Feasibility and accuracy of the 40-steps desaturation test to determine outcomes in a cohort of patients presenting to hospital with and without COVID-19

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ABSTRACT

Desaturation on exercise has been suggested as a predictive feature for deterioration in COVID-19. The objective of this paper was to determine the feasibility and validity for the 40-steps desaturation test.

A prospective observational cohort study was undertaken in patients assessed in hospital prior to discharge. One-hundred and fifty-two participants were screened between November 2020 and February 2021, and 64 were recruited to perform a 40-steps desaturation test. Patients who were able to perform the test were younger and less frail. Four patients were readmitted to hospital and one patient deteriorated within 30 days but no patient died.

The majority of patients showed little change in saturations during the test, even with pre-existing respiratory pathology. Change in saturations, respiratory rate, heart rate and breathlessness were not predictive of death or readmission to hospital within 30 days. Of 13 patients who had a desaturation of 3% or more during exercise, none was readmitted to hospital within 30 days.

Not enough patients with COVID-19 could be recruited to the study to provide evidence for the safety of the test in this patient group.

The 40-steps desaturation test requires further evaluation to assess clinical utility.

KEYWORDS: COVID-19, desaturation, exercise test, 40-steps test

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Background

Hypoxaemia in COVID-19

Since the emergence of SARS-CoV-2, the features of its causative disease (COVID-19) have been extensively studied and described.[1] One feature of the disease that gained prominence is the phenomenon of 'silent hypoxaemia', based on observations that critically ill patients with COVID-19 appeared to display minimal features of respiratory distress despite profound hypoxaemia.[2,3] This led to an intense focus on identifying hypoxaemia early in suspected COVID-19, which was compounded by preliminary findings that hypoxaemia in the context of COVID-19 could be an early indicator of clinical deterioration.[4–6]

In addition, it has been suggested that exercise-induced desaturation may also be a prominent early feature to indicate clinical deterioration in COVID-19.[7,8]

Exercise testing in COVID-19

The recognition of exertional hypoxaemia as a feature in COVID-19 linked to clinical deterioration has made testing for exertional hypoxaemia integral to the triage of patients presenting to healthcare services with acute dyspnoea.[9,10] The 6-Minute Walking Test was used in a small study of patients with COVID-19 at discharge and only completed in full by half of participants due to desaturation below 90%.[11] A shorter, 3-minute walk test has linked 2% desaturation to diagnosis of pulmonary embolism, and poor outcome within 14-days in acute dyspnoea in participants desaturating below 90% during the test.[12,13] Both 30 second and five repetition variations of a sit-to-stand test have been linked to future risk of acute exacerbations in chronic obstructive pulmonary disease (COPD), but there is little research that has focused on the short-term outcomes of relevance in COVID-19.[14] There are a number of tools that present different physiological stress and implementation challenges and, to date, none of these tests have been clearly validated in the context of prediction of outcomes for COVID-19 or feasibility of implementation.[15]

One of the proposed tests appearing in NHS guidance for both emergency departments and primary care settings is the 40-steps test, a short exercise test involving 40 steps of walking on a flat surface, with peripheral oxygen saturations (SpO_2) being

measured before and after the test.[16–18] A drop in saturation of 3% has been proposed as a significant to trigger further investigation and/or consideration of admission to hospital.[15] A negative test, where a patient does not desaturate, is used as an indication that the patient can be discharged safely.

Currently it is unclear which exertional test may offer the better prediction and be suitable for ease of delivery in a potentially small space (crucial in suspected COVID-19 patients where isolation from other patients is necessary).

Aim

Our study aimed to establish safety and feasibility of performing the 40-steps desaturation test before discharge in a population of medical emergency admissions. The secondary outcomes for the study were to establish normal values for the 40-steps test and describe the predictive value of physiological responses in patients with and without COVID-19 for future deterioration.

Methods

Study design

We performed a prospective cohort study in a single district general hospital.

