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Research and Applications

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Innovating in a crisis: a qualitative evaluation of a hospital and Google partnership to implement a COVID-19 inpatient video monitoring program

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ABSTRACT

Objective: To describe adaptations necessary for effective use of direct-to-consumer (DTC) cameras in an inpatient setting, from the perspective of health care workers.

Methods: Our qualitative study included semi-structured interviews and focus groups with clinicians, information technology (IT) personnel, and health system leaders affiliated with the Mount Sinai Health System. All participants either worked in a coronavirus disease 2019 (COVID-19) unit with DTC cameras or participated in the camera implementation. Three researchers coded the transcripts independently and met weekly to discuss and resolve discrepancies. Abiding by inductive thematic analysis, coders revised the codebook until they reached saturation. All transcripts were coded in Dedoose using the final codebook.

Results: Frontline clinical staff, IT personnel, and health system leaders ($N = 39$) participated in individual interviews and focus groups in November 2020–April 2021. Our analysis identified 5 areas for effective DTC camera use: technology, patient monitoring, workflows, interpersonal relationships, and infrastructure. Participants described adaptations created to optimize camera use and opportunities for improvement necessary for sustained use. Non-COVID-19 patients tended to decline participation.

Discussion: Deploying DTC cameras on inpatient units required adaptations in many routine processes. Addressing consent, 2-way communication issues, patient privacy, and messaging about video monitoring could help facilitate a nimble rollout. Implementation and dissemination of inpatient video monitoring using DTC cameras requires input from patients and frontline staff.

Conclusions: Given the resources and time it takes to implement a usable camera solution, other health systems might benefit from creating task forces to investigate their use before the next crisis.

Key words: COVID-19, electronic personal protective equipment (ePPE), telemedicine, patient safety, patient isolation, health care worker wellbeing

INTRODUCTION

The COVID-19 crisis emerged abruptly and has strained the health care systems around the globe. The rapidly increasing numbers of patients with COVID-19 needing hospitalization, staff shortages, and lack of sufficient personal protective equipment (PPE) generated many challenges, including the difficulty of providing enhanced monitoring of patients under isolation. Moreover, hospitals faced an urgent need to protect health care workers from highly infectious and deadly virus while providing optimal care to patients. Access to appropriate PPE and fear of infecting self and loved ones has been among the top sources of anxiety for health care workers and leaders during the pandemic.[1] To address these concerns, many hospitals increased their use of telemedicine tools that do not require physical proximity for medical screening and evaluations, and tools now referred to as electronic PPE, or ePPE.[2,3] One of the innovative responses that allowed adequate patient monitoring and helped to preserve traditional PPE (eg, N95 face masks) by minimizing noncritical contact with patients was using direct-to-consumer (DTC) cameras on COVID-19 floors.

DTC cameras have been familiar in non-health care settings for decades. For example, homeowners have used them in closed circuit television systems for security purposes; educators have used them in distant learning to reach remote learners; and parents have used them in baby monitoring systems to see and hear their infants from another room in the house. These systems have evolved, and now technology companies such as Google and Amazon sell their versions of products directly to customers, who can receive alerts of movement detection on their phone and speak with a delivery person through the doorbell camera installed outside their door. When the COVID-19 pandemic began, Turer et al[2] proposed inpatient monitoring using commercially available software platforms that are familiar to staff to expedite the adoption and correct use in the context of the pandemic. Mount Sinai Health System (MSHS) in the greater New York City area and other hospital systems took this innovative approach to facilitate patient monitoring.[4–6]

This study examines the use of DTC cameras at a 3815-bed academic medical center where the daily census of patients with COVID-19 reached almost 2000 in early April 2020, including over 400 patients in intensive care units (ICUs). Many of these patients were suffering from respiratory distress and were connected to advanced respiratory devices that required enhanced monitoring. MSHS leadership needed cost-effective cameras with simple installation that could be used by staff easily with minimal training. Minimum requirements included sufficient video image resolution to discern patient discomfort and clear views of the digital readouts of vital monitors. Originally designed as home monitoring systems, Google Nest cameras met these criteria and were leased by MSHS free of charge as an ePPE solution for inpatient monitoring. The health systems received and installed 170 Google Nest cameras and implemented them within 2 weeks at 4 hospitals.

The scale and speed of implementation of this intervention was unprecedented due to the pressures of the pandemic. The few prior studies of inpatient video monitoring that exist have described the use of other forms including telecare phone calls, telemonitoring app,[7] centralized video monitoring with in-room webcams,[8] tele-intensive care units (tele-ICUs),[9,10] and tele-critical care for family visitation during the COVID-19 pandemic.[11] These studies show the promise of each of these technologies specifically. Our study offers insight specific to the use of DTC cameras, contributes to understanding whether the adaptations for other forms of ePPE generalize to DTC cameras, and thus informs future implementations of ePPE in hospitals. Adaptation, a key concept in implementation, is a process of thoughtful and deliberate alteration to the design or delivery of an intervention, with the goal of improving its fit and effectiveness in a given context.[12,13] The objective of our study was to describe the adaptations needed to increase effective use of the cameras from the perspective of frontline clinical staff, information technology (IT) personnel, and hospital leaders.

MATERIALS AND METHODS

Setting

The early surge in the number of patients with COVID-19 in MSHS created the need to have continuous "eyes on the patient" from a distance. Within the first days of the pandemic, Mount Sinai Hospital added 60 ICU beds and converted 2 non-ICU units to accept patients with COVID-19. Unlike ICU floors, these floors had solid doors and walls, preventing needed external visualization of patient rooms. Being able to see patients was critical for timely detection of the need for intervention but the highly infectious and aerosolized nature of COVID-19 transmission required patients to be in isolation. Health care workers had to minimize in-person contact for their own and other patients' safety. Recognizing the visual need and building barrier, MSHS leaders reached out to tech companies about cameras. A contact at Google proposed the use of their DTC solution (Google Nest security cameras for home), which could be customized for hospitals. Partnership between clinicians, Google, IT, and engineering departments aided a quick rollout, given the urgency of the situation. Google loaned these cameras to MSHS temporarily free of charge. A team of engineers from Google and a multidisciplinary team from Mount Sinai that consisted of frontline clinicians, IT, and leadership met daily to design the patient monitoring console. A working prototype was ready to be deployed after 2 weeks of design and development and then a few dozen of Google Nest cameras arrived and were quickly installed. This was the first of many deliveries as the program scaled across MSHS hospitals. MSHS received 170 cameras in total and had about 100 patients being monitored using these cameras at once during peak usage. Cameras were deployed on inpatient units at 4 hospitals and other care settings (eg, dialysis).

