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Using a novel ambulatory monitoring system to support patient safety on an acute infectious disease ward during an unfolding pandemic

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Abstract

Aim: To gain staff feedback on the implementation and impact of a novel ambulatory monitoring system to support coronavirus patient management on an isolation ward.

Design: Qualitative service evaluation.

Methods: Semi-structured interviews were conducted with 15 multidisciplinary isolation ward staff in the United Kingdom between July 2020 and May 2021. Interviews were audio-recorded, transcribed and analysed using thematic analysis.

Findings: Adopting Innovation to Assist Patient Safety was identified as the overriding theme. Three interlinked sub-themes represent facets of how the system supported patient safety. Patient Selection was developed throughout the pandemic, as clinical staff became more confident in choosing which patients would benefit most. Trust In the System described how nurses coped with discrepancies between the ambulatory system and ward observation machines. Finally, Resource Management examined how, once trust was built, staff perceived the ambulatory system assisted with caseload management. This supported efficient personal protective equipment resource use by reducing the number of isolation room entries. Despite these reported benefits, face-to-face contact was still highly valued, despite the risk of coronavirus exposure.

Conclusion: Hospital wards should consider using ambulatory monitoring systems to support caseload management and patient safety. Patients in isolation rooms or at high risk of deterioration may particularly benefit from this additional monitoring. However, these systems should be seen as an adjunct to nursing care, not a replacement.

Implications for the Profession and/or Patient Care: Nurses valued ambulatory monitoring as a means of ensuring the safety of patients at risk of deterioration and prioritizing their workload.

Impact: The findings of this research will be useful to all those developing or considering implementation of ambulatory monitoring systems in hospital wards.

Reporting Method: This manuscript follows the Consolidated criteria for Reporting Qualitative Research (COREQ) guidelines with inclusion of relevant SQUIRE guidelines for reporting quality improvement.

Patient or Public Contribution: No Patient or Public Contribution.

KEYWORDS
clinical decision-making, clinical judgement, coronavirus, nurse–patient interaction, nursing observations, qualitative approaches, research in practice, telenursing, wireless monitoring

1 | INTRODUCTION

In recent years, interest has grown across many countries in implementing continuous patient monitoring to complement the usual practice of 4–6 hourly vital sign measurements (Michard et al., 2019). This can aid early detection and treatment of clinical deterioration (Michard et al., 2019). Traditionally this continuous monitoring comprised of wired devices connected to a central monitor. Wired systems have significant limitations as they restrict movement and can be uncomfortable to wear (Sahandi et al., 2010; Weenk et al., 2017). Evolving technology has allowed the development of comfortable wireless wearable devices that allow for continuous vital sign measurement without restricting movement (Areia et al., 2020). These devices have the potential to bridge the gap between intermittent monitoring and the need for wired bedside monitoring (Areia et al., 2020).

In March 2020, the World Health Organization (WHO) declared a public health emergency and global pandemic given the rapid spread of coronavirus 2019 (COVID-19) since it was first detected in December 2019 (Wang et al., 2020). Hospitals were forced to rapidly adjust to high volumes of patients being admitted, with many traditional acute care units being converted into COVID-19 overflow wards due to a lack of intensive care unit (ICU) beds (Andalib et al., 2022). At the start of the COVID-19 pandemic there was significant uncertainty about the risk of virus exposure to staff and PPE (personal protective equipment) guidance was rapidly evolving as knowledge about the virus progressed. The most critically ill patients were admitted to ICUs, but hospitalized patients not requiring ICU, however at risk of deterioration, were transferred within many hospitals to isolation wards (Andalib et al., 2022). These wards consisted of specialist side-rooms designed to contain highly contagious diseases, often with an antechamber between the patient's room and the ward. The overarching aim of utilizing these isolation wards was to maintain patient safety while containing spread of the virus to staff and other patients (Andalib et al., 2022).

During the COVID-19 pandemic, the use of remote vital sign monitoring systems to minimize patient–nurse contact and staff exposure was a highly sought-after prospect in many countries (Fan et al., 2021). NICE recommends that electronic virtual monitoring systems may counteract some of the limitations associated during manual observation rounds, such as allowing for earlier recognition of patient deterioration and reducing the need for face-to-face contact (Downey et al., 2018; NICE, 2007). These considerations were particularly pertinent for staff safety with PPE requirements being novel to many. In order to be of benefit clinically, these remote systems should be accurate, easy to utilize and importantly have clinical staff engagement with its use (Posthuma et al., 2020).

