**MAIN TEXT**

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# Spread of Covid-19 in hemodialysis centres; the effects of ventilation and communal transport

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## Abstract

**Aims:** Hemodialysis (HD) patients are at increased risk of respiratory infections, due to increased use of communal travel, waiting areas, close proximity to others when dialysing, and contact with healthcare personnel. We wished to determine the major factors associated with transmission of COVID-19 within dialysis centres.

**Methods:** We compared the differences in the number of COVID-19 infections in patients and staff in 5 dialysis centres during the 1st COVID-19 pandemic between March and June 2020, and analyzed differences between centres. Isolation policies and infection control practices were identical between centres.

**Results:** 224 (30.3%) patients tested positive for COVID-19, by reverse transcriptase polymerase chain reaction, ranging from 4.8% (centre 1 size 55 patients) to 41.5% (centre 5–248 patients) $p = 0.007$. Communal transport had a significant effect; with 160 of 452 (35.4%) patients using communal testing positive compared to 22.2% of those not using communal transport (X214.5, $p < 0.001$). Staff sickness varied; 35 of 36 (97.3% centre 5) dialysis staff contracting COVID-19, compared to 60% from centre 4 (189 patients 30 staff) ($p < 0.001$). Whereas centre 5 had no natural ventilation, and fan assisted ventilation did not meet standards for air changes and air circulation, centre 4 met ventilation standards.

**Conclusions:** Although there are many potential risk factors accounting for the increased risk of COVID-19 infection in hemodialysis patients, we found that differences in communal transport for patients and ventilation between centres was a major contributor accounting for the differences in patients testing positive for COVID-19 and staff sickness rates. This has important practical applications for designing kidney dialysis centres.

**KEYWORDS**
Covid-19, face masks, hemodialysis, infection control, transport, ventilation

## 1 | INTRODUCTION

COVID-19 is a respiratory infection, and previous studies in dialysis patients have observed a much greater risk for contracting lower respiratory tract infections in hemodialysis (HD) patients compared to those treated by peritoneal dialysis.[1] Dialysis patients were one of the groups advised by the United Kingdom (UK) government to

shield at home from March 23rd 2020 during the coronavirus (COVID-19) pandemic, as along with some 2.2 million other people they were classified by the UK National Health Service (NHS) as clinically extremely vulnerable.[2] Despite advice to shield, observational studies have reported that HD patients are at an increased risk of both contracting COVID-19,[3,4] and also mortality.[5] Although less than 0.1% of the UK population are treated by HD, 2% of all COVID-19 deaths in the first COVID-19 pandemic wave were HD patients.[5]

Compared to other highly vulnerable groups of patients at risk of contracting COVID-19 who can shield at home, HD patients have to travel regularly to HD centres for treatment, and may not be able to practice social distancing whilst traveling or attending for dialysis treatments. Most dialysis centres introduced screening procedures and enhanced infection control practices,[4] but infection rates in London.

HD units varied widely, from just a few cases up to 30% of patients.[5] We therefore reviewed our own practice, comparing COVID-19 infection in HD patients and staff in five in-centre dialysis units under the care of a university hospital to determine whether centre factors play an important role in disease transmission.

## 2 | METHODS AND PATIENTS

We reviewed the records of 740 adult patients dialysing in five dialysis centres in North London under the care of a university hospital (Table 1) between March and May 2020. Patient age and clinical frailty scores were obtained from computerized patient records.[6] There were two smaller centres and three larger centres dialysing three shifts (morning, afternoon, evening) six days a week. All centres used Fresenius 4008/5008 or BBraun Dialogue+

dialysis machines (Fresenius AG, Bad Homberg, BBraun, Melsungen Germany), with ultra-pure quality dialysis water. All dialysis machines were heat and chemically disinfected between patients and external surfaces cleaned with Microzid Universal wipes (Schülke and Mayr GmbH, Norderstedt, Germany). All dialysis centres were designed according to UK statutory regulations so that the minimum distance between dialysis machines was >1.5 m,[7,8] and ventilation to comply with UK standards for health care buildings.[9]

Centres differed in size, and the number of isolation rooms available, which were used for patients with hepatitis B, methicillin resistant Staphylococcus Aureus and Clostridium Difficile (Figure 1). Standard infection control practice included routine screening for nasal carriage of Staphylococcus Aureus on a monthly basis, and eradication protocols included mupirocin nasal cream, and chlorhexidine-containing body and hair washes. Dialysis staff routinely wore protective goggles or visor face masks and disposable gloves when connecting and disconnecting patients, but not at other times.