Study design

We employed a qualitative design using semi-structured in-depth interviews and focus group discussions, to assess the experiences and perceptions of MSHS staff about the use of Google Nest DTC cameras on COVID-19 floors.[14,15] Our study was guided conceptu-

ally by the Non-adoption, Abandonment, Scale-up, Spread, and Sustainability (NASSS) framework which is pragmatic, evidence-based and theory informed.[16] The framework was developed to help predict and evaluate the success of technology-supported health programs, including remote patient monitoring. The framework guides evaluation of technology adoption, non-adoption, and abandonment by focusing evaluation efforts on implementation constructs (domains) that have critical impact on program success. The NASSS framework includes 7 domains: condition, technology, value proposition, adopters, organization, wider system (ie, policy environment), and embedding and adaptation. We identified COVID-19 as the condition, DTC Google Nest cameras as technology. The value proposition was to improve patient safety, decrease staff anxiety about patients behind closed doors, and decrease staff exposure to COVID-19. Adopters (clinicians and IT personnel) and organization (organizational leaders) are key stakeholders involved in this early demonstration project within a single health system. We chose to conduct our study from their perspective because they were most knowledgeable about the adaptations needed for effective use of cameras.

Data collection

The interviews and focus groups took place between November 2020 and April 2021. During this period, New York City experienced a second wave of COVID-19 pandemic,[17] with schools switching to remote instruction by the end of November; COVID-19 vaccines receiving emergency authorization in December 2020; and schools reopening for in-person classes in February–March 2021. Interviews, which were conducted by a single researcher, occurred via phone or video conferencing, while focus groups were facilitated by 2 team members on site (initials removed for blinding) using video conferencing equipment to connect with interviewers (initials removed for blinding). We used focus groups with clinical staff to explore opinions, attitudes, and beliefs about camera implementation in a time-efficient manner. We added individual interviews with nurse managers, registered nurses, patient care associates (PCAs), and nursing assistants (NAs) to clarify emerging themes, gather detailed descriptions of processes, and capture any divergent opinions that could be missed in a focus group setting. We interviewed some physicians in leadership positions, and report them as "health system leaders" rather than physicians here. We interviewed no physicians working on the COVID-19 units. This was an intentional decision based on whose workflows were affected by the DTC cameras the most: nurses and patient care associates. While aware of the cameras, physicians continued to round on patients in person and did not use the cameras in their work or interaction with patients. We used the same interview guide for interviews and focus groups. The study team completed frontline personnel interviews early in the project. In seeking to understand the technical and administrative context, we recruited additional interviewees in IT and leadership roles in the spring. The study was deemed exempt by the Mount Sinai Program for Protection of Human Subjects. All participants voluntarily consented to be interviewed and recorded for anonymized transcription, and de-identified reporting of their comments.

Participant recruitment

We recruited a variety of stakeholders, including frontline clinical staff, IT personnel, and MSHS leaders ($N = 39$) for individual interviews and focus groups. The clinical staff included PCAs, nurse managers, registered nurses, and NAs ($N = 31$ in 6 focus groups and 7 individual interviews). We also conducted individual interviews with project management personnel, executive leaders, IT staff members, and a technical engineer from Google ($N = 8$). The primary inclusion criterion was working on a COVID-19 floor with cameras installed or having direct experience with the project.

The study team conducted 30-min interviews and focus groups via internet-based video conferencing. Participants were assigned identification (ID) codes to identify data collected from them. Focus group participants were reported as a single group without participants' ID codes, because all focus groups were with clinical staff and the main focus was in documenting their experiences.

The interviewer ensured that each participant answered questions in all domains of the interview guide (Table 1) including participants' roles in patient care, their experiences with the cameras, the impact on clinical workflows, patient safety, and staff morale, along with opportunities for improvement of camera use beyond the COVID-19 pandemic. Using an interview guide helped ensure consistency and reliability of collected data across participants.[18,19] The interviewers used probes for clarification of concepts to ensure data credibility, or truth value to the participants and the context.[20] Using probes can also elicit different explanations/details around certain constructs, thereby highlighting different facets of these phenomena. We reached saturation after we completed about two-thirds of the total number of interviews with clinical staff (4 out of 6 focus groups with clinical staff, $N = 2$ individual interviews with nursing staff, and $N = 1$ interview with a PCA). We followed accepted standards in qualitative research, which defines saturation as the point when new interviews yielded very little/no new information. We continued to interview a few more people beyond that point to make sure we have not missed anything. Then, we recruited IT personnel and executive leaders to add context and varying perspectives. Interviewers' personal preconceptions or biases regarding DTC camera use were discussed within the research team and documented prior to interviews to reduce bias in participant selection and data analysis.

Data analysis

A professional transcription service transcribed recorded interviews. The study team verified transcripts with interviewers' notes for consistency and accuracy and analyzed transcripts using the inductive technique, that is, using individual observations in the data to derive codes and themes.[18] We used Dedoose qualitative analytic software[21] to extract broad themes (aspects within the data that reflected single concepts) and assigned codes to them. Subsequently, we identified sub-codes under these main codes for more specific themes. Thematic analysis provided a flexible approach to identifying, analyzing, and reporting patterns.[22] Three analysts (AM, KG, and EIIE) coded a subset of transcripts ($N = 5$) independently, one at a time, met to discuss discrepancies, and agreed on a set of codes and definitions (initial codebook). Then, the same coders used the initial codebook to code Transcript 2, met and discussed discrepancies, updated the codebook with the changes introduced at Transcript 2. This process was repeated with 5 interview transcripts, until the coders were applying the latest version of the codebook and the codebook was stable, that is, coders were no longer suggesting to add, change, split, or combine codes. At this point, one analyst (initials removed for blinding) applied the codebook to the complete data set.

Table 1. Interview domains and sample questions

Domain	Sample question
Perception of being involved/being heard during the implementation/roll out	Tell me how this intervention was rolled out.
General feedback	What are your general thoughts about the intervention?
Changes to workflow	How did this intervention change your daily work, if at all?
Explaining to patients	Did you talk with your patients about the intervention? If so, what were those conversations?
Adverse events	Regarding your perceptions about potential to increase/decrease adverse events, how did you think the cameras affected patient safety?
Near misses	Can you think of any cases/examples when the intervention helped capture "a near miss"?
Staff morale	Do you think the intervention affected staff morale? How? (eg, less burden going in and out of the room)
Staff confidence and sense of security	Did the cameras help you feel more or less confident taking care of COVID-19 patients? Do you believe having the cameras gave you a sense of security that your patients would be ok?
Use of cameras with non-COVID patients	Did you still work on the unit when it was turned to non-COVID? Were the cameras still there?
Future implementation/scale-up	Do you see this kind of intervention being used outside of COVID context?
Other institutions	If other hospitals were to use Google Nest, what would you advise them?
Final thoughts	Is there anything we should have asked but didn't?