2 | BACKGROUND

The ambulatory monitoring system (AMS) utilized in this service evaluation was part of the ongoing virtual High-Dependency Unit (vHDU) project. This project aims to develop a wearable monitoring system for use in high-risk patients on general surgical wards, with the aim of rapid detection of clinical deteriorations (Areia et al., 2020). This has included wearability and accuracy testing of many devices to inform selection of the final devices used in the system (Areia et al., 2021; Santos et al., 2022). At the start of the pandemic, the vHDU AMS was adapted to meet the requirements of the clinical staff working on isolation wards (Santos et al., 2022). As clinical staff are utilizing and interpreting the output of the AMS, it is important their views of the subsequent impact on workload and perceived effect on patient safety are considered (Leenen et al., 2020; Prgomet et al., 2016). Having been through several phases of testing to optimize the system, it was vital to get data from the perspective of clinical staff.

The AMS consisted of a wireless chest patch to monitor heart rate and respiratory rate (VitalPatch, VitalConnect, USA) along with a finger-based pulse oximeter (Nonin WristOx2 BLE OEM, Nonin Medical Inc., USA). Both devices transmitted data via Bluetooth-Low-Energy both to a tablet at the patient's bedside and to a clinician dashboard at the nurses' station. This enabled the clinical staff to review each patients' vital signs remotely, either in real time or retrospectively. A detailed description of the system has been published elsewhere (Santos et al., 2021). Staff on the ward were supported by the research team, including research nurses and clinical engineers, who ensured the system was functioning as intended throughout the study period and maintained the equipment. The chest patch is single-use and is calibrated when applied.

3 | THE STUDY

This study aimed to explore the ways that staff working on a COVID-19 isolation ward environment experienced the implementation and impact of an ambulatory monitoring system.

4 | METHODS

4.1 | Design

This service evaluation used a qualitative approach to gain insight from staff about the use of the AMS through semi-structured interviews.

4.2 | Study setting and recruitment

One-to-one interviews were held with clinical staff working on an infectious disease ward which operated as a COVID-19 ward during the pandemic at the John Radcliffe Hospital, Oxford. Staff were invited to interviews either through email invitation sent via the ward manager, face-to-face contact, endorsement by a senior manager (matron, consultant) or snowballing from other participants. Although definitive guidelines for sample sizes in qualitative studies do not exist, guidance suggests participant numbers should be selected based on the aims of the study with a narrow-focused aim, requiring a smaller sample than a broad aim. The quality and richness of data is also likely to influence the sample size. As this was a single-site service evaluation with a focused aim, we aimed for a minimum of eight participants (Braun & Clarke, 2006). Although data saturation has been criticized as subjective and difficult to confirm, we did aim to achieve saturation (by continuing recruitment until no new themes were identified) if possible, within the pragmatic limits of our approach.

4.3 | Inclusion and exclusion criteria

Staff could participate if they had good knowledge of the AMS and had utilized the AMS during the pandemic. We anticipated this would include nurses, doctors, clinical support workers and allied health professionals. Participants were selected by purposive sampling to provide a range of views across professions and experience.

4.4 | Data collection

Interviews were conducted shortly after each peak COVID-19 admission rate had subsided (July–October 2020, February–May 2021), to protect staff time and limit burden. To offer flexibility, interviews were either conducted face-to-face or by telephone, as requested by the participating staff member. Written consent was obtained prior to the interview and covered audio and written transcriptions.

Each staff member who expressed an interest in participating was given a participant information leaflet and a verbal explanation of why the service evaluation was being conducted. During the interviews a topic guide was used to prompt questions and help direct follow up questions (Supplementary material). At the start of each interview, participants were again informed of the service evaluation purpose and outcomes before verbally consenting to be interviewed and audio recorded. All interviews were conducted in a quiet room with only the participant and interviewer(s) present if face-to face, or just the interviewer(s) present for telephone interviews. Recordings were transcribed and accuracy was checked by the research team prior to analysis commencing.