The first case of COVID-19 was recorded in March 2020. Initially testing for COVID-19 was restricted to symptomatic patients, needing hospital admission. Nasal and pharyngeal swabs were tested by COVID-19 real time reverse transcriptase-polymerase chain reaction (RT-PCR), initially by the UK Public Health Service laboratory, then subsequently by a UK approved immunoassay (Roche Cobas Immunoassay platform, Roche Diagnostics Ltd, Burgess Hill, UK).

As with many centres, additional infection control measures were introduced at entry into dialysis centres, including asking all patients to use an alcohol gel handwash, along with temperature checking, and completing a symptom questionnaire. Patients with a clinical diagnosis of Covid-19, and those with an increased temperature or

**TABLE 1** Characteristics of the five different dialysis centres

| Centre | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Patients | 55 | 75 | 173 | 189 | 248 |
| Age years | 55.5 ± 17.0** | 64.5 ± 15.7 | 65.0 ± 14.7 | 66.7 ± 13.7 | 62.9 + 14.5 |
| CFS | 3 (2.8–4)*** | 4 (3–6) | 3 (3.8–6) | 5 (4–6)** | 4 (3–6) |
| Covid +ve | 4 (7.3)*** | 20 (26.7) | 49 (28.3)* | 48 (25.4)** | 103 (41.5) |
| Dialysis stations | 12 | 16 | 29 | 30 | 47 |
| Isolation rooms | 2 | 2 | 4 | 2 | 4 |
| Shifts/week | 15 | 15 | 18 | 18 | 18 |
| Hospital transport | 23 (41.8) | 39 (52) | 113 (65.3) | 136 (72)* | 141 (56.9) |
| Covid +ve transport | 1 (25) | 10 (50) | 36 (73.5) | 42 (91.3) | 71 (68.9) |
| Dialysis staff | 7 | 19 | 26 | 30 | 36 |

*Notes*: Total number of patients testing positive for COVID-19, and staff sickness during the first pandemic wave of Covid-19. Results expressed as integer and percentage. Clinical frailty score (CFS). Data expressed as integer, percentage, mean, standard deviation or median and interquartile range. *$p < 0.05$, **$< 0.01$, ***$< 0.001$ vs Centre 5.
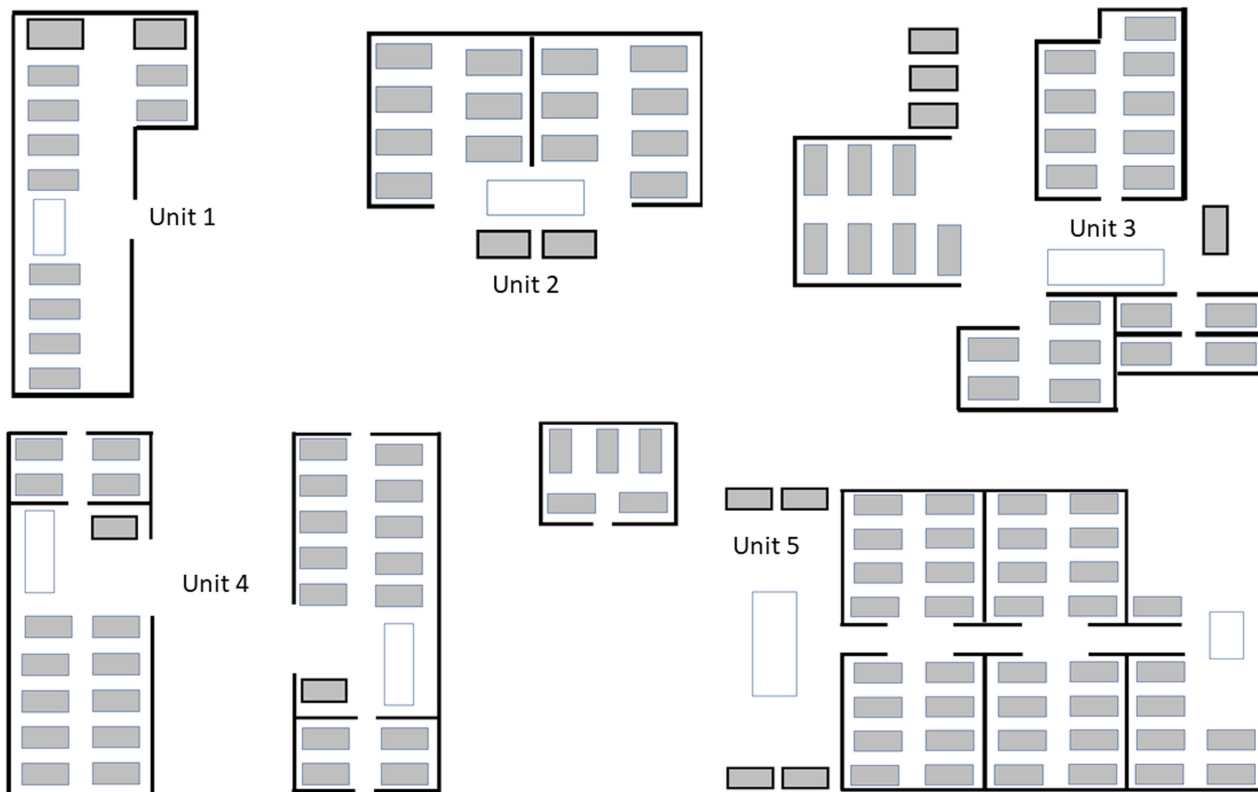
**FIGURE 1** Dialysis Centre configurations of the five centres. Dialysis stations—Gray rectangles, isolation dialysis stations—Dark outlines, nursing stations—Clear rectangles. Diagrams not to scale. Minimum distance between dialysis stations was 2.8 m.