We organized similar and related codes into broader themes through visual examination and meticulous consideration of their meanings. Research team discussions helped further refine codes. An integrated narrative was discussed among team members and colleagues to verify coherence of the themes and in-between themes, alongside the original research questions.

Analytical rigor was ensured through[18]:

1. Constant reference to participants' ID codes to ensure data was appropriately associated with participants' voices.
2. Consistency in data collection and monitoring of fidelity (use of interview guide, limited number of interviewers, mentorship and supervision of junior researchers).
3. Triangulation of methods (interviews and focus groups), participants (clinical staff, IT, leaders), and analysts (medical sociologist, 2 physicians).
4. Regular reference to source documentation, recordings and interviewers' notes to ensure data accuracy.
5. Weekly team meetings during all stages of the analytic process, to ensure agreement and reliability of codes and results.
6. Appropriate documentation, recording and secure storage of data with subsequent analysis for independent auditing for research integrity.
7. Discussions with various cadres of health care workers at MSHS during development of themes identified in this study.
8. Parallel data collection and analysis.

RESULTS

Interviewees' comments revealed 5 areas for adaptation required for effective DTC camera use for inpatient monitoring: technology, patient monitoring, workflows, interpersonal relationships, and infrastructure. Within each theme, respondents discussed solutions to challenges that surfaced during the implementation, or adaptations (Figure 1 and Table 2). Respondents also highlighted challenges that remained at the time of the interview (8–13 months after camera implementation), which we term opportunities for improvement (Figure 2 and Table 3). Their comments indicated that these opportunities would need to be addressed for sustained DTC use. Participants noted that patients had declined to use DTC after the units reversed to their pre-pandemic designations and began to care for non-COVID-19 patients. We also explored differences in perceptions of camera implementation and use among clinicians on 2 units that participated in this study. In the end, we did not identify any striking differences in the perceptions of clinical staff from the 2 units.

Technological adaptations

The Google Nest cameras needed technical adaptations for compliance with federal regulations concerning protections of patient data and privacy (Table 2, 1a). IT personnel modified functions to improve security of transmitted data by creating 2 levels of users (administrators and monitors) with varying permissions to video feeds. Then, Mount Sinai IT personnel created an enterprise solution in collaboration with Google that limited video feeds to designated viewers on MS campus (Table 2, 1b). Settings were modified so that no data from remote monitoring was sent back to Google.

IT personnel added a function to switch between livestream video and a series of snapshots taken every 5 s on 1 unit to relieve network limitations in streaming multiple videos simultaneously. On that unit, critical patients were prioritized for full streaming, while others had a series of snapshots at 5-s intervals (Table 2, 1c). Other features included zoom-in and "privacy" enabling camera shut-off at patients' request (eg, while changing), until a nurse approves further monitoring, a light on the camera indicated if monitoring was taking place. To preserve confidentiality, IT completely deactivated the recording feature (Table 2, 1d and e).

Patient monitoring

Our respondents described the cameras as "extra eyes" on the entire floor, for example, when there was a critical event with one patient, enabling the team to focus on the crisis, with one staff deployed to monitor the floor through the feeds (Table 2, 2a). Participants reported that without the cameras, they would have been worried about their other patient deteriorating while helping the patient in critical condition. Staff applied labels (paper post-it notes) to the screen to prioritize high-risk patients based on their oxygen modality and frequency of interventions during the previous shift. Supplementary Appendix A includes a handoff sheet that helped streamline

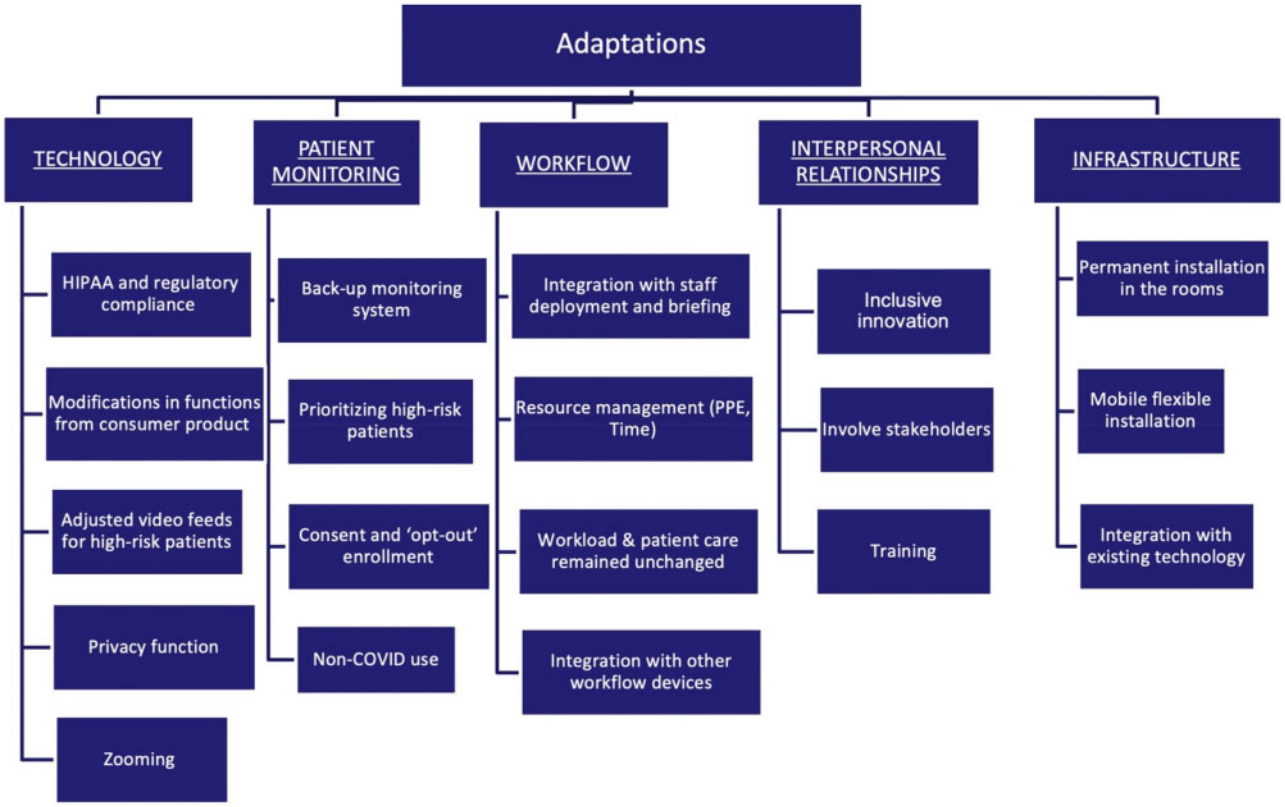

Figure 1. Documented adaptations.

the process of contacting the patient by phone or their assigned nurse to do a physical check-in (Table 2, 2b). The staffing model included patient monitoring, that is, one staff member was always watching the cameras, even if the unit was short staffed.