Screening

Adult participants were screened from the emergency department, acute medical unit and five medical wards on 30 days. Days of screening were chosen pragmatically based on availability of the two researchers.

Eligibility

Inclusion and exclusion criteria are listed in supplementary material S1. Patients were recruited prior to discharge and were required to be independently mobile. Patients were excluded if they were post-operative, had minor injuries, were electively admitted, were non-mobile patients or had abnormal physiological parameters at rest (SpO_2 <95%, heart rate (HR) >100 beats per minute or respiratory rate (RR) >25 breaths per minute).

Baseline characteristics

During the index visit, the age, gender, ethnicity, working diagnosis, COVID-19 status, and a past-medical history of heart failure, COPD, asthma or interstitial lung disease were collected for each participant.

Physiological monitoring

Baseline observations of SpO_2, HR, RR, blood pressure (BP) and temperature were recorded from the patient's vital signs chart, with readings performed within 4 hours accepted. In addition, the patient was asked to give a numerical dyspnoea score from 0 to 10 using a word-anchored, pictorial numerical rating scale (supplementary material S2). Dyspnoea score, RR (calculated by visually counting breaths), SpO_2 and HR were re-recorded immediately at completion of the 40-steps test and at 2 minutes after the test was completed.

40-steps test

The national recommendation for the 40-steps test does not include specifications. For our study, the test was standardised by walking on the spot to enable reproducibility and testing in locations with limited space. Participants were asked to walk 40 steps on the spot at a self-paced walking pace. The test was discontinued if the participant expressed that they could not continue for reasons including breathlessness, light-headedness or chest pain during the test. Saturations were measured during the test with a spot-check monitor (Carescape V100, GE Healthcare, Chalfont St Giles, UK).

No changes to medication were undertaken for the test.

Follow-up/outcome

The following outcomes were collated from medical records: rehospitalisation within 30 days, mortality within 30 days, subsequent COVID-19 diagnosis within 7 days of taking part of the test, clinical deterioration within 7 days and changes in decision to discharge.

Safety and feasibility

Safety was determined by the number of adverse events, feasibility by number of eligible patients and usability as the number of patients able to complete the test as a proportion of the number of invited patients.

Data analysis

Data were uploaded to MS Excel and IBM SPSS version 26 for data analysis.

The percentage of predicted HR achieved by participants in the 40-steps on the spot test using the maximum HR equation ((220 – age in years)/(208 – (0.7 × age in years))) was used to estimate the exercise intensity achieved by participants during the 40-steps test.[19]

All variables were tested for normality. Normal distributed variables were reported as mean and standard deviation (SD), non-normal distributed variables were reported a median and interquartile range (IQR). The chi-squared test was used for categorical variables. Significance was assumed for $p<0.05$. No adjustments were undertaken for multiple comparisons.

The STROBE guidelines for reporting observational studies was used for the reporting of the results.[20]

The sample size was based pragmatically on availability of investigators. No formal sample size estimate was undertaken. The study was closed due to an inability to recruit further patients.

Registration and ethics

The study protocol was designed in collaboration with clinicians and scientists at Oxford Brookes University, Betsi Cadwaladr University Health Board (BCUHB) and Bangor University. The study was registered with the Health Research Authority (IRAS reference 283998) and ethical approval was obtained (REC 20/WA/0286). All participants provided written informed consent. No external funding was received.