with respiratory tract symptoms were segregated. Dialysis patient waiting areas were reviewed and seats either removed or chairs closed to increase spacing between patients waiting. In addition, a series of enhanced infection control measures were implemented: (1) patient transport was cohorted, so that COVID-19 positive patients did not travel with COVID-19 negative patients, with segregated adapted vehicles available from 20th March (2) from 25th March—surgical grade IIR masks were made available for all staff, (3) from 31st March—dialysis start times were staggered to reduce patient waiting times, (4) from 3rd April—surgical grade IIR masks were to be worn by patients on transport, on entry to dialysis centres and during dialysis sessions, and (5) from 29th April—weekly nasal and pharyngeal swabbing and RT-PCR testing was introduced for all patients. We continued to provide patients with a sandwich and a drink. However patients were encouraged not to eat during the dialysis session, but to eat the sandwich after the dialysis session. Patients were permitted to remove their face mask when drinking, but then required to replace the mask after drinking.

Patients with COVID-19, or those suspected of COVID-19, who did not require emergency admission to hospital were dialysed in an isolation area in the dialysis centre. With staff wearing a single use disposable apron, gloves, a fluid resistant surgical grade IIR mask, and a full-face shield. As the number of patients with COVID-19 increased, patients were then cohorted in segregated areas, and then moved to dialyse in the evening dialysis shifts.

Prior to the pandemic staff routinely wore white disposable plastic aprons, gloves and either a face shield or safety goggles when connecting and disconnecting patients to their dialysis machines, but not at other times. When dealing with COVID-19 patients, staff additionally wore surgical grade IIR masks, and from March 25th all staff wore these masks when in the dialysis areas.

## 2.1 | Statistical analysis

Results are expressed as mean ± standard deviation, or median and interquartile range, or percentage. Data was analyzed using the D'Agostino & Pearson normality test, and numerical data analyzed by t test if normally distributed or by Mann Whitney U test if non-parametric data, and anova or Kruskal Wallis with appropriate post-hoc testing. Categorical data was analyzed using the Chi square test, with appropriate corrections for small numbers and multiple testing applied. Statistical analysis was performed using Graph Pad Prism (version 9.2, Graph

Pad, San Diego, CA, USA), Statistical Package for Social Science version 27.0 (IBM Corporation, Armonk, New York, USA). Statistical significance was taken at or below the 5% level.