The units used opt-out consent, with all patients having cameras unless they declined (Table 2, 2c). One clinician mentioned that patients had to meet certain criteria to have the camera turned off. Some patients asked to have cameras turned off or pulled them off the wall. Patients were less receptive when they were not preinformed (eg, admitted in a confused state), or when the unit went from COVID to non-COVID (Table 2, 2d).

Workflows

The cameras modified staff deployment and briefing. Nurse managers reported that they had to ensure they had a staff member (usually a Patient Care Associate, PCA, or a Nursing Assistant, NA) watching the screen showing the feed of all cameras ($N = 38$), even if they were short staffed (Table 2, 3a). The NA alerted assigned PCA or nurse when walk-ins were needed, through a speaker system or 'Vocera', a wearable voice over internet protocol communication device (eg, accidental bell push or patient removing an oxygen device), thus having PCAs and nurses prepared to handle the situation before they entered the room (Table 2, 3b). The cameras did not change the workload or nature of patient care, though they did help triage non-urgent requests (Table 2, 3c). Cameras also provided extended floor coverage when staff had assignments to patients in other parts of the unit (Table 2, 3d).

The cameras affected staff processes in terms of length of stay in patient rooms, frequency of checking on patients, and reduced the number of times they needed to don and doff PPE. With the goal of reducing staff exposure to the virus in isolation rooms and in the context of staff shortages, cameras allowed clinical staff to check on patients remotely some of the time (Table 2, 3e and f).

Interpersonal relationships

The implementation team and frontline clinicians designed a handoff sheet (Supplementary Appendix A) to create an integrated team strategy and facilitate training of personnel (Table 2, 4a and c). It included patient information, assigned PCA's and nurse's names, patient oxygen modalities, fall risk, and phone number of the room. NAs on duty could use the phone to call the patient and ask them, for example, to put their oxygen device back on. Direct input of frontline staff was key to implementing the intervention because the need for cameras emerged organically from the units and was not imposed from above. This secured staff buy-in (Table 2, 4b).

Infrastructure

Engineering teams temporarily secured cameras on ceilings, which was useful in moving them around, especially for patients who could move around the room (Table 2, 5a and c). Flexibility in camera integration with existing technology was also useful. For example, 1 unit experimented with having patient video streams on iPads outside patient rooms, allowing nurses to be by the "bedside" monitoring their patients in the hallway (Table 2, 5b).

Technology-related opportunities for improvement

The most frequently stated concern by participants was ability to communicate with patients via camera microphone and speaker (Ta-

Table 2. Documented adaptations

Themes and definitions	Illustrative quotes
1.*Technological Adaptations*: software-related adaptations that ensured secure, effective, compliant use of DTC cameras	1a. HIPAA and regulatory compliance"*And then we ended up with an enterprise solution and mapping that to the Google G Suite which we were able to marry that with individuals' email accounts on the backend within our own IT and then, based on having a G Suite account, they could limit where and when you could see this, and it wasn't tied to your phone anymore. And they also were able to put limitations, like you could only see the people if you were on the Wi-Fi at the hospital." (IT personnel)*
	1b. Access control and data retention
	"*So a normal consumer product, I would say there were two major modifications. They were access control and data retention. [. . .] For access control, a normal consumer product, there's a single user who's considered the owner of the devices and then they can share the devices with other users. But it isn't what I would consider enterprise grade. [. . .]one of the things we did was built a different access control system. So we have this concept of administrative users and monitoring users and the monitoring users can log in and see the camera streams. The administrative users just add and remove monitoring users. And so this allows the hospitals to self-manage its own monitoring users. We have to add and remove administrative users, but that's a good balance of security and also self-management, so the hospital doesn't have to call us every time you want to add or remove a user. The other major change we made was. . . for cameras that are enrolled in this program, we don't automatically record any of the video or retain any video recordings. [. . .] for a bunch of reasons, including regulatory compliance, we removed that feature so that the monitoring system is live. It shows you what's there. But it doesn't record any or store any of that video." (IT personnel)*
	"*And we put together a group of people to try to build something that met all the requirements but that we could still build quickly, right? So we made some minimal changes to our existing systems and built the new monitoring interface and then pushed that out. . . .we had executive sponsorship and product management who came up with some proposals for how it would work. The engineering team built on top of what we already had and built the new monitoring UI and then I worked directly with the Sinai team along with one of my colleagues and we just helped analyze your environment in order to make sure that the solution would work in your environment and then did the documentation and the training in order to make sure that it could get installed properly." (IT personnel)*
	1c. Adjusted video feeds for high-risk patients
	"*They implemented a feature where you could—they have thumbnail views and then if you click the thumbnail of each room, you could bring up a larger—you can drill into the camera content and make it bigger, right? So they instituted a feature where you can see either full video on any camera in the thumbnail, or a series of snapshots that change every five seconds. And so you have the option of seeing—without isolating one camera, you can see all the cameras [that] provide video. The only issue with that is that sometimes a camera—the computer isn't fast enough to show 10 different videos simultaneously, so it helps to return some of the cameras to static stills and leave a few more important rooms or critical rooms in full video so you can quickly see five rooms at a time for example while all the other ones are static images. So but now you have the flexibility of seeing many rooms at once with video." (Clinician)*
	1d. Privacy feature
	"*They wanted a feature to turn off the camera if a patient complained that they didn't want to be looked at while they were changing for example. So they wanted a button to disable the camera temporarily and I believe Google did execute that feature so that the workstation, the main—someone at the main workstation can temporarily turn off a camera in—a specific camera in a room." (IT personnel)*
	"*They would let the nurse know yeah, oh, I'm going to change so I don't want nobody watching me. So the nurse would tell us and we would privacy. So the screen would be blacked out for the patient until the patient did what he had to do and then we would put it back once the nurse would tell us to." (Clinician)*
	1e. Zooming
	"*You can zoom in on them, you can see if their respiration's going too fast, their behavior, if they're fidgety, they're looking at the IVs and so forth. . . "Hey, nurse, you might want to go and look at this patient and see. You know? (Clinician)*
2. *Patient Monitoring*: collecting information about	2a. Back-up monitoring system

