Assessing a novel, lab-free, point-of-care test for SARS-CoV-2 (CovidNudge): a diagnostic accuracy study

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Summary

Background Access to rapid diagnosis is key to the control and management of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Laboratory RT-PCR testing is the current standard of care but usually requires a centralised laboratory and significant infrastructure. We describe our diagnostic accuracy assessment of a novel, rapid point-of-care real time RT-PCR CovidNudge test, which requires no laboratory handling or sample pre-processing.

Methods Between April and May, 2020, we obtained two nasopharyngeal swab samples from individuals in three hospitals in London and Oxford (UK). Samples were collected from three groups: self-referred health-care workers with suspected COVID-19; patients attending emergency departments with suspected COVID-19; and hospital inpatient admissions with or without suspected COVID-19. For the CovidNudge test, nasopharyngeal swabs were inserted directly into a cartridge which contains all reagents and components required for RT-PCR reactions, including multiple technical replicates of seven SARS-CoV-2 gene targets (*rdrp1*, *rdrp2*, *e*-gene, *n*-gene, n1, n2 and n3) and human ribonuclease P (*RNaseP*) as sample adequacy control. Swab samples were tested in parallel using the CovidNudge platform, and with standard laboratory RT-PCR using swabs in viral transport medium for processing in a central laboratory. The primary analysis was to compare the sensitivity and specificity of the point-of-care CovidNudge test with laboratory-based testing.

Findings We obtained 386 paired samples: 280 (73%) from self-referred health-care workers, 15 (4%) from patients in the emergency department, and 91 (23%) hospital inpatient admissions. Of the 386 paired samples, 67 tested positive on the CovidNudge point-of-care platform and 71 with standard laboratory RT-PCR. The overall sensitivity of the point-of-care test compared with laboratory-based testing was 94% (95% CI 86–98) with an overall specificity of 100% (99–100). The sensitivity of the test varied by group (self-referred healthcare workers 94% [95% CI 85–98]; patients in the emergency department 100% [48–100]; and hospital inpatient admissions 100% [29–100]). Specificity was consistent between groups (self-referred health-care workers 100% [95% CI 98–100]; patients in the emergency department 100% [69–100]; and hospital inpatient admissions 100% [96–100]). Point of care testing performance was similar during a period of high background prevalence of laboratory positive tests (25% [95% 20–31] in April, 2020) and low prevalence (3% [95% 1–9] in inpatient screening). Amplification of viral nucleocapsid (n1, n2, and n3) and envelope protein gene (e-gene) were most sensitive for detection of spiked SARS-CoV-2 RNA.

Interpretation The CovidNudge platform was a sensitive, specific, and rapid point of care test for the presence of SARS-CoV-2 without laboratory handling or sample pre-processing. The device, which has been implemented in UK hospitals since May, 2020, could enable rapid decisions for clinical care and testing programmes.

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Introduction

Since its emergence in December, 2019, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has led to more than 18 000 000 confirmed cases of COVID-19 and 700 000 deaths globally by the end of July, 2020.[1,2] Improved access to diagnostics is key to controlling ongoing transmission. The viral load in the upper respiratory tract appears to be highest at—or shortly before—the onset of symptoms[3–5] and most patients with COVID-19 are diagnosed using RT-PCR from nasopharyngeal or oropharyngeal swabs.

Since the publication of the first genome sequence of SARS-CoV-2 in January, 2020, several in-house and commercial diagnostic kits have been deployed globally.[6,7] Laboratory RT-PCR remains the standard of care for detection of SARS-CoV-2, although false-negative results

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Research in context

Evidence before this study

WHO has highlighted the development of rapid, point-of-care diagnostics for detection of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) as a key priority to tackle COVID-19. The Foundation for Innovative Diagnostics has identified over 90 point-of-care near-patient or mobile tests for viral detection of SARS-CoV-2. However, the most widely available rapid tests to date require some sample handling, which limits their use at point-of-care. In addition, pressure on supply chains is restricting access to current diagnostics and alternatives are needed urgently.