## 3 | RESULTS

During the first wave of COVID-19, 224 (30.3%) patients tested positive for COVID-19. More patients dialysing in the largest centre tested positive (Table 1), with a prevalence of 41.5% for centre 5, compared to 7.3% in the smallest centre, centre 1 which was a self-care centre (X2 7.3, $p = 0.007$). Patients in centre 1 were younger than those in the other 4 centres. As expected, patients in centre 1 had lower clinical frailty scores than centre 5, but clinical frailty scores were highest in dialysis centre 4. Significantly fewer patients tested positive for Covid-19 in dialysis centre 4 compared to centre 5.

Following the introduction of routine screening then there was an increase in positive tests in asymptomatic patients in dialysis in centre 3, but not the other centres (Figure 2). The majority of patients used communal hospital transport to attend for their dialysis sessions, and 160 of 452 (35.4%) tested positive for COVID-19, which was greater than those who used their own or public transport (22.2%, X2 14.5, $p < 0.001$). The proportion of patients using hospital transport was least for centre 1 and greatest for those patients attending dialysis centre 4. The proportion of patients who tested positive for COVID-19 and used communal transport differed between the individual centres (Table 1), being least for centre 1 and greatest for centre 4.

Just as the number of patients testing positive in the dialysis centres differed, so did staff sickness, with only 1 of 36 (2.7%) of the permanent dialysis staff working in centre 5 not contracting COVID-19 compared to 40% staff sickness in centre 4, the second largest centre (X2 14.3, $p < 0.001$) (Figure 3).
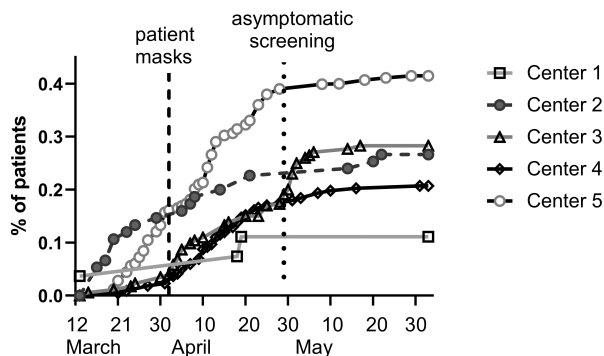


**FIGURE 2** Percentage of patients attending dialysis centres who tested positive for Covid-19.
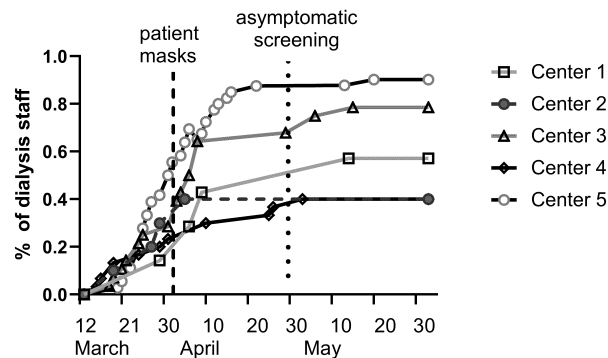


**FIGURE 3** Percentage of dialysis staff working in dialysis centres who tested positive for Covid-19.

The minimum distance between dialysis stations was 2.8 m in all centres. However, ventilation only met building regulations in terms of fresh air, and air circulation in centre 4, when there was natural ventilation. Centre 5 had no natural ventilation and testing did not meet requirements in terms of air changes. No centre had high-efficiency air filters fitted for air recirculation.

## 4 | DISCUSSION

Previous observational studies have reported that hemodialysis patients are at increased risk of respiratory tract infections,[1] and at greater risk of Covid-19 infection.[4] In addition, clinical frailty has been reported to be associated with greater clinical severity of Covid-19 infection and mortality.[10]

Almost one third of our hemodialysis patients contracted COVID-19 during the first pandemic wave. However, the number of patients, and staff contracting COVID-19 differed between our five centres. Standard public health measures included increased patient hand hygiene, screening at entry into dialysis centres. All dialysis centres had a waiting area, for patients to wait when entering the centre until their dialysis machine was ready, and post-dialysis for those waiting for transport home. To minimize patients sitting together in the waiting areas, in addition to increasing the distance between seats, we introduced a one-way flow pathway was introduced and dialysis start times were staggered, to try and reduce patients congregating in communal areas. Within the dialysis centres, all centres met UK national guidelines, with all dialysis machines a minimum of 2.8 m apart.[6,7]