(continued)

Table 2. continued

Themes and definitions	Illustrative quotes
the patient in real time, with or without the use of technology, to identify any changes in status that may require intervention.	*"Well, like she said, it helps with the workflow plus a lot of times we are very busy with some critical patients and it takes us extra time in another room so if we don't hear the PCA that is monitoring the camera calling for the nurse for another of our patients, we assume that everything is okay and that give us an extra time to spend with the other patient." (Clinician)*
	2b. Consent and opt-out enrollment
	"They'll ask question like, "Is that a camera?" And then we have to explain [to] them the reason why they need it. Some of them, they agree to leave it, some of them will tell you to take it away. They don't want it." (Clinician)
	"So we decided as a unit that it would be—there would be no exclusion criteria. That [would be] opt out. We would have the cameras in all rooms unless a patient didn't want it because that's what made us feel more comfortable safety wise." (Clinician)
	"There have been patients that ask to turn it off for privacy, but they would have to follow a—be in a certain criteria as in they're able to walk, they're pretty independent, then we're able to turn it off. If not, then unfortunately we can't turn it off for safety purposes." (Clinician)
	2c. Prioritizing high-risk patients
	"So if a patient removes their mask, you can—they put little stickers—they have a system in place where they put stickers on the cameras to see who the patients are who probably aren't oriented who like to take their mask off. That way you know that hey, where this red sticker is and where this patient is, you need to zoom in and just specifically watch this patient because this is what they're known to doing." (Leader)
	"...to save time because you just have to call, 'can you peek on this patient? I know that he's confused and I want to make sure that he's fine, or he's [calling] right now. I want to make sure that he's fine. If you cannot go at the moment, you're not going to worry about oh, he might need something because somebody might tell you... oh, no, no, he's fine." (Clinician)
	2d. Using cameras with non-COVID-19 patients
	"...once it became non-COVID and we just had regular patients up there, we started getting complaints, like why are there cameras in the room? Why are you monitoring us? And so on the COVID areas, no one—there's no—we haven't had any issues. But we did have that one—this was back in the spring—unit that went from COVID to non-COVID when we were coming down from the surge. And under normal conditions the patients were not—and maybe we didn't message it very well, but the patients were not—didn't want to be on camera." (Clinician)
3. *Workflow*: a sequence or pattern of activities to complete a task.	3a. Integration with staff deployment and briefing
	"...there's always somebody in front of the camera monitoring what's going on with the patients and whenever they see something going on, they always call the nurse and right away we go inside the room and address the problem." (Clinician)
	"Yes, and a PCA would be on the floor so if somebody was to move or do something out [of] the ordinary, the NA would then tell the PCA that this patient is moving and then the PCA would go in there." (Leader)
	"Like last week we had a patient that kept taking off his nose [cannulas] and his oxygen would drop down to 60. So that was kind of good because as soon as we['ve] seen the going down, we knew he took his mask off. And then we would just alert the nurse that he took his mask off and to go back in there and put it back on." (Clinician)
	3b. Integration with other workflow devices
	"So for the person who's watching the cameras, we have a headset in the front so if we do need to communicate, we can. But we also—for the person watching the cameras, being that they are stationed there and they're not able to leave that station, they'll contact us through Vocera, so whatever that they're seeing and hearing, it's communicated to us through the Vocera. So we're still all in communication of the patients' needs." (Clinician)
	3c. Workload and patient care remained unchanged
	"You still have to check on your patient. There are certain things you still have to do. So it's kind of a 50/50 for me. A camera can't clean a patient. A camera can't give medication. That's your workload. A camera can't draw blood. So in terms of workload, your workload remains the same. Does it help you to catch a fall or see a patient who's taking off the oxygen mask? Yes." (Clinician)

(continued)

Table 2. continued

Themes and definitions	Illustrative quotes
	"...to save time because you just have to call, 'can you peek on this patient? I know that he's confused and I want to make sure that he's fine, or he's [calling] right now. I want to make sure that he's fine. If you cannot go at the moment, you're not going to worry about oh, he might need something because somebody might tell you... oh, no, no, he's fine." (Clinician)
	3d. Extended floor coverage
	"*Yeah, especially in certain rooms, like rooms that are far away from the nursing station. I think that's smart because sometimes you can—your assignment in the same zone or same area and you have to walk really far or you can't hear certain things, you know? If there's someone getting intubated and there's someone in room 11, I'm sorry. You're going to be in the intubation. You're not going to be worried about the patient who's the potential fall risk because you have an airway to protect. So I think it's definitely helpful. I think it would work post COVID because these things happen 24/7." (Clinician)*
	3e. Resource management, including PPE and staff
	"...you have an issue with having isolation of patients, that you want to keep some patients isolated and yet you still need to take care of them and so it would help if you could remotely monitor them without having folks put on—don and doff PPE every single time they need to see how the patients are doing. There are times when you can just observe them remotely and that would be enough. Right? And save some PPE, some effort." (Clinician)
	"...we wanted to make sure the amount [of time] that we were in the COVID rooms wasn't at a long exposure time." (Clinician)
4.*Interpersonal Relations*: communication between hospital leaders, managers, and staff; training and learning; organizational culture	4a. Inclusive innovation approach
	"...we make this available on request so only the areas asking for it we're setting it up and so we're not forcing this. And so for that reason, I think there's not much pushback. The only reason [two units] have it is because they asked for this." (Leader)
	4b. Involving stakeholders is critical
	"*Make sure the people who are going to use it—make sure you're not designing without having gone to the area where the problem is. You can't just make a solution from your office or from a conference room. You need to go in the [room], the place where the work is actually done. See for yourself what the problem is. When we did this design for [iPad] monitors, we had, at that point, one empty unit... And I mocked it [up]. I got beds, I got night tables, I got fake monitors and we mocked it up to say this is what it would look like. Does it work? We brought up nurses, doctors... biomedical engineers... All the various people that would be needed to make the change, I brought them to a mock room and we changed this, we changed that, and based off of feedback. So you have to be willing to go to where the problem actually is." (Leader)*
	"...we make this available on request so only the areas asking for it we're setting it up and so we're not forcing this. And so for that reason, I think there's not much pushback. The only reason [two units] have it is because they asked for this." (Leader)
	4c. Training
	"*We also have the Google Nest paper where we can write if the patient is at risk for falls or if they're going to pull their oxygen off. We have someone monitoring like a PCA or a tech, so we kind of give them a report as to what to look out for. So it gives you that extra safety net, so I think it's a positive and it's essential during COVID, so we love it." (Clinician)*
5.*Infrastructure*: hardware, power supply, buildings and facilities, maintenance	5a. Installation in the rooms
	"So what we did was we secured the cameras from the ceiling. We had engineering secure them down from the ceiling. One camera pointed at the bedside monitor from Philips, so we could see all the wave activity. We could see the whole monitor. The other camera came down and faced the patient." (Leader)
	5b. Integration with existing technology
	"*And what we did was we had iPad stands and we did—one iPad was facing up. The other iPad was flat on the table of the stand so that as a nurse walked past the room—and we put these outside of the room. So we had the cameras inside and then we had iPads outside and they could see the patient and they could see the wave pattern and all the vitals. [...] and that iPad stand was in the hallway so even if the door was closed, right, in an inpatient room where it's you can't see anything, I can see the vitals and I can see the patient." (Leader)*