Added value of this study

We describe the development and clinical validation of CovidNudge, a novel point-of-care RT-PCR diagnostic, evaluated during the first wave of the SARS-CoV-2 epidemic (from Dec 2019). The platform achieved high analytic sensitivity and specificity from dry nasopharyngeal swabs within a self-contained cartridge. The absence of downstream sample handling makes it suitable for use in a range of clinical settings, without need for a laboratory or specialised operator. Multiplexed assays within the cartridge allow inclusion of a positive human control, which reduces the false-negative testing rate caused by insufficient sampling.

Implications of all the available evidence

Point-of-care testing can relieve pressure on centralised laboratories and increase overall testing capacity, complementing existing approaches. These findings support a role for the CovidNudge point-of-care test as part of the strategies to improve access to rapid diagnostics to SARS-CoV-2. Since May, 2020, the system has been implemented in UK hospitals and is being rolled out nationwide.

can occur in patients presenting with a clinical syndrome compatible with a diagnosis of COVID-19.[8] However, standard RT-PCR is time-consuming, not always available, and the technical requirements usually can only be met by centralised diagnostic laboratories. Allowing for sample handling and processing, laboratory based tests typically take 4–6 h to complete, and the transportation of clinical samples can often increase the turnaround time to more than 24 h,[9] potentially resulting in delays in diagnoses and inappropriate infection-control precautions. An additional limitation to several commercial kits is the absence of a human gene target to control for sample adequacy (such as Ribonuclease P [*RNaseP*]), thereby failing to identify inadequate samples and contributing to false-negative results.[10,11]

Point-of-care diagnostics have the potential to improve patient management and control of infectious disease epidemics,[12] and were identified by a WHO expert group as the first of eight research priorities in response to the COVID-19 outbreak.[13] Point-of-care diagnostics accelerate clinical decision making, enabling effective triage and timely therapeutic and infection control interventions,[14] alleviating pressure on overburdened centralised labs, and allowing testing in community settings. However, many existing point-of-care diagnostics still require some sample processing, which limit their use.[9,15]

In response to the SARS-CoV-2 pandemic, the CovidNudge point-of-care real-time RT-PCR platform (DnaNudge, UK) was redesigned from its previous commercial use in human DNA typing, to provide true sample-to-answer multiplex RT-PCR diagnosis of SARS-CoV-2, without the need for any laboratory facilities and trained personnel.[16,17] To assess the performance of this novel diagnostic platform, we did a diagnostic accuracy study for the diagnosis of SARS-CoV-2 infection versus laboratory-based RT-PCR.

See Online for appendix

Methods

CovidNudge point of care test for SARS-CoV-2

The platform comprises two components: the DnaCartridge and a processing unit (NudgeBox) (figure 1). The DnaCartridge (25×78×85 mm; 40 g) is a disposable, sealed, and integrated lab-on-chip device that enables sample-to-result PCR. The DnaCartridge consists of two main parts: an amplification unit and a sample preparation unit. A nasopharyngeal or oropharyngeal swab is immediately inserted directly into the swab chamber of the sample preparation unit at the time of collection. The swab is broken, leaving the swab tip and the sample within the chamber, which is then sealed. Cartridges are placed in the Nudgebox processing unit (28×15·5×13·5 cm; 5 kg), which provides the pneumatic, thermal, imaging, and mechanics required to run a real-time RT-PCR reaction outside a laboratory setting. The sample preparation unit consists of a rotating mixing unit and circumferentially distanced chambers containing buffers to extract and purify RNA from the swab sample, as well as a lyophilised PCR master-mix to mix with the extracted RNA (figure 1). The sample preparation unit mixing chamber fits on top of a motor-driven spigot in the NudgeBox, which rotates the mixing unit through each stage of sample processing before filling the wells of the amplification unit, inside which the PCR reaction takes place. Exposed surfaces of the instruments are cleaned regularly between operators with 10% bleach, followed by an isopropyl alcohol wipe to remove any residual bleach. Following the test, the single-use cartridge is disposed of following standard laboratory disposal procedures.