Despite the introduction of increased hand hygiene, mask wearing and increased social distancing, all of which measures have been reported to reduce the transmission of COVID-19 in a meta-analysis of public health studies,[11] the transmission of COVID-19 continued to increase differentially between centres. Patients were dialysed in two

smaller centres, and three larger centres. The smallest centre, centre 1 was initially set up for howe dialysis training, but then expanded to be a self-care or minimal care centre, with patients being able to set up their own dialysis machines, but requiring nursing assistance with needling, and as such had fewer staff members per patient. So we looked at potential differences in infection rated between the centres. Centre 1, the smallest dialysis centre had the lowest number of infected patients, compared to the largest centre, centre 5, with the greatest number of patients affected. Although, there were fewer patients who tested positive in the second largest centre compared to centre 5, there were no differences with the other smaller centres, suggesting that centre size per se was not a key factor in determining the spread of infection. Patients in centre 1 were younger, and previous studies have reported that older patients were more vulnerable to Covid-19.[12] However, patient age was similar in the other centres. Pre-existing patient frailty has also been reported to be important in Covid-19 infections,[13] and clinical frailty scores were lower in centre 1, a self-care dialysis unit. However, frailty scores were lower in centre 5 with a higher number of patients with covid-19, compared to centre 4, and recent studies have demonstrated that frailty is not a risk factor for contracting Covid-19.[14]

Patients using communal transport arranged by the hospital spent more time traveling with other patients and waiting both to start and at the end of their dialysis session in communal areas. Proportionally more patients using communal transport tested positive for Covid-19. However, the number of patients using communal transport and the proportion testing positive differed between centres. More patients in centre 4 used communal transport, but only 31% tested positive for covid-19. compared to 50% in centre 5. Similarly, the proportion of positive patients using communal transport compared to the total number of cases in the centres differed from 25% for centre 1 to 69% for centre 5 and 91% for centre 4. This would suggest that although communal transport was a risk factor for contracting Covid-19, other factors are also important. We were unable to accurately determine the component elements of communal transport; the time spent traveling together, number of other patients, waiting times in communal areas awaiting starting dialysis and post-dialysis waiting for transport home.

Hemodialysis machines generate heat, and the temperature in dialysis units will increase due operating the dialysis machine, and also body heat from both patients and staff. As such, all dialysis centres had air conditioning units, and although an air flow of 10 L/hour per person has been recommended, the main areas of the dialysis centres had lower exchange rates.[15,16] No centre had a flow as low as 1–3 L/hour per person, which has been

reported with a number of super-spreading COVID-19 outbreaks.[15,16] However, dialysis centre 5, with the highest numbers of infection had no natural ventilation, and the ventilation system did not meet standards designed for air change rates, in terms of bringing in fresh air.[17,18] The air conditioning system in centre 4 also simply recirculated air, but with natural ventilation, achieved 5–6 air changes per hour. Whereas the windows could not be opened in centre 5 to allow natural ventilation, the windows, and the doors at either end of the dialysis unit in centre 4 could be opened, so allowing a throughput of fresh air. Ventilation was also found to be substandard in dialysis centres 2 and 3, with only 1.5 air changes per hour in centre 3.

As COVID-19 is spread through very small aerosols and droplets which can spread more than 2 m in the air, then this can increase the risk of transmitting infection.[18,19] This potential infection risk is increased in poorly ventilated in-door settings, and when people are in close proximity for several hours, such as a dialysis centres. This risk could potentially be reduced by wearing face masks, and pooled analysis of six studies ranging from the USA to Hong Kong suggested a 53% reduction in the incidence of COVID-19.[15] Surgical grade face masks were introduced for staff from the 25th March and for all patients from 31st March. Reviewing the number of patients testing positive for COVID-19, there was no noticeable reduction in patient infection numbers following the introduction of face masks. Staff and patients were issued with fluid-resistant (Type IIR) surgical face masks, as recommended by the NHS England and NHS Improvement (NHSE&I), and the British Renal Society.[20] However, some other dialysis groups have advocated wearing FFP3 masks for staff, rather than standard surgical face masks.[21] As patient masks are not often replaced, and may become permeable after wearing for 4 or more hours, and Type IIR masks may also allow passage of air at the sides, if not well fitting the face, then if not changed or well-fitting, these masks may not provide sufficient protection when patients and staff are in close proximity for prolonged periods of time in poorly ventilated dialysis units.