(continued)

Table 2. continued

Themes and definitions	Illustrative quotes
	". . .then we went from trying to put them one in a room to then we had two in a room. [. . .] So then what we did was we moved the cameras from looking at the monitor and the person to taking that down altogether and having one Google camera looking at two people." (Leader)
	5c. Camera Position: moveable and non-permanent installation
	"I think right now the way it's being used is perfect. Every room has one. I guess the ability to probably move it mobile-y from where they're sitting, just in case the patient gets up and walks. But other than that, I think that's—I think it works very well now" (Leader)

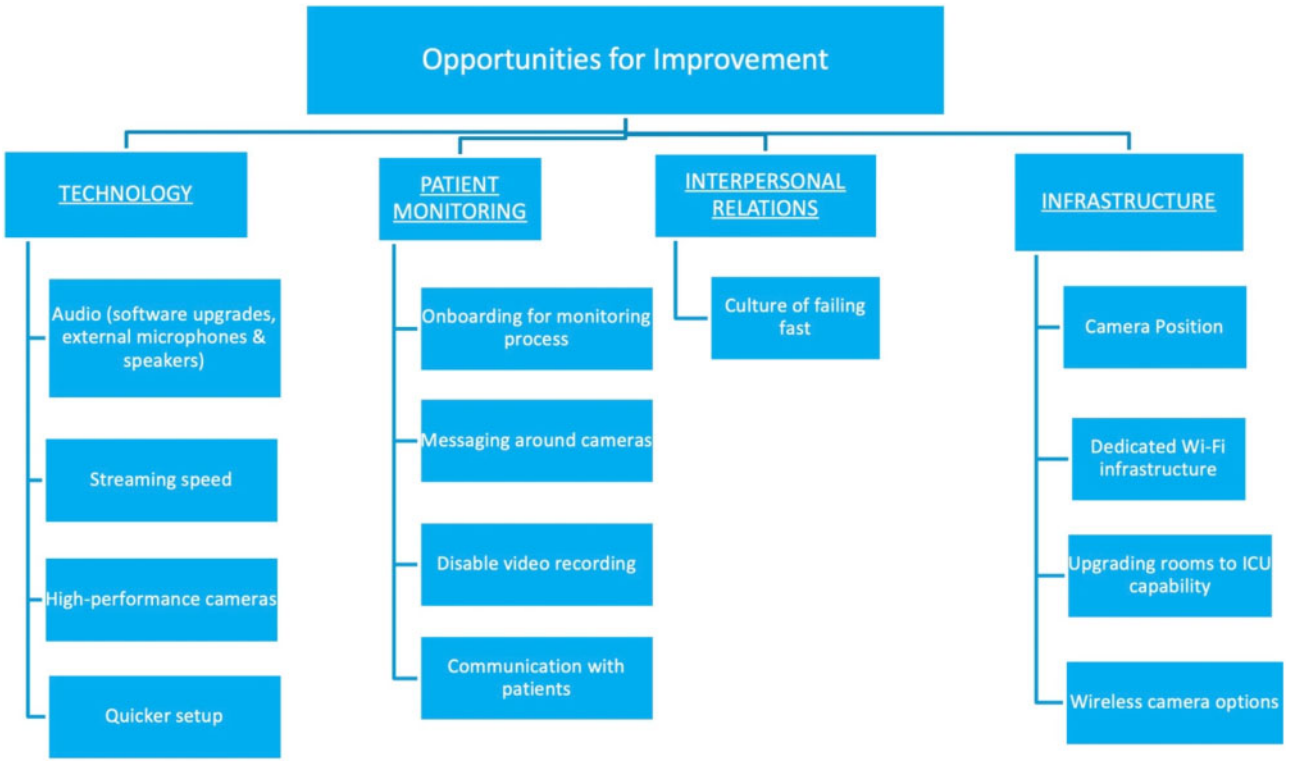

Figure 2. Opportunities for improvement.

ble 3, 1a). They stressed that the cameras were distant from the patient, located on the opposite wall to capture their full body and the noise of medical equipment and extractor fans in isolation rooms interfered with the audio quality. Bedside teams called the phone in the patient rooms and had patients use call bells. External microphones and speakers would be desirable enhancements in future applications (Table 3, 1a).

Delays in data transmission also affected video and audio quality. Reducing lag from cloud transmission and routing feeds directly to the browser interface, might improve video and audio quality (Table 3, 1b). Respondents recommended considering newer camera models with higher capabilities (Table 3, 1c), better picture quality and motion sensors for coverage of patients who could walk and improved quality to zoom-in on monitors (eg, pulse oximeters) without entering the rooms. Quick and convenient deployment of cameras between rooms was critical during the pandemic, and participants mentioned the ease of deploying and using new cameras as essential (Table 3, 1e).

Patient monitoring opportunities for improvement

Increasing reliability of communication between patients and staff was among the most frequently suggested improvements (Table 3, 2a). However, external speakers may compromise patient privacy, especially in double occupancy rooms. Patients' and caregivers' ideas can be incorporated in the consent process and parameters developed for assessing consent capacity (Table 3, 2b). Standardized consent workflows may improve consent rates, thereby improving patient safety. Positive messaging about cameras (eg, telling patients that "*this is a tool that we offer for your safety*"), and letting them opt out may also improve consent rates and decrease disconnection rates. Recording may be disabled by vendors prior to rollout due to privacy and liability risks.