Results

Screening

One-hundred and fifty-two participants were screened between November 2020 and February 2021, and 64 (42%) were recruited

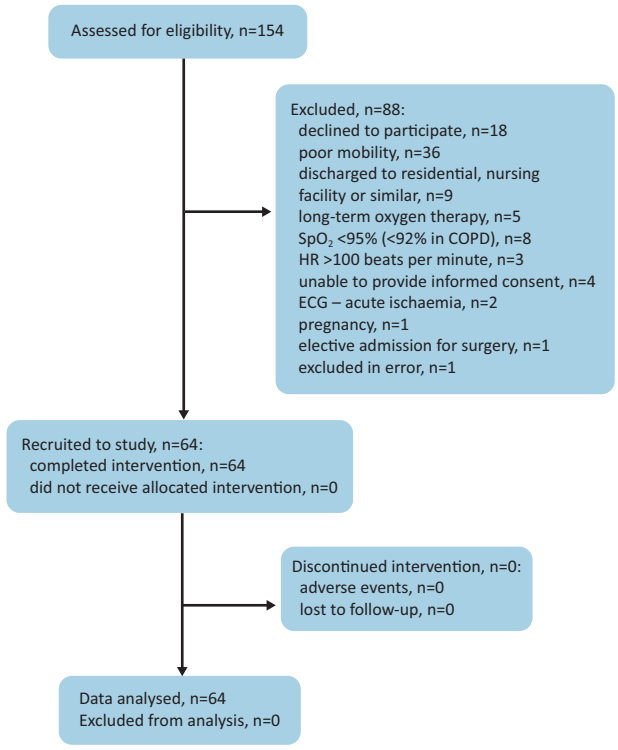

Fig 1. Process for inclusion in 40-steps test study. COPD = chronic obstructive pulmonary disorder; ECG = electrocardiography; HR = heart rate; SpO_2 = peripheral oxygen saturation.

to the study. The attrition of patients screened to participants recruited and their outcomes are summarised in Fig 1 with reasons for exclusion outlined. Participants in older age groups were more likely to meet criteria for exclusion. The mean age of included participants was significantly younger at 63 years (range 19–90) vs excluded participants at 71 years (range 24–98; p=0.008).

Demographics

Fifty per cent of participants were recruited from inpatient wards, 36% from the acute medical unit and 14% from the emergency department (Table 1). The mean age of patients recruited was 62.5 years (SD 18.7). The sample included 35 women and 29 men. Sixty-one participants were White, one was Asian, one was Black/African-Caribbean and one was Arabic.

Pre-existing comorbidities potentially affecting cardiopulmonary exercise were presented in 22 (34%) patients (16% COPD, 19% asthma, 2% pulmonary fibrosis and 3% heart failure). Eleven (17%) COVID-19 positive patients were included, of whom, two had pre-existing asthma and one with COPD had a comorbid lung condition.

Safety

Of the 64 participants recruited, 100% completed the 40-steps test in full. There were no adverse events or early terminations of the test recorded. One participant was identified as requiring physiotherapy after appearing unsteady during the exercise test. Several participants were noted to need to hold on to a surface to stabilise themselves during or immediately after the test.

Table 1. Demographic data

	Total, n=64	Readmission, n=4	No readmission, n=60
Gender, n (%)			
Men	29 (45.3)	0 (0.0)	29 (48.3)
Women	35 (54.7)	4 (100.0)	31 (52.7)
Age, years, mean (SD; range)	62.5 (18.7; 19–90)	76.3 (19.6; 47–88)	61.7 (18.5; 19–90)
Ethnicity, n (%)			
White	61 (95.3)	4 (100.0)	57 (95.0)
African-Caribbean	1 (1.6)	0 (0.0)	1 (1.7)
Asian	1 (1.6)	0 (0.0)	1 (1.7)
Arabic	1 (1.6)	0 (0.0)	1 (1.7)
Other	0 (0.0)	0 (0.0)	0 (0.0)
Location, n (%)			
ED	9 (14.1)	2 (50.0)	7 (11.7)
AMU	23 (35.9)	1 (25.0)	22 (36.7)
Ward	32 (50)	1 (25.0)	31 (51.7)
Ambulance	0 (0.0)	0 (0.0)	0 (0.0)
Primary care	0 (0.0)	0 (0.0)	0 (0.0)
Comorbidity, n (%)			
COPD	7 (10.9)	0 (0.0)	7 (11.7)
Asthma	9 (14.1)	0 (0.0)	9 (15.0)
COPD and asthma	3 (4.7)	0 (0.0)	3 (5.0)
Pulmonary fibrosis	1 (1.6)	0 (0.0)	1 (1.7)
Heart failure	2 (3.1)	0 (0.0)	2 (3.3)
COVID-19, n (%)			
Positive	11 (17.2)	1 (25.0)	10 (16.7)
Negative	49 (76.6)	3 (75.0)	46 (76.7)
Not tested	4 (6.2)	0 (0.0)	4 (6.7)

