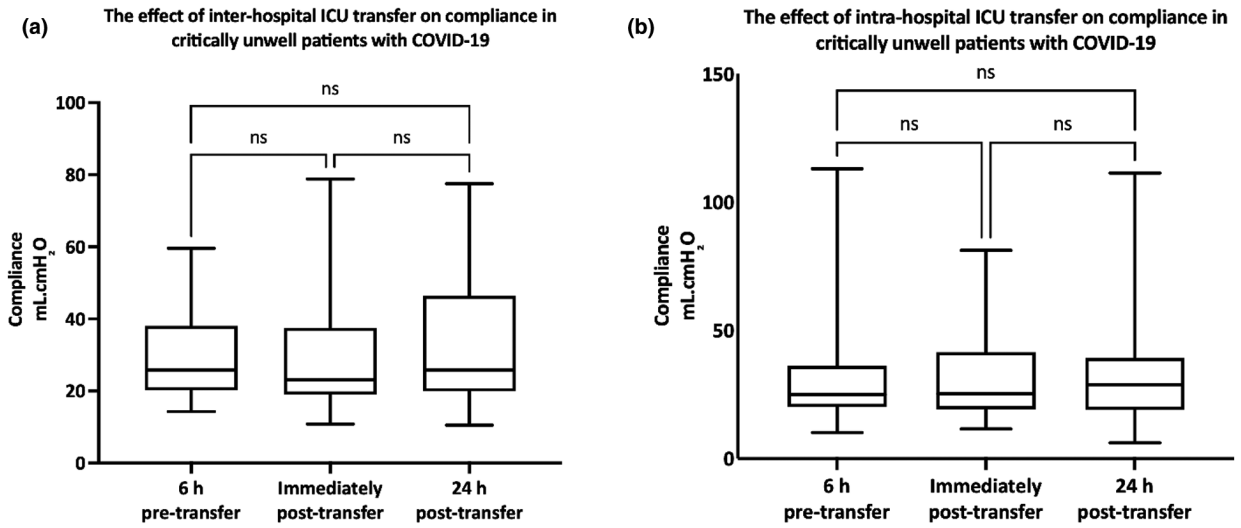

Figure 2 Effect of external and internal transfer on ventilatory compliance.

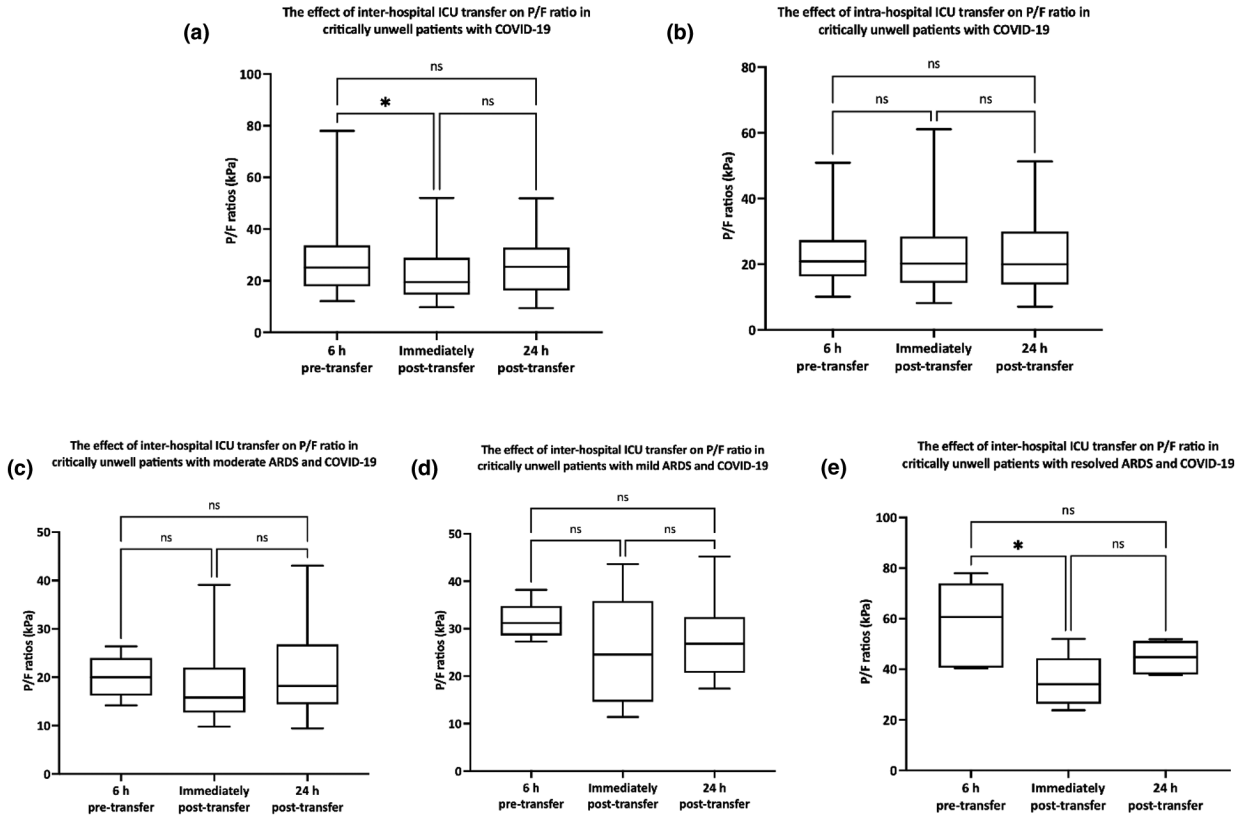

Figure 3 Effect of external and internal transfer on patient PaO_2/F_IO_2 (PF) ratios. ARDS, acute respiratory distress syndrome. *$p < 0.05$.

