Remote monitoring of oxygen saturation in individuals with COVID-19 pneumonia

To the Editor:

Coronavirus disease 2019 (COVID-19), an illness caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, has spread rapidly worldwide, resulting in significant mortality and placing major strain on healthcare systems. Although the clinical course is variable, one in five patients will require hospitalisation for management, with older age and the presence of comorbidities increasing the risk of more severe disease [1–3]. The median time from first onset of symptoms to development of acute respiratory distress syndrome in those who progress to severe disease is estimated to be 8.0 days [4]. Currently, there is an increased pressure on acute hospital-based care and a corresponding demand for novel solutions to address this. One approach is to utilise telemedicine to facilitate efficient and safe discharge from acute hospitals. Due to the highly contagious nature of SARS-CoV-2, routine or urgent clinical follow-up is difficult within the primary care or community settings. Hence, the ability to remotely monitor symptoms and vital signs in mild-to-moderate cases may be one mechanism to alleviate the pressures on healthcare systems, and we present here some initial data on one such approach.

Over a 1-month period, 193 COVID-19-positive patients were admitted to St Vincent's University Hospital, an 836-bed tertiary referral centre in Dublin, Ireland. All patients were offered enrolment into the All-Ireland Infectious Diseases Cohort Study, a multicentre, prospective cohort recruiting patients accessing clinical care related to infectious diseases presenting to several affiliated hospitals in Ireland. A proportion of patients that had pulmonary infiltrates on chest radiographs and did not need or no longer required supplemental oxygen were provided with a NoninConnect 3230 Bluetooth Smart Pulse Oximeter (Nonin Medical Inc., Plymouth, MN, USA) upon discharge from hospital. The oximeters were linked to a mobile application specifically developed to monitor oxygen saturation and self-reported breathlessness in individuals with COVID-19 (patientMpower Ltd, Dublin, Ireland). All data were encrypted and sent to a secure cloud database that was accessible only to members of the COVID-19 monitoring team. The mobile application sent an automatic prompt to check oxygen saturations at rest and not following exertion, four times daily for 14 days after discharge from hospital, and patients could enter additional data/measurements at will. A prompt also asked if the patient felt breathless. If the patient selected "yes", then they were asked to use a visual analogue scale to measure this from 1–10; however, most patients did not report being breathless. If oxygen saturation measurements were $\leqslant$94%, an alert was generated, resulting in an SMS text message being sent to the monitoring team, composed of respiratory physicians and nurse specialists. Following an alert, the person was contacted by the team and if there was persistent hypoxia, a deterioration in symptoms, or any other cause for concern, they were instructed to present to the hospital for an assessment.

In the reported period, 26 patients were suitable for home monitoring as part of clinical care, and 18 patients that utilised the remote monitoring platform consented for their data to be used. Table 1 outlines the demographic and clinical characteristics of this cohort during their initial admission. Over this period, 917 data-points regarding peripheral capillary oxygen saturation (S_{pO_2}) were generated, resulting in a total of 51 alerts (5.5% of all S_{pO_2} measurements). Patients were instructed to record saturations for 14 days, but several patients recorded for a shorter or longer period and the median time spent on the monitor was 12 days. These alerts resulted in five reassessments and four individuals were readmitted to hospital as outlined. These patients were readmitted 2, 3, 8 and 10 days after their initial discharge from hospital. There were no apparent differences in the initial admission profiles of the patients requiring

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TABLE 1 Demographic and clinical characteristics of the remote monitoring cohort