The three participants investigated further included one patient having a D-dimer test that was normal, one had a chest X-ray that confirmed a hospital-acquired pneumonia and one who had a COVID-19 PCR result that was positive. The patient who clinically deteriorated was the patient who was diagnosed with a hospital-acquired pneumonia. AMU = acute medical unit; COPD = chronic obstructive pulmonary disease; ED = emergency department; SD = standard deviation.

Exercise intensity of the 40-steps test

Using the standard calculation for maximum predicted heart rate (HR_{max}), 17% of the cohort generated a HR less than 50% their predicted maximum (light intensity) during the 40-steps test. Most participants (66%) exercised to a moderate intensity during the 40-steps test (HR 50%–70% of maximum predicted), and a further 17% were vigorously exercising during the test (>70%). Mean percentage of maximum predicted HR during the test was 60% (SD 11.51; Fig 2).

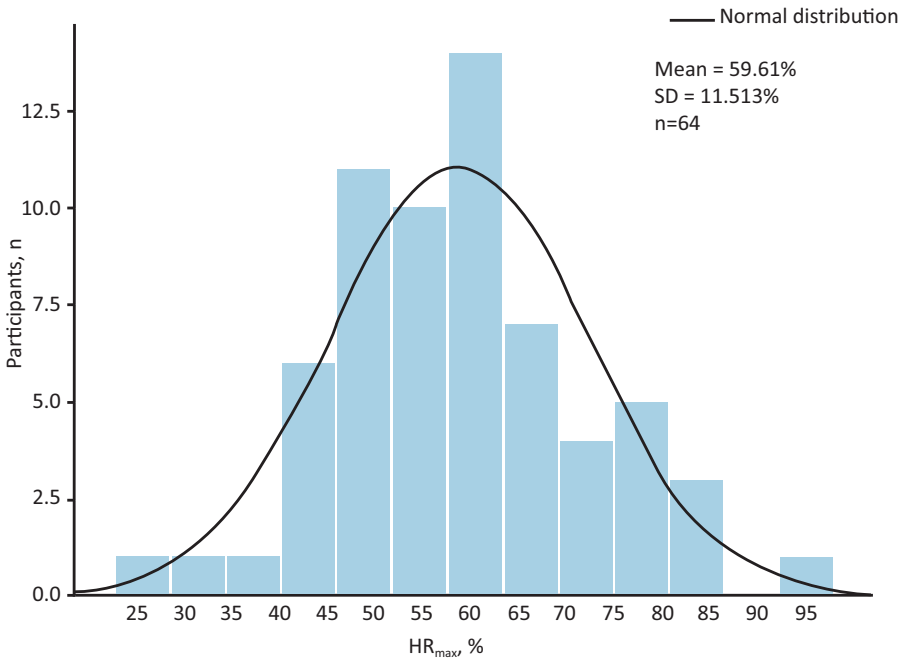

Fig 2. Distribution of maximum predicted heart rate from the 40-steps test. Maximum heart rate was calculated using end-test heart rate/(220 – age in years) × 100. HR_{max} = maximum heart rate; SD = standard deviation.