Previous studies reported that the introduction of screening detected a number of asymptomatic hemodialysis patients.[3] In our centres, there was only a noticeable increase in centre 3 on introduction of nasal and pharyngeal swabbing. This may reflect a much higher prevalence of infection in our hemodialysis population prior to the introduction of screening asymptomatic patients compared to other series, or may reflect that current diagnostic screening strategies may be limited in their ability to detect acute infection.[22]

In addition to differences in patient infection rates, staff sickness also differed between centres. All but one member of the permanent staff for centre 5 became unwell,

and other staff had to be redeployed to allow patient dialysis treatments to continue. Each unit had a communal staffroom, and staff did not wear personal protection equipment when eating and drinking. The staffrooms did not have the benefit of natural ventilation, and air circulation was below 10 L/h per person at the main break times for the larger dialysis centres. Centre 4, which had the advantage of natural ventilation had proportionally the lowest staff sickness. Compared to other centres, centre 3 had increasing staff sickness after the introduction of asymptomatic screening. This may have been due to the transfer of patients with COVID-19 from centre 2, due to the lower capacity of centre 2 to provide isolated patient dialysis, and centre 3 then dialysing COVID-19 patients in bays. As such this may account for the higher staff infection rates we report compared to other studies were staff wore greater amounts of personal protective equipment, including N95 face masks, or other studies were staff infection rates reduced after the introduction of additional personal protective equipment.[23,24]

At the time of this first wave of COVID-19, only symptomatic patients presenting to acute hospital medical services were tested for COVID-19, and as such we cannot comment on the infection rates of people living in the neighborhoods of the dialysis centres, as symptomatic individuals and those isolating at home either due to symptoms or as contacts to cases were not tested. However, the cumulative COVID-19 positive rates between March and May in the neighborhood of dialysis centres 1 and 4 ranged between 47.3 to 229.5 per 100 000, centre 2 around 329/100 000, centre 3 between 252 and 329/100 000 and centre 5 between 158–169/100 000, respectively.[25] As such, the neighborhood COVID-19 reported cases would not appear to explain the differences in the infection rates we found in our dialysis centres. At the time of the study vaccinations against COVID-19 were not available. Staff vaccination started in January 2021, and the majority of hemodialysis patients had their first vaccination between February and March 2021.[26] As such, we cannot comment on how voluntary vaccination may have affect transmission in our dialysis centres.

We report that just over 30% of our hemodialysis patients tested positive for COVID-19 during the first wave of the pandemic in London, UK. The patient infection rates differed between the 5 dialysis centres. Although more patients who traveled to and from the dialysis centres using communal transport arranged by the hospital tested positive for COVID-19, other factors than communal transport and waiting areas accounted for the differences in infections between centres. Despite issuing all staff and patients with Type IIR face masks, this did not appear to impact on the number of patients and staff contracting Covid-19. Investigation of the ventilation systems in the different units revealed that most dialysis centres had lower air flows than that originally designed, and that the centre with no natural ventilation and the least fresh air ventilation had the highest rates of both patient and staff illness, whereas proportionally the centre meeting fresh air flow targets with the aid of natural ventilation had the lowest patient and staff sickness. Our evaluation of the COVID-19 infections in our hemodialysis population highlights the importance of the design and maintenance of ventilation systems in hemodialysis units.

## AUTHOR CONTRIBUTION

CG organised collection of data and revised manuscript SG supervised infection control policies and testing and revised manuscript AD analysed data and wrote first draft all authors contributed to final version.

## CONFLICT OF INTEREST

The authors have no conflicts of interest.

## DATA AVAILABILITY STATEMENT

UCL Department of renal medicine R drive. SC provided infection control and revised manuscript. CG collected data and revised manuscript. AD conceived concept and revised manuscript.

## ETHICS STATEMENT

Ethical approval was obtained (20/SW/0077) for the collection of data from Covid-19 patients. Retrospective analysis of data complied with regulations for audit and service development, with all patient data appropriately anonymised.

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