4.5 | Data analysis

Interviews were transcribed, anonymized and uploaded to NVivo 12 (*NVivo qualitative data analysis software; QSR International Pty Ltd. Version 12*) where they were analysed following the six phases of thematic analysis (Braun & Clarke, 2006). The first phase involved familiarization of the data with the transcripts being read several times by SV and AJ. Initial codes were then generated by the two researchers (AJ and SV). These initial codes were then developed via comparison and discussion between the research team. Data saturation was determined when no new codes were identified. Initial themes were developed via mind maps and team discussions with ongoing development and refinement until final agreement. Participant quotations were then extracted to illustrate the final themes and findings. Finally, a report of the themes and sub-themes was written by AJ before refinement by the whole team.

4.6 | Ethical considerations

We contacted the Research and Development department of our local NHS trust, who confirmed in accordance with the UK Health Research Authority guidelines that this was a service evaluation not requiring ethical board review. The project was registered as a service evaluation locally with reference Datix 5973. Service evaluation participation was voluntary and there was no conflict of interest between the researchers and participants. Interview audio recordings and transcripts were stored electronically after being anonymized. Participants were assigned reference numbers to maintain confidentiality. All data were stored in a research environment behind two swipe access doors.

4.7 | Rigour and reflexivity

Three interviewers were involved including two registered nurses (LY/SV) both with previous experience of qualitative research. The

last interviewer (AJ) was a critical care physiotherapist seconded to a split clinical and research post at the time of the interviews. To help ensure trustworthiness, SV provided training and assisted AJ with two interviews to ensure minimization of bias, including avoiding leading questions. The service evaluation participants knew the researchers through their assistance implementing and troubleshooting the AMS on the ward throughout the pandemic.

Field notes were taken by the interviewers, documenting any potential biases relating to the participant or situation for the reviewers to reflect on when transcribing. These consisted of observations related to the conditions of the interview, comments on rapport between interviewer and interviewee and any follow up questions or specific points raised at the interview (Supplementary material).

Credibility was achieved through sustained engagement with data and team meetings to develop and discuss core codes and potential themes (Lincoln & Guba, 1985). Trustworthiness was achieved through maintaining filed notes and considering these in the context of the analysis. The service evaluation was also led by an experienced qualitative researcher with appropriate training and support for less experienced team members.

Dependability and confirmability were achieved by an audit trail with clear records being kept of analysis decisions made, including mind maps of developing themes. Direct quotes were used to illustrate clinical staff's viewpoints with researcher biases also being acknowledged and discussed during team meetings (Lincoln & Guba, 1985).

5 | FINDINGS

5.1 | Characteristics of participants

Fifteen staff members were included in the service evaluation involving various professions of differing ages, genders, and professional experience (Table 1). Participants were predominantly nurses, with two doctors and one clinical support worker interviewed. This was due to difficulty contacting the doctors who had worked in the ward during the pandemic, as the junior doctors had rotated to their next job. No physiotherapists worked regularly on the ward during the pandemic peaks. The average length of the interviews was 19 min with the shortest being 13 min 26 s and the longest being 32 min 30 s.

TABLE 1 Professions involved in interviews.

Interview number	Staff role
1	Ward manager
2	Staff Nurse
3	Doctor
4	Clinical support worker
5	Staff Nurse
6	Staff Nurse
7	Staff Nurse
8	Staff Nurse
9	Staff Nurse
10	Staff Nurse
11	Staff Nurse
12	Staff Nurse
13	Ward sister
14	Consultant
15	Deputy sister

5.2 | Adopting Innovation to Assist Patient Safety

All interviewed staff demonstrated a willingness to adopt this new technology to aid them in managing an unprecedented change in their clinical workload. Adopting Innovation to Assist Patient Safety was identified as the overriding main theme, composed of three subthemes each examining a facet of how the system supported patient safety: (i) Patient Selection, (ii) Trust in the AMS and (iii) Resource Management.

5.3 | Sub theme 1: Patient Selection

One of the challenges clinical staff faced was the decision of who should be set up on the virtual monitoring system, given the limited number of devices available. The stark reality of a ward consisting of side rooms, limiting easy observation of these patients, meant there was careful consideration of who would benefit most. This was especially pertinent given the limited number of monitoring systems available. There was consensus among the clinical staff that patients with COVID-19 were clinically different to their usual caseload. Both nurses and doctors described these patients as at high risk of deterioration, especially rapid decreases in oxygen saturations and increases in respiratory rate. Criteria staff used included those on high-flow oxygen, patients requiring frequent observations, and patients who staff anticipated may deteriorate.