Physiological variables during exercise

The mean starting SpO_2 was 97%, with a mean decrease of 1% at the end of the 40-steps test. Mean oxygen saturation at 2 minutes was also 96%. The mean starting HR for all participants was 82 beats per minute, increasing a mean of 11 beats per minute to 93 beats per minute at completion of the 40-steps test, before recovering to a mean of 88 beats per minute at 2 minutes. The mean resting RR in our cohort was 18 breaths per minute, which rose to 19 breaths per minute after 40 steps and returned to a mean of 18 breaths per minute at 2 minutes. The mean numerical dyspnoea score given at rest was 2 out of 10. This increased by an average of 1 to a mean of 3 at test completion, before decreasing to a mean of 2 at 2 minutes.

Patients with COVID-19

In the cohort of patients with COVID-19, mean pre-exercise saturation was 96%, with a mean post-exertion saturation of 94%. Mean SpO_2 at 2 minutes after completing the test was 97%. The mean oxygen desaturation in patients with COVID-19 was 2%, however, there was a wide clinical variability (Fig 3).

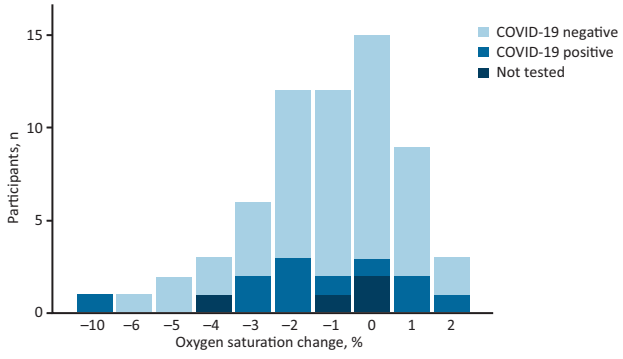

Fig 3. Post-exertional oxygen saturation changes according to COVID-19 status. Change in oxygen saturation was measured from baseline to immediately after completion of the 40-steps test.

The difference in SpO_2 at baseline, test completion and at 2 minutes after between patients with COVID-19 and without COVID-19 was not statistically significant. The difference between the mean SpO_2 change from baseline to test completion in the patients that were COVID-19 positive and those that were negative cohorts was <1% (p=0.656).

Patients that were COVID-19 positive and COVID-19 negative had a similar mean baseline heart rate, but patients that were COVID-19 positive had a mean increased HR of 16 beats per minute by test completion compared with 10 beats per minute in those without COVID-19.

The mean baseline RR in patients that were COVID-19 positive was higher than the group that were COVID-19 negative; however, the difference in respiratory rate change observed following the 40-steps test was less than 1 breath per minute between COVID-19 and non-COVID-19 cases.

The difference in baseline, end-test and at 2 minutes after numerical dyspnoea score between patients with COVID-19 and without COVID-19 were all significant at p<0.05 (p=0.021, p=0.029 and p=0.042, respectively), with patients that were COVID-19 positive reporting dyspnoea scores on average twice as high as those without COVID-19. However, the difference in change of dyspnoea score prompted by the 40-steps test in the two groups was 0.2, which was not statistically significant (p=0.584).

A third of patients that were COVID-19 positive required further inpatient hospital stay after the 40-steps test was completed, 9% were readmitted, 27% were investigated further and 18% clinically deteriorated.

30-day follow-up

No deaths were recorded during 30-day follow-up.

Same-day discharge occurred in 49 (76.6%) participants. Fifteen (23.4%) participants required further inpatient hospital stay; five

(7.8%) were discharged the following day, nine (14.1%) within 7 days and one (1.6%) within 14 days of the 40-steps test.

Three participants (mean desaturation 4%; all COVID-19 positive; range –10% to 0%) had further investigations as inpatients following the 40-steps test: one had a D-dimer test to assess for pulmonary embolism following marked desaturation on the 40-steps test (due to 10% desaturation), one had repeat chest imaging that confirmed a hospital-acquired pneumonia and another had a COVID-19 test that confirmed COVID-19. Only one (2%) patient experienced clinical deterioration while still in hospital and was diagnosed with hospital-acquired pneumonia.