The amplification unit comprises dried primers and probes uniquely spotted into 72 reaction wells providing multiplex analysis (figure 1; appendix, p 3). For the SARS-CoV-2 assay, the array consists of seven viral targets (*rdrp1*, *rdrp2*, *e*-gene, *n*-gene, n1, n2, and n3)[7,18,19] and one host gene as a sample adequacy control (Ribonuclease P,

RNaseP). Each target has from six to nine technical replicates. The amplification unit sits on top of an active heating and cooling plate, which drives the thermal cycling conditions for the PCR reaction. Multiple cycles of PCR are run generating florescence data similar to conventional PCR instruments (figure 1).

For a well to be classified as having amplified, the amplification curve should reflect the exponential growth and decay of a standard PCR reaction.[20] A test is considered valid if at least three of six replicates of human *RNaseP* amplify, reflecting adequate mucosal sampling (appendix p 5). If two or fewer replicates amplify, it is assumed that sample collection was inadequate and the test is labelled as invalid. We defined a positive test when at least two replicates of at least one viral gene target amplified, otherwise a test was considered negative for SARS-CoV-2.

Study design and participants

Clinical assessment took place between April and May, 2020, at three sites in the UK: St Mary's Hospital, Imperial Healthcare NHS Trust, London; Chelsea & Westminster Hospital NHS Foundation Trust, London; and the John Radcliffe Hospital, Oxford University Hospitals NHS Foundation Trust, Oxford (OUH). All participants consented to two nasopharyngeal swabs being taken.

Samples were collected from three groups: self-referred, health-care workers or their family members with suspected COVID-19 who were not admitted to hospital (between April 10 and May 12, at St Mary's Hospital and the John Radcliffe Hospital); patients admitted to an emergency department with suspected COVID-19 (between April 2 and 24, at St Mary's Hospital); and consecutive hospital inpatient admissions with or without suspected COVID-19 (between May 12 and 18, at Chelsea & Westminster Hospital). Suspected COVID-19 was defined as a patient presenting with any of the following: temperature of 37·8°C or more; clinical evidence of pneumonia (eg, cough or dyspnoea); or hypoxia or an abnormal chest radiograph. Hospital staff were encouraged to self-refer and were eligible for testing if they self-reported any of the following symptoms: fever of 37·8°C or more or subjective fever, fatigue, or malaise, cough or sputum production,