	Whole cohort	No readmission	Readmission
Patients n	18	14	4
Age years	48 (41–60)	46 (37–57)	56 (48–63)
Male	12 (66.6)	11 (78.5)	1 (25)
Female	6 (33.3)	3 (21.5)	3 (75)
Current smoker	1 (5.5)	1 (7.1)	0 (0)
Ex-smoker	5 (2.7)	4 (28.5)	1 (25)
Interval between symptom onset and admission days	9 (5.75–11.25)	8.5 (4.25–10.5)	10 (8.25–13.25)
Length of initial hospital admission days	8 (5.5–11.5)	10 (6.75–12.25)	4 (3–7)
Required supplemental oxygen	16 (89)	13 (92.8)	3 (75)
ICU admission	4 (22)	4 (28.5)	0 (0)
Mechanical ventilation	0 (0)	0 (0)	0 (0)
NIV	5 (27)	5 (35.7)	0 (0)
Received hydroxychloroquine and azithromycin	13 (72)	10 (71.4)	3 (75)
Time on home monitor days	12 (9.75–18)	12.5 (10–18)	5.5 (2–10)
Number of data inputs	46.5 (27.25–68.75)	51 (37.25–68.75)	10.5 (4.5–99.75)
Mean number of data inputs per day	4.58	3.99	5.7
S_{pO_2} for all data %	96 (95.75–97)	96 (96–97)	94.5 (92.5–96)
Number of alerts	1 (0.5–4.5)	1 (0–4)	3 (1.25–14.5)
S_{pO_2} for alerts %	92 (92–93)	93 (92–93)	91.5 (89.5–92)

Data are presented as median (interquartile range) or n (%), unless otherwise stated. Data for readmission patients relates to the initial hospital admission only. ICU: intensive care unit; NIV: noninvasive ventilation; S_{pO_2}: peripheral capillary oxygen saturation.

readmission apart from a shorter initial length of stay. The median S_{pO_2} of these alerts was 91% and the lowest S_{pO_2} recorded was 82%. Three patients that were readmitted had progressive infiltrates and worse hypoxia related to COVID-19, and one patient had pneumonia unrelated to their previous radiographic changes of COVID-19, which had resolved on initial discharge. None of the readmitted patients required noninvasive or invasive ventilation during readmission.

The utility of remote monitoring systems has been an increasingly studied subject, and there is growing evidence that remote monitoring can facilitate more streamlined approaches to observational studies and the delivery of patient care, especially in pulmonary diseases [5, 6]. We believe that this system contributed positively to patient confidence and reassurance regarding discharge from hospital, especially with COVID-19 being a relatively unknown entity, and in a climate of significant concern and anxiety about their condition. However, given the scope of this report, patient confidence or satisfaction was not formally assessed. Nevertheless, in this cohort of patients, there was excellent adherence, which can be a surrogate for patient acceptance [7]. Indeed, the median number of measurements per day was 3.9 in the group which did not require readmission and 5.7 in those readmitted, both higher than 97% adherence [7]. This may have been aided by the minimal inputs needed and the acute aspect of this illness compared to the difficulties and challenges noted in compliance with remote monitoring in chronic diseases [8, 9].

The use of modern mobile technology to specifically monitor individuals with COVID-19 allowed us to facilitate discharge in patients with mild-to-moderate disease in a safe and appropriate manner. While in this study a relatively high number of patients were readmitted, we believe this reflects the severity of the initial illness. Only patients who required hospitalisation and had pulmonary infiltrates were enrolled to home monitoring. Potentially, those with milder COVID-19 could be monitored for any deterioration, and this could indeed identify patients deteriorating at home. However, we did not examine this. Moreover, the discharge strategy we employed relieved demand for hospital beds during this period of significantly increased demand. During the reported 1-month period our hospital was operating at surge capacity with 125% occupancy of the intensive care unit, utilising other wards/areas to mechanically ventilate patients. The patients who utilised this monitoring system were discharged from an acute care hospital system under strain in a manner that contributed to increased bed availability without compromising safe patient care. Use of remote monitoring ensured early recognition of acute deterioration in recently discharged patients and enabled reassessment and readmission when necessary. This type of approach has the potential to conserve hospital resources for those most in need, while simultaneously enabling early identification of those who deteriorate acutely and require urgent assessment.

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