> I think the monitoring system actually came at a handy time … we actually had a lot of COVID patients and at the time we were not really sure how to use, how to monitor these patients in terms of like how do we go in there frequently? Or you know how many times should we monitor them per day? We actually used it for all COVID patients that were isolating on high flow oxygen.
>
> Participant 001 (Ward manager)

> I used it with patients that really require monitoring especially with patients in isolation to minimise staff

going into the room especially in the required monitoring frequency.

Participant 003 (Doctor)

we would escalate somebody to use the system if on our general observations we noted that there was a deterioration, or we felt there was likely to be a deterioration.

Participant 007 (Nurse)

During the pandemic, the caseload of patients admitted to the ward was very different to the usual infectious diseases' cohort. This included COVID-19 cardiac outliers and other patients that required closer monitoring than the clinical staff were used to. Many nurses identified this as challenging within their practice, requiring prioritization of vital signs observations within their workload. Staff described the system as valuable for watching the vital-signs trends of patients they were concerned about, while enabling them to continue with their clinical duties. This was described as particularly useful when nursing staff had several unwell patients in their caseload, to aid prioritization.

It helped us to work without too much exposure, but I personally think it was very good if the patient also has like cardiac problems who need to be monitored more in our ward as we don't have those monitors.

Participant 003 (Doctor)

A patient who has a high heart risk and ECG [electrocardiogram) on them and the doctors want us to keep an eye on their heart rate just to know how things are going with them. Some people tend to have a higher respiratory rate especially during this COVID time. The patients that come to us tend to have a high respiratory level as well and we can keep an eye on that as well.

Participant 005 (Nurse)

The changes would prompt us to gown up and go in and see the patient so really, really helpful.

Participant 014 (Consultant)

As the pandemic progressed, staff expertise in managing patients with a higher level of acuity grew. Confidence also rose in predicting patients who would most benefit from using the remote devices. Staff described becoming more selective in their use of the system overtime, balancing the perception of increased patient safety with the drawbacks of the system. They reported the system was less useful for some groups of patients, including those with cold peripheries (this impeded the oxygen saturation monitoring); patients who were confused or restless; and those who were anxious about their oxygenation levels. Staff appeared to become increasingly confident in not using the system for patients who were deemed 'well', and for those who were recognized to be at end-of-life, for which the system was felt to be inappropriate.

the patients who are confused and restless or got cold hands or who is just fidgety and they just want to take it off … you find the monitoring on the floor or on the table because they just want it off.

Participant 011 (Nurse)

for non-COVID patients who were well and deemed medically fit I wouldn't have opted for the continuous monitor.

Participant 008 (Nurse)

there were some patients for who it was useful but it was a double edged sword and so patients who were anxious about their oxygen levels, I found were watching the number on their wrist go up and down and that was clearly having a bit of an impact on them.

Participant 006 (Nurse)

It became clear throughout the interviews that as awareness and knowledge of COVID-19 and its impact on vital signs grew between the first and second pandemic waves, clinical staff felt more confident in using the system. This included feeling empowered to select the most appropriate patients for whom the system would aid with clinical decision-making and caseload management. While the remote monitoring was perceived to assist the nursing staff, there were also limitations associated with the system use, so careful consideration had to be made about which patients would benefit from it the most.

5.4 | Sub theme 2: Trust in the AMS

With the development of a novel AMS, a core element of its success is ensuring the multidisciplinary team trust the information generated. Patients with COVID-19 have been shown to rapidly deteriorate requiring quick medical intervention to ensure adequate oxygen saturations (Filipovic et al., 2020). Ensuring monitoring systems are accurate is fundamental to the safety of these vulnerable patients.

That monitoring became essential. We used it as a sort of early warning for early engagement from intensive care and respiratory for our patients.

Participant 014 (Consultant)

It was clear most of the clinical staff wished to ensure accuracy of the system when coming onto shift. Five nurses described how they would measure accuracy by comparing the virtual monitoring observations with their usual ward monitoring system. Accuracy

was a key element underlying trustworthiness of observations gained.