Four (6%) participants were re-hospitalised within 30 days of taking part in the study, including one who presented to the emergency department and was then discharged. The reasons for readmission included worsening symptoms of metastatic cancer, COVID-19-related diarrhoea and vomiting, and back pain. None of the physiological parameters measured during the 40-steps test showed a significant association with readmission to hospital within the period studied, including the change in HR, RR, SpO_2 and dyspnoea.

Same-day discharge

Of the patients with COVID-19, the oxygen saturation changes from baseline to test completion ranged from –10% to 2% in those hospitalised further and, in the COVID-19 negative cohort, SpO_2 change ranged from –5% to 1%. The observed mean differences in SpO_2 at baseline, test completion and after 2 minutes between those hospitalised further and those discharged on the day of the test as planned were less than 1%. The mean change between SpO_2 at the end of the test from baseline was –2% in those further hospitalised compared with –1% in those discharged on the same day.

The HR values for those hospitalised further were, on average, lower than those discharged on the same day, and both groups increased HR by a mean of 11 beats per minute during the 40-steps test. End-of-test RR was 2 breaths per minute lower in the same-day discharge group, which was statistically significant ($p=0.038$), but the difference in change in RR during the test between the groups was <1 breath per minute. Dyspnoea scores did not differ significantly between the groups.

Physiological thresholds

Using an SpO_2 threshold of 3% as currently recommended for admission to be considered, we found that 27% of patients with COVID-19 desaturated more than 3% compared with 18% of patients without COVID-19.[16] None of the readmitted patients desaturated more than 3% during the 40-steps test. In those who continued to be hospitalised despite planned discharge, 27% had desaturated ≥3% during the test. Thirty-six per cent of patients with COVID-19 in the study were hospitalised further following the 40-steps test, of whom, 50% had desaturated 3% during the test (Table 2).

The area under the receiver operator characteristic curve (AUROC) for changes in SpO_2 for readmission at 30 days was 0.72 (95% confidence interval 0.532–0.872). AUROC for patients without COVID-19 was 0.697 and for those with COVID-19 was 0.700. There were not higher AUROCS for changes in RR,

Table 2. Using physiological thresholds during the 40-steps test to predict outcome

	COVID-19, n		Readmission, n		Same-day discharge, n		Further investigation, n		Clinical deterioration, n	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Oxygen desaturation										
≥3%	3	9	0	13	9	4	2	11	0	13
<3%	8	40	4	47	40	11	1	50	1	50
Heart rate										
≥15 beats per minute	5	13	0	18	14	4	0	18	1	17
<15 beats per minute	6	36	4	42	35	11	3	43	0	46
Respiratory rate										
≥4 breaths per minute	3	9	1	12	9	4	1	12	1	12
<4 breaths per minute	8	40	3	48	40	11	2	49	0	51
Dyspnoea score										
≥3	3	11	0	15	10	5	0	15	1	14
<3	8	38	4	45	39	10	3	46	0	49

Thresholds refer to the change from the baseline measurement to the measurement immediately after completing the 40-steps test.

HR or dyspnoea for any of the measured outcomes including deterioration within 7 days or need for further investigations.

Discussion

What we have found

To our knowledge this is the first study to assess the 40-steps on-the-spot desaturation test: our study indicates that the 40-steps test is feasible and safe in mobile patients within the acute setting and could potentially be applied in a pathway as a pre-discharge tool. We found that many patients were unable to undertake the test. Without a pre-described pace, exercise was often sub-maximal, with moderate or above levels of exertion achieved by over 75%.

In this small cohort, we did not find an association between desaturation during the test and a diagnosis of COVID-19 or any other outcomes including readmission and clinical deterioration.

HR change was higher in patients with COVID-19 at the end of the 40-steps test and at 2 minutes, with a HR increase of 15 beats per minute or more seen more commonly in patients with COVID-19. Higher dyspnoea scores were observed in participants with COVID-19 diagnosis, those further investigated, those continued to be hospitalised and those who clinically deteriorated.