Table 3. Opportunities for improvement

Themes and definitions	Illustrative quotes
1.*Technology*: improvements related to software, additional devices, and network characteristics.	1a. Audio improvements: ability to communicate via speakers and microphone
	"[W]e tried on the software side to adjust the sound, but unfortunately one limitation is that in the patient room, the audio is not very strong. So for—the other thing is because of these COVID rooms, we also have fans in there to make negative pressure and a lot of the patients are on respiratory devices so a lot of things in the room make noise. So you need something loud to overcome all the noise already happening in the room. And the Nest cameras didn't work very well for that." (IT personnel)
	"And then if you add the microphone, that's even 100% better because like you said, we won't have to go in there. I could tell a patient hey, can you have a seat? Hey don't get out of bed. And they could say OK and [as] opposed to me telling a PCA to run into the room and attend to them." (Clinician)
	1b. Streaming speed
	"…if they could work with—without the Google cloud so that if the Google cloud goes off-line, the cameras can work internally. But—meaning if you could put up a browser and connect directly to the camera as opposed to going through the Google cloud, it would probably make the video look a little better and—because the video is not traveling through the Internet to get back to the work stations." (IT personnel)
	1c. High-performance cameras
	"Certainly, a dedicated healthcare product would be great. … I would say that we initially started with the indoor cameras which are fine. I think the outdoor cameras provide better qual—or sorry, the IQ cameras which is a newer product model provide better quality. … I think trying to find some way of possibly deploying these IQ cameras I think would result in a better quality—the image quality would be better." (IT personnel)
	1e. Quicker setup
	"The other problem is when you install them, based on the feature set that they have now… [m]oving the cameras from one unit to another wasn't simple. You really had to take them down, re-provision them and then put them back up so that they would be associated with a different room. …it could take you a few hours …to remove them from one unit and re-provision them for another unit… And I mean not even including the physical labor of that because …they had special personnel for that, people who would put on the gear and all that…" (IT personnel)
2.*Patient Monitoring*: improvements needed in collecting information about the patient in real time, with or without the use of technology, to identify any changes in status that may require intervention.	2a. Communication with patients
	"I think that would help us a lot when it comes to if a patient is calling where we can find out what it is that they want before we get inside the room. I think that will actually help our workflow if we can actually communicate with them because some patients can't really pick up the phone. So if we can either communicate with them via camera seeing what they may actually need or speaking to them that way, it would be easier for us workflow wise, so we don't have to gown up and then call somebody because we need something else. We already know what we need when we're going inside the room." (Clinician)
	"…maybe some kind of a beeping system or something that can alert the patients—I mean, now we have the audios. Like I said, I haven't been able to use that feature yet so actually that helps a lot because that would've been my suggestion so that we are able to speak directly into the camera and kind of redirect the patient or have them sit down or whatever the case is."(Clinician)
	2b. Messaging around cameras
	"…think if we incorporate it and message it appropriately that this is a tool that we offer for your safety and give patients, when appropriate, the ability to opt out, I think that it can be part of the way that we deliver care in the future. I think that there's a lot of things we could do with this imaging data. So like for example falls detection, people's gait, there's a lot of valuable information you can get off images. And I do think it could give this extra layer of safety. But we need to be careful on how it's used, how it's message, and we don't want patients thinking we're just recording them. It needs to be a process for turning it off as well when you're getting care." (leader)
	"They should already be in the units and every patient should be notified that they're being watched on camera because a lot of them were unaware." (leader)
3.*Interpersonal Relations*: improvements needed in relations between and	3a. Develop a culture of failing fast
	"If you don't have a culture like that, then bring together a team of facilitators who have—I'm sure most hospitals have somebody who does process improvement. You can bring together facilitators and use all the core principles of define the problem; making very certain what is the problem. Once you have the

(continued)

Table 3. continued

Themes and definitions	Illustrative quotes
among hospital leaders, managers, and staff	*problem, figure out who are the stakeholders, bring them together, and then just brainstorm. What are the gaps? What do we have? What can we try? What's our ideal state? What experiment can we do? How quickly can we do it? How quickly can we come back to debrief on it? Did it work? Did it not work? Do we have to modify? And that's it. It's a pretty simple structure." (leader)*
4.*Infrastructure*: hardware, power supply, facilities and buildings, maintenance	4a. Camera Position
	"Yeah, but you have to—there are blind spots. So if it's only facing the bed, you can't see to your left. So if the patient leaves the bed, you won't be able to see past. . . ." (Clinician)
	"I think it has more to do with the positioning from what I'm looking at here because they're showing me. I'm seeing that some cameras are much further in location than others." (Clinician)
	"The cameras were located in such a way that we could see the entire—the patient and the room as much as possible. The complete—patient as a whole and the surrounding areas. Yeah, but sometimes the—it would just—the positioning would be a little off because I guess we need to have fixtures where we could fix the camera properly. Yeah. Because it was all new, I don't think there was time to go over that." (Clinician)
	4b. Outlets
	"I think it really is the camera location. And of course that may be contingent on what's available in terms of power outlets in the rooms as well." (leader)
	4c. Dedicated Wi-Fi infrastructure
	"And I think that also the hospital team was limited in terms of their ability to deploy or reuse existing Wi-Fi infrastructure. . . . we got the feedback from nurses that they wanted really high-quality streams, that they wanted to be able to read, in some cases read diagnostic equipment that was in the room with the patient over the camera for remote monitoring like on the equipment level. And the challenge there is that that quality of stream takes up a lot of bandwidth and so . . . there needs to be more network bandwidth available to make that sort of thing happen. Yeah." (IT personnel)
	4d. Upgrading rooms to ICU capability
	"I mean, number one, I think there should never be a room in a hospital ever again. . . that isn't designed to have a hybrid ability to be this sort of semi-ICU room because, think about it. Who comes to the hospital? It's people who are very sick. The days where you would come to the hospital with sort of a minor something or another, those days are gone. People get treated in the ambulatory world. People who come to the hospital are folks that have very high degree of illness. So we should never build a room ever again that doesn't have the ability to visualize the patient, to visualize monitors, to have monitors that plug in. So I think there's a lot of lessons learned there. You should have the ability to be like an accordion and flex up and flex down. So use it as a regular room, but if you need to surge, you should be able to surge very seamlessly." (leader)
	4e. Wireless camera options
	"And maybe if possible a wireless [camera would be needed] just because I did have instances where. . . I mean somebody almost [tripped]—you know, tripping or just having so many wires already in the room that it just kind of makes it more chaotic." (clinician)

Interpersonal relationships opportunities for improvement

One respondent emphasized that a culture of failing fast should be encouraged outside of crisis or pandemic context (Table 3, 3a). This hospital leader described their process of innovating in a crisis: "Once you have the problem, figure out who are the stakeholders, bring them together, and then just brainstorm. What are the gaps? What do we have? What can we try? What's our ideal state? What experiment can we do? How quickly can we do it? How quickly can we come back to debrief on it? Did it work? Did it not work? Do we have to modify?"