> For me when I'm starting my shift and I have a patient on the device I will go in with the obs[ervation] machines as well just to double check to know what their reading is, and I don't see any difference.
>
> Participant 005 (Nurse)

> Sometimes I go into the room, and I have the obs[ervation] machine with me and the monitor will be on and I check the sats [oxygen saturations] and everything is accurate.
>
> Participant 004 (Healthcare assistant)

Most clinical staff interviewed highlighted the importance of having confidence in what observations the system was displaying. There were times where a discrepancy arose, particularly with the saturation probe numbers. Interviewed nurses described wide variation in how they handled these discrepancies. The Nonin pulse oximeter, when compared to the standard ward observation machine, would show lower oxygen saturations and signal a review of the patient. This was described by some staff to be safer than a system which over-reported saturations. For COVID-19 patients, where saturations were a defining point in signalling early deterioration, some staff felt that this slight under reporting in fact allowed for more trust in the system and appropriate escalation to the multidisciplinary team (MDT). Reportedly, a few nurses on the ward with less trust in the monitors chose not to use the system thereby highlighting the importance of a reliable monitoring system on the wards.

> Even though there was a discrepancy between saturations it wasn't a significant difference so you could still get the readings and if the sats went down you could be pretty sure their sats were going down.
>
> Participant 008 (Nurse)

> The saturation we noticed it was a little bit lower than what other machines were reading so that was another reason some people did not use them.
>
> Participant 007 (Nurse)

> if you get a false positive then the patient needs observation so it is better when they under read.
>
> Participant 008 (Nurse)

With patient safety being the foremost thought of the clinical staff interviewed, trust in the observations was shown to really be a vital component underlying how clinical staff utilized the AMS in practice.

5.5 | Sub-theme 3: Resource Management

At the start of the pandemic there was significant uncertainty about the risk to staff though exposure with rapidly evolving guidance on PPE. Donning PPE also meant room entry was time consuming where time was at a premium. The AMS was initially implemented as a means to reduce the frequency of room entries. Although there was local agreement that with the use of the AMS, the protocolized frequency of blood pressure monitoring could be reduced to lower the required room entries, many of the staff interviewed described discomfort with this. They emphasized the need for contact with patients to ensure safety and appropriate care delivery.

> I think also weighing on our shoulders we're completely accountable for our patient care and I don't know, even if I'm told not to do something for my own benefit so that I know how my patient is I'm going to want to know exactly how they are.
>
> Participant 007 (Nurse)

> I think because of the frequency of observations and the fact it was recording so frequently it took a little bit of pressure off if you had multiple unwell patients yourself and you felt that you were keeping a closer eye on them because it was not practical to be dipping in and out of rooms when you've got six sick patients and that's a high ratio of patients to one that's not practical and you can't get PPE [Personal Protective Equipment] on, get in the room and do the observations, come out, act on them and go into the next one so it's really reassuring to be able to walk past, have a quick look at other patients and go okay prioritise or not.
>
> Participant 007 (Nurse)

Throughout the pandemic most nurses interviewed reported an extra workload demand from the volume of patients admitted, staff absence due to sickness and the time required to don and doff PPE between patients. Those who trusted the observations reported that the AMS assisted with managing their caseload as efficiently as possible by allowing them to assess observations without entering the patient's room. This also preserved PPE supplies, which was particularly important at the start of the pandemic when PPE guidance was frequently changing, and availability was precarious.

> with patients where you have to wear the Level 2 the donning and doffing itself takes about 10–15 min then if you want to go in there and read the obs[ervations] all the time it's a waste of resources in terms of

> donning and doffing … it has saved time and resources I would say.
>
> Participant 009 (Nurse)

> instead of going in and out every half hourly or hourly we can document and everything so it's really helpful in saving our time.
>
> Participant 012 (Nurse)

When trying to manage high caseloads and rapidly deteriorating patients, most nurses reported that the AMS allowed for reassurance of patient stability and assisted with prioritization of patients. This meant they could ensure timely delivery of essential medications.