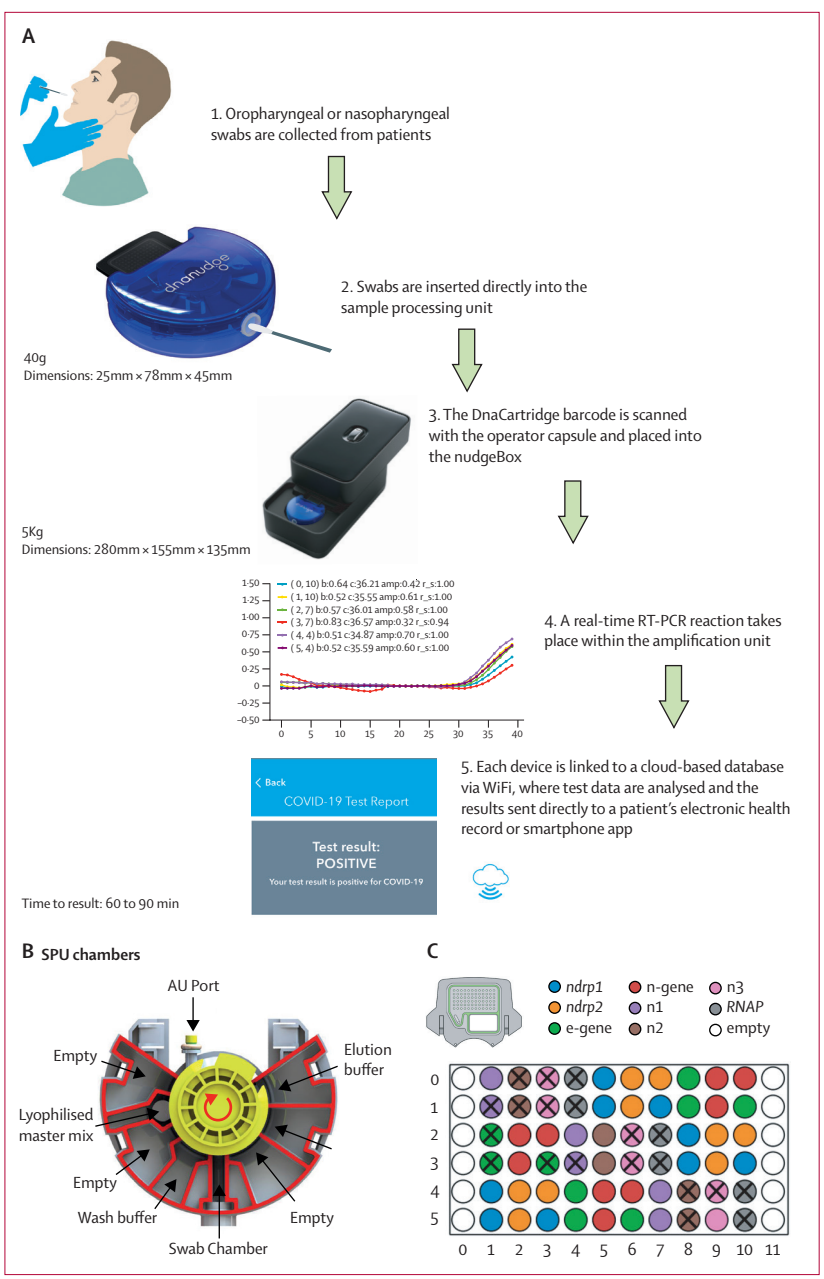

Figure 1: **CovidNudge point of care diagnostic for SARS-CoV-2**
(A) Schematic of the workflow. A swab is collected and loaded directly into the sealed DnaCartridge, comprising a sample preparation unit (SPU) and amplification unit (AU). The DnaCartridge is placed into a slot on the lower half of the processing unit called the NudgeBox, where the SPU mixing chamber fits on top of a motor-driven spigot and the amplification unit sits on top of an active heating and cooling plate. The spigot also connects the DnaCartridge mixing chamber to the pneumatic subsystem. By sliding the upper half to close the NudgeBox, the imaging system aligns on top of the DnaCartridge amplification unit. The upper half also consists of a thermal subsystem which is thermally connected to a mesh plate sitting on top of the amplification unit, which drives the PCR reaction. Data are delivered by WiFi to a cloud-based analysis platform and results are delivered directly to the patient's electronic health record or smartphone app. (B) Schematic of SPU. The test starts with moving the lysis buffer to the swab chamber. The lysis kills and deactivates the (viral) sample and releases the sample RNA. Silica frit filters are mounted on to the port in the mixing chamber which can capture RNA molecules. The lysis buffer moves from the swab chamber to the mixing chamber and the extracted RNA strands bind to the silica frit filter. In the next step, wash buffer is passed through the mixing chamber and any debris is removed. In the third step, the elution buffer releases the RNA strands from the frit. The elution buffer containing the sample RNA is used to reconstitute the lyophilised RT master mix. In the last step of sample preparation, the mixing chamber turns toward the amplification unit filling port of the SPU to fill the amplification unit. (C) Schematic of the amplification unit. The wells are formed by sealing a mesh membrane to the bottom of the chassis, each less than 1·8 µL in volume. Primers and probes for each assay are spotted in nL into the wells, and air dried. To provide redundancy and increase reliability, they are distributed into several wells. The spotting pattern is used by the algorithm to analyse the PCR amplification signals. Each well is represented by a circle coloured according to its assay deposition. Crossed wells indicate the targets replicated that have amplified in a specific reaction.

muscle aches, headache, sore throat, or profound loss of smell and taste.

Paired samples collected from the same site in the same patient or staff member were tested in parallel in the point-of-care and laboratory platforms, with results from CovidNudge testing reported before laboratory results were available. Smaller calibre (paediatric) swabs were used to insert into the CovidNudge cartridge, most commonly a flexible minitip FLOQswab (COPAN Diagnostics, Brescia, Italy), while a second parallel, combined, oropharyngeal and nasopharyngeal swab was collected using a standard swab and placed in viral transport medium for processing in a central laboratory as per local protocols (appendix, p 1).