Infrastructure opportunities for improvement

Camera positioning is crucial for adequate coverage of the rooms and enhanced video quality. Some rooms had 1 camera per 2 patients as the number of patients rapidly increased, resulting in poor camera positioning, creating blind spots that compromised patient safety, and warranted regular walk-ins (Table 3, 4a). Participants in one focus group emphasized that ideally, each room should have more than 1 camera, strategically positioned at equal distances around the bed and the door, for full coverage of the rooms, hallways, and bathrooms. More power outlets in the rooms will reduce the distance between cameras and enhance clearer visualization of the floors (Table 3, 4b).

Table 4. Recommendations for DTC camera implementation in an inpatient setting

Technology recommendations:
Use a combination of high-quality external microphones and speakers to enhance patient—clinician communication. Consider using motion detection cameras.
Patient monitoring recommendations:
Transparent communication about camera monitoring between patients and clinicians may help improve patient acceptance and consent rates, as well as decrease disconnection rates.
Workflow recommendations:
Camera interventions require a modified staffing model with 1–2 personnel always watching the cameras.
Integrating cameras with existing communication systems (Vocera, phones in patient rooms, etc.) requires input from frontline staff.
A flowsheet to track communication and high-risk patients must be adapted to the local context and patient needs.
Interpersonal relations:
Accept failure quickly if DTC cameras are not accepted by clinicians or patients. Engage frontline staff in designing workflows around patient monitoring. Expect this to take time. Start before the next crisis/surge.
Infrastructure recommendations:
Ideally, each room should have more than one camera in order to increase patient visibility from multiple angles, especially in rooms with two or more patients.
Upgrading all hospital rooms to have potential for ICU visualization may ease future transitions to ICU-level care. Equipping rooms with transparent doors and walls can make adaptation to ICU rooms both easier and safer for patients. When possible, choose wireless cameras to reduce tripping hazards.
General recommendations:
Technologies ought to be adapted to local hospital context and clinical needs.
Discussions around privacy and safety are ongoing and will require further clarifications.

Relevant internet upgrades suitable for high-quality video streams will aid visualization of readings from diagnostic equipment over the cameras (Table 3, 4c). Upgrading all hospital rooms to have the potential for ICU-level visualization and hard-wired monitoring capability will help in a potential future surge (Table 3, 4d). Minimally, these should include transparent doors and/or walls for direct visualization of patients. Wireless cameras may reduce the risk of tripping and falling (Table 3, 4e).

DISCUSSION

This is the first study to our knowledge that describes the use of DTC cameras as ePPE in a hospital setting, with the goals of improving patient *and* health care worker safety. Our study focused on the implementation process of deploying DTC cameras in the inpatient setting. The DTC cameras were deployed rapidly during the initial surge in New York. Several leaders we interviewed spoke about the need to adapt these technologies to the unique contexts of their institutions, which varied even within the same health system. Table 4 summarizes general recommendations for implementing DTC cameras in an inpatient setting.

In contrast with studies of tele-ICUs, which reported some pushback from staff, we found that frontline clinicians at MSHS initiated and implemented many adaptations to make camera use more effective.[9] This finding is consistent with early reports about using telemedicine at ePPE during the COVID-19 pandemic.[2,3] This may be explained by several factors. First, video monitoring was conducted on the same floor, by NAs who were part of the unit staff (rather than external staff in several tele-ICU studies), and at the request of the unit. Secondly, the camera intervention was implemented during a global pandemic, and promised to reduce the exposure to the virus and thus reduce their risk of falling ill with the novel pathogen. The fear of contagion and the risk of infecting self or loved ones was likely a strong impetus to embracing the project. With the scarcity of the PPE, anything that preserved PPE was well appreciated by the frontline staff. Third, cameras helped staff to feel more confident in their ability to perform their duties while someone else was watching their other patients. Prior to the implementation of DTC cameras, nursing staff reported feeling anxious about their ability to deliver quality care behind closed doors with no visibility. Research shows that feeling helpless was common among health care workers during the pandemic, and is in fact one of the indicators of professional burnout.[23]

Designing a standardized workflow for identifying patients who can benefit from video monitoring, timeframes when they need to be monitored (eg, 24/7 or only at night), developing patient-centric protocols to identify patients who should be offered to opt in rather than using the global opt-out strategy, and investing in health care specific plug-and-play cameras can protect patient lives, improve patient and family satisfaction, protect health care personnel from infection and burnout and reduce health care costs. While video monitoring has been used in health care in the past to enforce compliance to protocols such as hand hygiene[24] our study indicates that both patients and staff will likely accept being monitored if it is meant to protect them from harm. However, vendors need to develop products specifically tailored for health care and adhering to regulations regarding patient privacy.

With a number of adaptations to local context, DTC cameras are a promising tool and can be used in a variety of health care settings, such as inpatient units caring for patients with brain injury, delirium, dementia, or on certain medications. Further research is needed to evaluate how and to what extent inpatient video monitoring could improve patient safety and health care workforce psychological well-being.

Our study has some limitations. This was a single case study that may not generalize to other hospitals and health systems. MSHS is a large health system located in New York City, with access to advanced monitoring technology and Google Nest cameras during the pandemic. Other hospitals may not have these resources at their disposal. Another limitation involves generalizability of our findings outside of the COVID-19 pandemic context. It is unclear whether and what kind of the adaptations would be needed in other, less urgent and threatening conditions. Given the uncertainty and intensity of the COVID-19 pandemic, patients and staff may have been more likely to welcome

these new forms of monitoring. However, in a non-public emergency environment, patients and staff may value their privacy and be reluctant about being subjected to constant monitoring.

In sum, our findings indicate that the effective use of ePPE and DTC cameras is contingent on adaptations, based on the observations of frontline staff and leaders. As our study shows, developing the workflows takes time, and discussions around patient privacy and everyone's safety are still ongoing. Using camera solutions during "normal" times may help improve patient safety and reduce staff anxiety on units caring for patients with limited physical and/or cognitive capacity, such as dementia, or on certain medications. We urge health care leaders to begin this conversation with their frontline clinicians today rather than wait for the next crisis.

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AUTHOR CONTRIBUTIONS

All the authors meet criteria for authorship as stated in the Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals. Study concept and design: KG, RF, and MM. Acquisition of data: KG, AM, PH, TS, LX, and TS. Analysis and interpretation of data: KG, AM, EIIE, and IN. Drafting of the manuscript: KG, AM, EIIE, SP, MM, DR, PH, RF, and CS. Critical revision of the manuscript for important intellectual content: KG, AM, EIIE, SP, PH, TS, IN, CS, LX, DR, MM, and RF.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

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CONFLICT OF INTEREST STATEMENT

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DATA AVAILABILITY

The data underlying this article cannot be shared publicly due to the privacy of individuals that participated in the study. Anonymized data will be shared on reasonable request to the corresponding author.

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