> because it helps actually, the monitoring it really helps time management of the staff because of the reassurance looking at the central monitor.
>
> Participant 003 (Doctor)

> sometimes you forget and you need to do obs[ervations] on this patient but you are so busy and if you can just glance at the big screen and the patient is okay … I can go to that patient later and I attend to some other patient who maybe needs pain medication.
>
> Participant 005 (Nurse)

As the response to the pandemic evolved, guidance changed to no longer require as extensive PPE for all patients with COVID-19, and staff became more comfortable with exposure to the virus. The use of the AMS evolved so that instead of predominantly being used as a way to reduce patient contact, it also informed the management of their workload. Staff recognized ongoing benefits of the system on a ward where most patients were in side-rooms and therefore not easily visible. The system was used as an adjunct to regular manual observation measurements which included blood pressure and temperature, which the system did not offer. In this way, staff described being able to get a quick overview of the well-being of their patients.

> Yes, absolutely I think it's great to have it available just because of the practicalities of side room nursing and not even to do with COVID and PPE, it's just having the patient observed when you're not there, it's another set of eyes on them really isn't it.
>
> Participant 007 (Nurse)

> you couldn't really go into the room all the time you're trying to also you know you're trying to avoid going into the room all the time but then again you can actually sit down virtually, and you can actually observe and see how the patients are actually doing. Without you going there all the time.
>
> Participant 001 (Ward manager)

Overall, the AMS was described as a useful adjunct by many of the clinical staff as a way of protecting them and their patients. Observing trends assisted with planning the frequency of intermittent monitoring. As clinical staff grew more accustomed to the physiological presentation of COVID-19 patients they were able to utilize the AMS to support their clinical decision making around caseload management.

6 | DISCUSSION

This service evaluation investigated the experiences of clinical staff during an unprecedented pandemic which saw a dramatic change in the clinical caseload admitted to their ward. We report a novel approach to the use of AMS on an isolation ward where patient safety was paramount and have demonstrated that the clinical staff experienced this as being generally positive. Adopting Innovation for Patient Safety was the main overarching theme identified in this analysis. Three interlinked sub-themes, representing contributory factors to this were identified: Patient Selection, Trust In the System and Resource Management. The AMS reportedly assisted with patient safety in a challenging environment at a time where uncertainty around staff safety and risk of exposure was high. However, despite the trust placed by the staff in the output generated by the system, the use of AMS cannot replace the need for nurses to have face-to-face contact with their patients to gain more subjective information than data on a monitor.

This concept of staff intuition and detecting deterioration from parameters outside of electronic data and early warning scores has been previously discussed in other studies (Donohue & Endacott, 2010; Ede et al., 2020). Visual assessment of patients has been reported as hugely important in recognizing early deterioration rather than focusing simply on trends and figures (Donohue & Endacott, 2010; Ede et al., 2020). These visual assessments can aid recognizing changes in patients' pallor or observed work of breathing which can often precede deterioration and cannot be picked up by electronic vital sign measurements (Donohue & Endacott, 2010).

Successful use of continuous monitoring systems rests on trust in the data collected (Downey et al., 2018; Jeskey et al., 2011). In this service evaluation, we found that it was mainly oxygen saturation readings which raised concerns relating to patient status. This is likely due to hypoxia being a vital early warning of COVID-19 patient deterioration and the clinical staff being unaccustomed to rapidly desaturating patients. We recognize the importance of accuracy of devices both in terms of patient safety and staff trust in the data, which we identified in earlier qualitative work as an important factor for both patients and staff. As part of our work developing the AMS, we tested multiple devices for accuracy by simulating common patient activities and hypoxia in health volunteers (Areia et al., 2020; Santos et al., 2022). In this study, we identified the Nonin device, used in this service evaluation, sometimes reported lower oxygen saturation readings than usual care ward devices (Santos et al., 2022). It was however the most accurate compared to blood gas samples and the only device tested that could regain connectivity to the AMS

without nurse intervention. The later was deemed essential to assist reducing the need for staff to enter the isolation rooms to reconnect devices (Santos et al., 2022). Future work is needed to improve the accuracy of wearable pulse oximeters for use in acute clinical settings. Additionally, this study highlighted wearability issues, that need to be understood and addressed. As the COVID pandemic progressed and the clinical staff became more accustomed to not only the use of PPE, but also the clinical caseload admitted, they developed greater confidence in using the AMS to aid time management. This is a likely consequence of greater trust in the system by better understanding those patients who would most benefit and competently interpreting trends. This aided detecting deterioration early as demonstrated in previous studies (Brown et al., 2014; Prgomet et al., 2016).