Laboratory samples were processed at United Kingdom Accreditation Service laboratories. Samples collected at Chelsea & Westminster Hospital and St Mary's Hospital were processed at the North West London Pathology Laboratory (Charing Cross Hospital, London, UK). Those collected at the John Radcliffe Hospital were processed at the same hospital. Assessment took place at the peak of the pandemic in the UK and performance of CovidNudge was compared with the standard platform in use at the time of collection in local laboratories (appendix, pp 1, 16). Centralised laboratory testing and point-of-care testing were done by separate staff members. Staff doing the centralised laboratory testing were masked to the point-of-care test results and vice-versa.

Participants in the second group, patients admitted to an emergency department with suspected COVID-19, were consented as part of the communicable disease research tissue bank (ethical approval ref 15/SC/0089). Following derogation from the UK Medicines and Healthcare products Regulatory Agency evaluation, within-staff testing at all three sites was done as a service evaluation in parallel with routine SARS-CoV-2 RT-PCR testing. Verbal or written consent for an additional swab was obtained from each participant and results from point-of-care testing were not given to the individual participants. Analysis of results from the third group, hospital inpatient admissions with or without suspected COVID-19, was done as a service evaluation approved by the point-of-care committee at Chelsea & Westminster NHS Foundation Trust and results were used to inform patient care.

Statistical analysis

The data analysis was done using R version 4.0[21] using the epiR[22] and the pheatmap[23] packages. The primary analysis, to compare the sensitivity and specificity of the point-of-care CovidNudge test with laboratory-based testing, was done for paired samples collected on the same day. A secondary analysis was done by subgroup, including sample month, study site, location of sampling, and comparator platform. Samples that were invalid on the CovidNudge testing platform were not included in the primary sensitivity analysis and were analysed separately. A batch of eight samples collected