baseline to 24 h post-transfer. Our data suggest that inter-hospital transfers of patients with COVID-19 whose lungs are being mechanically ventilated can be carried out safely and effectively. We aimed to address the paucity of data around what formed a crucial part of national strategy during the COVID-19 pandemic. COVID-19 has posed an unprecedented challenge to the worldwide critical care community, with the rate of infection and critical illness

putting significant pressure on ICU beds [12]. Data from the first wave of infections in the UK show that daily admissions to ICU trebled during the first peak around March–April 2020 [13], with a large London ICU performing tracheal intubation on 7.5 COVID-19 patients every day [8]. Patients with COVID-19 ARDS often require prolonged pulmonary mechanical ventilation [14], dramatically increasing the need for critical care beds. Indeed, during the second wave in the UK, the three hospitals in this study facilitated a surge capacity of around 150% in ICU beds [15]. Particularly instrumental in allowing for surge capacity of ventilated COVID-19 patients was the creation of additional ICUs at these three hospitals. Despite this, it was still necessary to transfer patients between the three sites for efficient utilisation of beds, which allowed us to investigate the burden placed upon patients undergoing pulmonary ventilation during inter-hospital ICU transfers.

In our study, we have demonstrated that inter-hospital transfer of patients resulted in an immediate but short-lived deterioration in gas exchange, which resolved within 24 h. Our detailed sub-group analysis, stratifying by the severity of ARDS, showed short-lived deterioration occurred only in the resolved ARDS sub-group. Inter-hospital transfer of ICU patients did not cause deterioration in pulmonary compliance, acid–base balance or haemodynamic stability. Our results show that acute physiology of ICU patients undergoing inter-hospital transfer is very comparable with those intra-hospital transfers where patients are transferred to ICUs within the same hospital.

Our overall findings are consistent with what limited data already exist during this pandemic. A recent study in France found that P/F ratios did not deteriorate 24 h post-transfer in intubated patients with COVID-19, although the authors did not investigate if there was an immediate deterioration post-transfer [16]. A case series of six COVID-19 patients with severe ARDS whose lungs were mechanically ventilated and were evacuated via amphibious assault ship, reported no significant change in P/F ratio post-transfer [17]. Data from the USA also confirmed that inter-hospital evacuation of COVID-19 patients whose lungs were mechanically ventilated did not increase mortality [18]. Previous data in transfer of non-COVID ARDS patients are, similarly, sparse. In 2002, a study of 66 patients reported a significant improvement in P/F ratio over the course of an hour-long transfer (8.5 ± 2.7 kPa pre-transfer and 9.7 ± 3.6 kPa post-transfer) [19] and this is comparable with studies which have investigated the effect of transfers in critically ill ICU patients and shown no increase in mortality [20, 21]. Several studies also exist which demonstrate an increase in mortality following inter-hospital transfer of ICU patients [22, 23], which highlights the severe risks associated with non-clinical transfer of patients between institutions. However, our data are reassuring in that it suggests that inter-hospital transfer of suitably selected COVID-19 patients (i.e. those with moderate, mild or resolved ARDS) is a safe strategy to manage bed pressure in those hospitals with overwhelmed ICU capacity.

This study has a number of strengths. First, we have examined multiple ventilatory and biochemical parameters. These data describe the physiological effect of moving patients between hospitals. Second, we have analysed sub-groups to identify any patients with ARDS that may be particularly susceptible to complications during transfer. We have also compared our patients with a suitable comparison group (COVID-19 patients undergoing intra-hospital transfers). However, there are some limitations. Our patients were selected and deemed suitable for ICU transfer for bed capacity reasons. Consequently, very few had severe ARDS and, therefore, we were not able to assess the complication rate in this group. We were unable to assess the non-physiological impact of transfer such as the effect on continuity of care, impact on families and need for repatriation. Furthermore, inter-hospital transfers all occurred within a 7 km radius in central London so may not be representative of longer journeys. Finally, COVID-19 patients transferred for clinical reasons (e.g. surgical or radiological procedures/scans) were not included as they may have had deranged physiology as a result of their procedure rather than the transfer.

In conclusion, patients with COVID-19 undergoing mechanical pulmonary ventilation do not undergo lasting physiological deterioration when transferred between nearby hospitals. This finding is a significant success for national critical care strategy in the face of unprecedented demand during the ongoing COVID-19 pandemic.

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