Our overriding theme was that of Adopting Innovation to Assist with Patient Safety which is becoming an increasingly prevalent topic. The finding that staff did not perceive the AMS as replacing manual observations and face-to-face interaction suggests that wearable technology should not be a substitute for direct contact with patients (Prgomet et al., 2016). The description of staff determination to ensure patient safety has been highlighted in other studies with either no change or increased face-to-face contacts despite implementation of wireless vital sign monitoring systems (Weenk et al., 2017). We found that nurses valued patient contact and emphasized that the AMS could not replace face-to-face assessment. Several studies have also reported the importance of face-to-face nursing contact and the role manual vital sign measurements play in this interaction (Downey et al., 2018; Ede et al., 2021; Gao et al., 2020). Authors suggest physiological numbers may not reflect the overall state of the patient and the concept of 'knowing' the patient by direct contact beyond that of observing vital sign data has been widely researched (Downey et al., 2018; Gazarian et al., 2010; Tanner et al., 1993). This aligns with implications made in our service evaluation by the nursing staff that despite the known exposure risks to themselves, they did not fully rely on the AMS to gain an overall picture of the patient they were professionally responsible for. Therefore, despite the rise in interest and use of AMS, detecting deterioration should not be underestimated. Remote monitoring systems are unable to detect factors such as patient appearance and work of breathing, which skilled clinicians look for when assessing the condition of a patient (Prgomet et al., 2016).

6.1 | Strengths and limitations of the work

The research design allowed staff to share their experiences and provided useful insight into their perceptions of the benefits of the system, as well as their concerns about it. A further strength of the methodology was the length of the study period, which captured changing views as experience in managing patients with COVID-19 increased.

This service evaluation was limited by a single site approach, impacting the transferability of findings. It was challenging to recruit professionals outside of the nursing staff. Only two doctors and one clinical support worker were interviewed, despite the best efforts of the authors to gain a greater diversity of staff. This was due to time constraints and staff changing roles (particularly junior doctors rotating) following the pandemic. While the sample size was small it was within our anticipated target. Despite the lack of representation of the wider multidisciplinary team, data saturation was achieved with no new codes being generated from the final two interviews.

All interviewed staff were generally positive about the system. Although we observed widespread enthusiastic adaptation of the system during the pandemic, it is likely those willing to be interviewed were also those who viewed the AMS positively. Not accessing negative perspectives of the system may further limit transferability of our findings.

We did not investigate the patients perspective of wearing the AMS as previous studies have done (Downey et al., 2018). Although the patient perspective is important, it was not feasible to follow up discharged patients up within the confines of this service evaluation approach and the unfolding pandemic.

6.2 | Recommendations for further research

Future research should consider patient perspectives and acceptability of wearable vital sign monitoring especially given that many nurses reported abandoning the use of AMS in agitated or anxious patients. The majority of interviewed staff reported the AMS was useful for prioritization of their caseload, but it is important to investigate the impact of AMS on patient outcomes in particular, and implications for patient safety.

6.3 | Implications for policy and practice

This qualitative service evaluation has demonstrated staff found use of the AMS acceptable, and quickly adopted it into their practice. They valued the system in supporting care of a high-risk group of patients. It is likely that other clinical settings with acutely ill patients or those at risk of deterioration would also welcome AMS. Further work is needed to investigate which populations of patients would most benefit from this system. In particular, given the increasing focus on delivering care to patients outside of the hospital, AMS may well be useful in supporting initiatives such as community virtual wards.

7 | CONCLUSION

The staff interviewed for this study were supportive of the introduction of an ambulatory monitoring system and over time developed their own expertise in how best to utilize it, in order to meet their needs and those of their patients. They valued the system as supporting prioritization of their workload to ensure patient safety in a high-risk patient population. Where ambulatory monitoring systems

are implemented, training and ongoing support will be needed to address any concerns regarding the accuracy of the system, patient suitability and the retention of regular face-to-face clinical reviews.

Future research should continue to explore the potential impact wireless technology can have on patient safety and monitoring especially given ongoing staff shortages and pressure on nursing caseload management.

AUTHOR CONTRIBUTIONS

All the authors made a significant contribution to the concept and design of the service evaluation. LY, AJ and SV conducted the interviews. SV and AJ completed the initial coding with HE and CB assisting with refinement of themes and sub-themes. All the authors have contributed to and reviewed the draft and final versions of this manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/jan.15977.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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