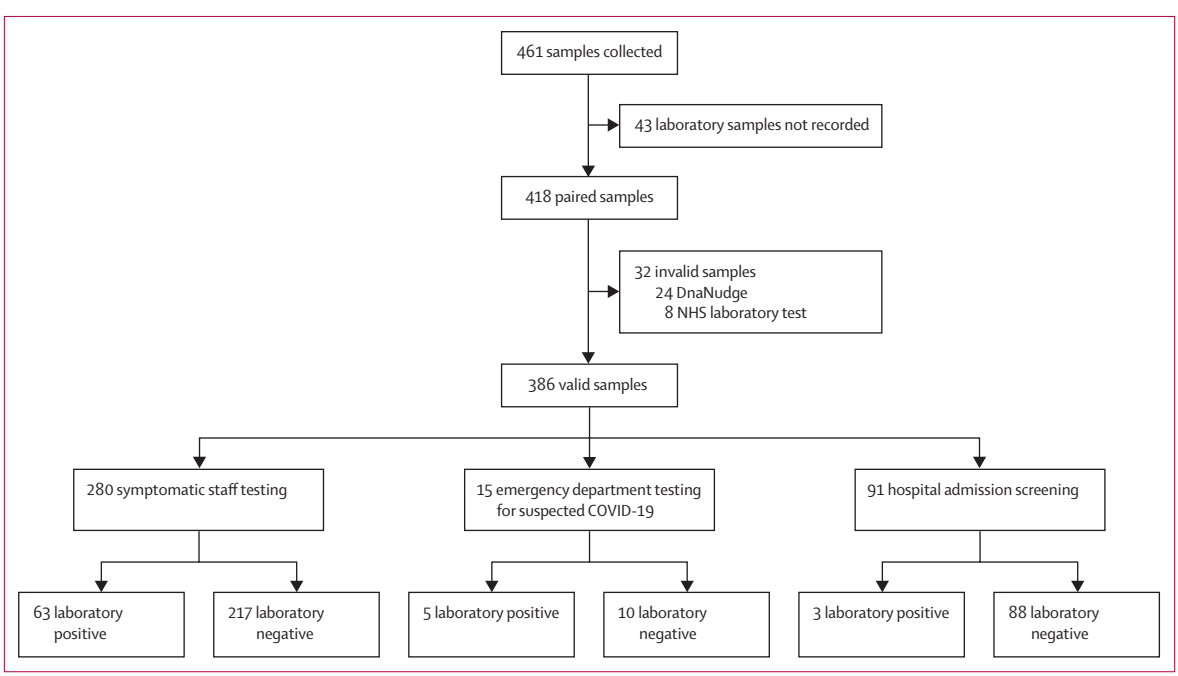

Figure 2: **Profile of clinical study**
Tests were considered valid if at least three of six replicates of RNaseP amplified. Suspected COVID-19 in the emergency department was defined as a patient presenting with any of the following: temperature of 37·8°C or more; clinical evidence of pneumonia (eg, cough or dyspnoea); or hypoxia or an abnormal chest radiograph. Health-care workers were eligible for testing if they self-reported any of the following symptoms: fever of 37·8°C or more or subjective fever, fatigue or malaise, cough or sputum production, muscle aches, headache, sore throat, or profound loss of smell and taste. NHS=UK National Health Service.

on one day at one site were also excluded from the primary analysis because of laboratory assay failure.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. DnaNudge supplied the test cartridges and NudgeBox processing units. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

In-vitro analysis with spiked SARS-CoV-2 RNA (appendix, p 6) found the lower limit of detection (LLOD) to be 5 viral RNA copies per µL for the *n3* assay, 10 viral RNA copies per µL for *n1*, *n2*, and *E* assays while the LLOD for *rdrp1* and *rdrp2* was 50 viral RNA copies per µL (appendix, pp 11–13). When the cartridge was spiked with whole virus particles into the lysis buffer chamber, the lower limit of detection was 1×10^4 viral particles per sample for the *n1*, *n2*, and *n3* targets (appendix, pp 14–15).[5]

Clinical assessment was done over a 6-week period between April 2, and May 18, 2020. 449 same-day samples were collected. Complete clinical data paired with laboratory tests were available for 386 samples, which were included in the primary analysis. The median age of study participants was 46 years (IQR 31–66) and 262 (68%) were female. 280 (73%) samples were collected from self-referred healthcare workers, 15 (4%) from patients in the emergency department, and 91 (23%) from hospital inpatient admissions (figure 2). 24 samples processed on the point-of-care platform were reported as invalid because of their failure to amplify human *RNaseP* in the point-of-care test. 22 of these 24 samples had corresponding results from a laboratory specimen; of these, 16/22 (73%) tested negative.

In the valid samples, the overall prevalence of laboratory-positive tests was 18% (71/386) with the highest prevalence in patients attending the emergency department with suspected COVID-19 and in samples collected in the month of April, 2020 (table). The prevalence was lower in the staff testing and inpatient screening groups. In the primary analysis, the overall sensitivity of the point-of-care test compared with laboratory-based testing was 94% (95% CI 86–98) with a specificity of 100% (99–100%; table). The platform did equally well when compared with a range of laboratory-based platforms and in different clinical settings (table 1; appendix, pp 16–17).

A subset of samples collected from symptomatic staff testing (102/386; 26%) were run on three RT-PCR platforms (the CovidNudge point-of care test, the Public Health England RT-PCR assay targeting *rdrp*, and the ThermoFisher assay targeting *orf1ab*, the spike gene, and the nucleocapsid gene (appendix, p 9). Of these, 78/102 (76%) tested negative on all three platforms. Of samples testing positive with at least one assay (24/102 [24%]), 22/24 (92%) were congruent across all three assays (appendix, p 9). The viral targets amplified varied markedly between individuals, with the most common amplified targets in clinical samples being the *n3*, *e*-gene, and *n1* targets (appendix, p 10).