In our sample, previously recommended thresholds for desaturation were not found to be predictive of clinical deterioration, and further work is needed to establish valid thresholds for changes in HR, RR and dyspnoea.

Limitations

Despite being one of the shortest, less vigorous exercise tests within the literature, many patients had to be excluded from participating in the study, mainly due to poor mobility. This limits the potential wider applicability of the 40-steps test as a widespread screening tool. Predictive modelling is challenging with the small number of participants, and the main finding of our study is the limitation of the 40-steps test in an elderly population while there is still an absence of the predictive performance of the 40-steps test in younger patients.

Discharge from hospital is a complex process, especially in frail patients with limited mobility. Some hospitals have developed checklists to support the process but thresholds for mobility are often poorly defined.[21]

Due to the small sample size obtained, we were unable to assess validity of the test as a predicator or future deterioration, readmission or indeed mortality. Consequently, to substantiate our findings, further studies with a larger sample size is desirable, especially in patients with COVID-19.

What others have found

In a scoping review into the use of exercise testing in the acute setting (submitted for publication), we found limited evidence for using desaturation as a clinical decision tool in acute conditions including COVID-19. Desaturation predicted diagnosis of pulmonary embolism (both in COVID-19 and non-COVID-19), pneumocystis pneumonia, clinical deterioration and hospital readmission within 14 days in various small studies involving 6 minute walking test, 3 minute walking test and bicycle stepper tests.[11–13,18] In a COVID-19 study measuring post-exertion desaturation following a non-standardised period of exertion, we identified modest evidence linking 3% desaturation and 30-days outcome in a select group of patients with oxygen saturations above 94% at rest.[9] Similarly mixed results were seen using the 10-feet desaturation test in COVID-19; a higher proportion of patients who deteriorated clinically or died desaturated more than 3%, however, 51% of the stable cohort also met this criterion.[22]

Dyspnoea as a symptom in COVID-19 at admission has also been linked to deterioration from the disease.[23,24] These are intriguing findings given the widespread focus on silent hypoxaemia.

Implications for clinical practice

As one of the shortest tests ever recommended in the clinical setting, it is likely that the 40-steps test is not sufficiently challenging to elicit exertional desaturation. Importantly, not desaturating during the test did not rule out future clinical deterioration or readmission and, therefore, other clinical features should be considered alongside the presence or absence of desaturation during 40-steps test when deciding to discharge.

More evidence linking dyspnoea scoring and outcomes is required to assess whether there is a link between perceived dyspnoea and COVID-19 outcomes.

Implications for research and or policy

Given the inclusion of the 40-steps test in national guidance as well as its widespread clinical use, analysis of a larger sample assessed for discharge using the 40-steps desaturation test is required to conclusively provide insight into the relevance of desaturation and clinical deterioration in COVID-19.

Our study was open for recruitment in UK hospitals and several hospitals had started the sign-up process but without readily available funding and infrastructure felt unable to contribute to the data collection despite using the test for clinical purposes. The urgency of the pandemic dictated the deployment of 'imperfect' solutions. Drug trials benefited from the existing NHS research infrastructure.[25] Studies in acute care were challenged by the lack of readily available skilled teams that could conduct such work at scale. Our findings might highlight the need for infrastructure funding for acute care research.

Conclusion

We demonstrated that the 40-steps test is a safe and feasible sub-maximal test for use in the acute setting in mobile patients. However, it may not be achievable for a significant proportion of hospitalised patients. Therefore, the evidence to support the use of very-short exertional tests to predict outcomes and facilitate safe discharge from hospital remains limited. ■

Supplementary material

Additional supplementary material may be found in the online version of this article at www.rcpjournals.org/clinmedicine:
S1 – Inclusion and exclusion criteria for study.
S2 – A word-anchored, pictorial numerical rating scale for dyspnoea.

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Conflicts of interest

Dr Matt Inada-Kim is chair of the COVID pathways group at the NHS.

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