Discussion

During this study, the incidence of COVID-19 in the UK peaked.[24] We showed that the laboratory-free, point-of-care diagnostic CovidNudge test for SARS-CoV-2 had 94% sensitivity and 100% specificity when compared with standard laboratory-based RT-PCR. The key advantage of

	Tested (n)	Laboratory testing		Point-of-care testing		Prevalence	Sensitivity (95% CI)	Specificity (95% CI)	Positive predictive value (95% CI)	Negative predictive value (95% CI)	Negative likelihood ratio (95% CI)
		Positive	Negative	Positive	Negative						
Total	386	71	315	67	319	0·18 (0·15–0·23)	94% (86–98)	100% (99–100)	1·00 (0·94–1·00)	0·99 (0·97–1·00)	0·06 (0·02–0·15)
Sample context											
Symptomatic staff testing	280	63	217	59	221	0·23 (0·18–0·28)	94% (85–98)	100% (98–100)	1·00 (0·94–1·00)	0·98 (0·95–1·00)	0·06 (0·02–0·16)
Emergency department	15	5	10	5	10	0·33 (0·12–0·62)	100% (48–100)	100% (69–100)	1·00 (0·48–1·00)	1·00 (0·69–1·00)	0·00 (NC)
All hospital admissions	91	3	88	3	88	0·03 (0·01–0·09)	100% (29–100)	100% (96–100)	1·00 (0·29–1·00)	1·00 (0·96–1·00)	0·00 (NC)
Sample period											
April, 2020	272	68	204	64	208	0·25 (0·20–0·31)	94% (86–98)	100% (98–100)	1·00 (0·94–1·00)	0·98 (0·95–0·99)	0·06 (0·02–0·16)
May, 2020	114	3	111	3	111	0·03 (0·01–0·07)	100% (29–100)	100% (97–100)	1·00 (0·29–1·00)	1·00 (0·97–1·00)	0·00 (NC)

Data are for paired samples collected contemporaneously. 24 samples that were invalid on the point of care test and eight that were invalid on the NHS laboratory test were not included. Results are presented according to location of testing, context of testing, laboratory platform, and period of testing. All samples were collected via nasopharyngeal swabs. SARS-CoV-2=severe acute respiratory syndrome coronavirus 2. NC=not calculable.

Table: **Clinical assessment of point of care testing for SARS-CoV-2 compared with laboratory RT-PCR**

the point-of-care platform is that it is a fully automated direct sample-to-answer platform, removing the need for the laboratory infrastructure required for traditional RT-PCR. The run-time (less than 90 min) is more rapid than other laboratory based diagnostic platforms.[9,13] The data suggest that the platform has similar or greater sensitivity and specificity than other rapid assays using dry swabs,[15,25] which will require head-to-head evaluation in future. By contrast with other rapid tests that still require viral transport medium and a simple sample transfer step,[15] with CovidNudge swabs are loaded directly into a fully sealed cartridge, which allows safe testing outside a laboratory setting, potentially including primary care and community settings. We acknowledge that accuracy and a rapid run-time represents only some of the necessary aspects of real-world point-of-care test deployment. Prospective effectiveness studies are required to assess operational challenges, including access to equipment, impact on clinical decision making, cost effectiveness, and equity of access.

The cartridge design allows the inclusion of multiple assays. One of these, human *RNaseP* control, helps to ensure sample adequacy, a major challenge with many existing assays that cannot distinguish a true negative from an insufficient sample. In our study, 73% of samples reported as invalid on the point-of-care platform (due to negative control) were reported as negative on laboratory assays that did not have a sample adequacy control, some of which might have been false negatives. Reporting invalid results rapidly allows clinical decision makers the opportunity to repeat a test where the information is needed for clinical management.

At the onset of the pandemic, the inclusion of several validated assays for different viral targets was expected to improve sensitivity. Surprisingly, one target in the N gene (*n3*) was positive in all positive cases, whereas the *rdrp1* and *rdrp2* targets did less well, consistent with previous reports.[26] The design of the cartridge, with each assay distributed across the analytical unit, means that this difference is more likely due to biological differences in assay performance, than technical performance of the cartridge. Future adaptations will be to replace redundant assays with targets for respiratory syndromic screening (eg, influenza or respiratory syncytial virus) in anticipation of the diagnostic challenges on entering annual influenza season. Further work is required to understand how the algorithm relates to standard PCR measurements such as the cycle threshold value, as well as virus viability, viral load, transmissibility, and the performance of sgRNA targets in the cartridge to assess infectivity.[5,27]

We acknowledge the limitations of our study. The clinical assessment took place during a period of exceptionally heavy demand on clinical and laboratory services in the UK. It was not possible to use a single laboratory platform for comparison, as the supply of reagents was inconsistent and unpredictable. Cross-platform comparison of two laboratory platforms was done in a subset of samples. Given that the point-of-care assay showed a similar performance as a range of other commercial platforms run in different laboratories, it is reasonable to expect that a similar performance would be observed in different clinical settings. Following CE marking in Aug, 2020, to allow testing outside hospitals, and UK National Health Service (NHS) procurement, a standard process for the rollout is being developed by the NHS taking into account this issue. Nevertheless, we advocate for local assessment to compare performance against existing local standards of care when the device is first deployed in a new setting. The falling incidence of infection during the period of study meant that it was not possible to validate the test with a larger number of positive samples; however, the high specificity in a cohort with low background prevalence is reassuring given the risks of incorrectly placing a patient without infection into a ward designated for SARS-CoV-2 infected patients.

Centralised testing with RT-PCR has the advantage of high throughput processing that cannot be achieved by the CovidNudge platform at present. Because each processing unit can process only one cartridge at a time, the assay has relatively low throughput and multiple processing units might be required depending on the clinical setting. However, judicious application of point-of-care tests could relieve the burden on central laboratories and increase overall testing capacity, complementing existing approaches. The platform has a role in testing strategies where results can affect real-time decision making such as prescribing specific SARS-CoV-2 therapy (eg, remdesivir or dexamethasone), triaging unscheduled admissions (eg, to emergency departments and maternity units), and screening elective admissions or staff (eg, before procedures such as surgery or chemotherapy). Additionally, each device is linked to a secure cloud-based database via WiFi, allowing results to be delivered directly to clinical information systems. The potential exists to link to patients' smartphone applications or test and trace facilities, although further work on acceptability, privacy, and information governance are planned for the future. In principle, the platform is well suited to testing in primary care and community settings (eg, long-term care facilities or contact-tracing programmes) with potential for use in non-health-care settings (such as prisons, transport hubs, or offices). However, further studies of real-world effectiveness in non-clinical settings would be required before widespread deployment.

Enhanced testing forms a central pillar of global efforts to control SARS-CoV-2.[27] We have described the first report of the development and clinical assessment of a highly sensitive and specific rapid point-of-care platform for the detection of SARS-CoV-2, validated in frontline clinical settings during the first peak of the COVID-19 pandemic. The device has already been in use in clinical

settings in the UK since May, 2020, and is one component of the testing strategy that is required to contain the COVID-19 pandemic.[28]

Contributors

Assay design and development was done by CT (genetics and bioengineering design), RS (assay development and molecular biology), MS (platform technology and cartridge design), MK (genetics and microbiology), T-KH, SDM, KYFL, JB, and AO. Laboratory development was supported by WB, GPT, and GSC. Clinical evaluation was led by MMG, JB-N, BF, RK, GD, LSPM, NM, KJ, DC, GSC, and AB. National Health Service laboratory testing was undertaken by CH, AR, AB, KS, PR, DM, DC, and KJ. Analysis was done by MMG, CT, GSC, RS, and MS. The first draft of manuscript was written by MMG and GSC. All authors reviewed and approved the final manuscript.

Declaration of interests

CT, RS, MS, MK, T-KH, SDM, K-YFL, JB, and AO are employees of DnaNudge. CT is the co-inventor of the DnaNudge CovidNudge system and is named on the patent for the method and apparatus for analysing biological specimens on the DnaNudge platform (US Patent No: US 10 093 965.B2).[16] LSPM has consulted for bioMerieux (2013–20), DNAelectronics (2015), Dairy Crest (2017–18), Pfizer (2018–20), and Umovis Lab (2020), received speaker fees from Profile Pharma (2018), received research grants from the UK National Institute for Health Research (NIHR; 2013–2019), Leo Pharma (2016), and CW+ Charity (2018–19), and received educational support from Eumedica (2016–17). NM has received speaker fees from Beyer (2016) and Pfizer (2019), and received educational support from Eumedica (2016) and Baxter (2017). MMG and GC are partly supported by the NIHR Imperial Biomedical Research Centre. GC is an NIHR research professor and investigator within the NIHR London in-vitro diagnostic co-operative. All other authors declare no competing interests.

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