BMJ Open

Exploring the safety and quality of mobile X-ray imaging in a new infectious disease biocontainment unit: an in situ simulation and video-reflexive study

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To cite: Wyer M, Hor S, Barratt R, *et al*. Exploring the safety and quality of mobile X-ray imaging in a new infectious disease biocontainment unit: an in situ simulation and video-reflexive study. *BMJ Open* 2024;**14**:e080152. doi:10.1136/bmjopen-2023-080152

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (https://doi.org/10.1136/bmjopen-2023-080152).

Received 27 September 2023
Accepted 23 January 2024

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ABSTRACT

Objectives During a precommissioning inspection of a new biocontainment centre, radiographers noted structural features of quarantine rooms that could compromise staff and patient safety and the X-ray image quality, even after significant modifications had been made to an earlier radiography protocol. The aim of this study was to explore the safety and effectiveness of the modified protocol, in the new space, and identify improvements, if required.

Design A qualitative study using in situ simulation and video-reflexive methods.

Setting A newly built biocontainment centre, prior to its commissioning in 2021, in a large, tertiary hospital in Sydney, Australia.

Participants Five radiographers, and a nurse and a physician from the biocontainment centre, consented to participate. All completed the study.

Interventions Two simulated mobile X-ray examinations were conducted in the unit prior to its commissioning; simulations were videoed. Participants and other stakeholders analysed video footage, collaboratively, and sessions were audio recorded, transcribed and analysed thematically. Problems and potential solutions identified were collated and communicated to the hospital executive, for endorsement and actioning, if possible.

Results Four themes were identified from the data: infection exposure risks, occupational health and exposure risks, communication and X-ray image quality. Facilitated group reviews of video footage identified several important issues, across these four areas of risk, which had not been identified previously.

Conclusions In situ simulation is used, increasingly, to evaluate and improve healthcare practices. This study confirmed the added value of video-reflexive methods, which provided experienced participants with a richer view of a familiar protocol, in a new setting. Video footage can be examined immediately, or later if required, by a broader group of stakeholders, with diverse experience or expertise. Using video reflexivity, clinicians identified potential safety risks, which were collated and reported to the hospital executive, who agreed to implement modifications.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study employed video as the primary means of data collection, during an in situ simulation, with the footage analysed with participants, to identify latent safety threats prior to the commissioning of a new unit.

⇒ A strength of using video footage is that it can be examined immediately, or later if required, and by a broad group of stakeholders with different experience or expertise.

⇒ Collating video evidence and expert consensus about safety and quality risks was enough to convince the hospital executive that significant structural modification was needed to address them.

⇒ Only two simulations were reviewed in this study; however, findings were consistent between them.

INTRODUCTION

In the last few decades, there has been increasing focus on the built environment in acute healthcare settings, including how spatial layout and design features, furniture, equipment, and other physical characteristics, can impact teamwork, patient and staff safety and health outcomes.[1–4] Healthcare design improvements are often based on problems revealed by in-use experience, observation or survey data *after* a healthcare facility has been commissioned.[5] System-based and evidence-based approaches to design are now recognised as essential, to ensure patient and staff safety and well-being.[2 6 7] However, design teams do not necessarily draw on these approaches,[7] or may be unfamiliar with the multitude of ways that the environment can impact safety.[1] Furthermore, design flaws and solutions relevant to one setting may not be applicable or appropriate in others.[7] Even with meticulous planning, latent safety threats[8] can be present in new designs, and areas for improvement may be only apparent once a new space is operationalised.[1 9]

In situ simulations conducted in actual clinical environments, rather than in simulation centres, are an effective method used in healthcare to: understand why critical incidents occur; practice and develop individual/team capability; assess individual/team competency; and design and test new clinical spaces and equipment.[10] In order to understand and assess complex clinical work, in situ simulation studies are usually conducted in fully functioning healthcare facilities.[11] However, addressing issues relating to the built environment after patients have been admitted can be expensive and disruptive.[5] Therefore, some facilities have used in situ simulation to evaluate new spaces in the postconstruction phase, prior to occupation[12]; examples include a paediatric intensive care unit (ICU)[9]; outpatient clinics[1]; trauma operating rooms[13]; neonatal intensive care[9 14]; maternal care[15]; emergency departments[16–19] and whole hospital transition.[20]

A facilitated debrief is an important component of an effective simulation.[21] Various methods used to guide debriefs include scripts, checklists and questionnaires.[22] Review of video footage of the simulation, during debriefing, is a powerful, yet underutilised, method to identify problems.[5 21] A literature search for in situ simulation studies, designed to evaluate operational readiness of new or refurbished healthcare facilities, produced only a few studies that included video footage in their data collection. In several of these studies, video analysis for latent safety threats took place after the simulation and debrief, and was conducted by researchers, rather than participants themselves.[9 13 15] A study by Geis *et al*[16] used video debriefing with participants, but the authors suggested that their study could have been strengthened by involving participants in more in-depth video debrief and analysis. Bender *et al*[14] mainly used verbal debrief to identify issues, but used video to highlight or clarify particular events. Keil *et al*[23] mention the use of video debrief but did not detail how it was done. Of these studies, the paper by Krammer *et al*[9] is the only one that discussed the benefits of video analysis. This study detected 91 issues during simulations carried out prior to moving into a new neonatal/paediatric ICU, and an additional 13 were discovered during analysis of video recordings of the simulation by the researcher.

This paper adds to this body of work by describing video as the *primary* means of data collection to identify latent safety threats during an in situ simulation, prior to the commissioning of a new unit. Our decision to do this has its foundations in video-reflexive ethnography (VRE), which involves videoing *real-time* (ie, not simulated) healthcare practices in situ, and showing the footage back to participants to enable collective sense-making and improvement of their work.[24] It was not possible during our study to video a procedure with an actual patient but we drew on the significant body of VRE literature, and its methodological principles—*exnovation, collaboration, reflexivity and care*[24]—in our study design.

VRE has been used in a variety of settings to explore what creates safe care and to improve healthcare practices. Examples include infection prevention and control,[25–31] palliative care services,[32] interprofessional communication and collaboration,[3 33 34] clinical handover and ward rounds,[35–37] polypharmacy management[38] and medical training and education.[39–41] With regard to healthcare facility design, Collier *et al*[42] used VRE to explore how people, nearing the end of life, experience healthcare spaces as safe or unsafe. Another study by Hor *et al*[3] used VRE to study the impact of environmental features on communication and safety in an ICU. More recently, Hor *et al*[43] also videoed an in situ simulation exercise involving an ED presentation and subsequent transfer between two hospitals, of a (volunteer) 'patient' with suspected COVID-19. The footage was reviewed and analysed by participants and their colleagues in collaborative group reflexive sessions to explore the complexity of the transfer and to identify good practice, highlight challenges and design system improvements.

The current study was undertaken at a large, tertiary hospital in Australia in 2021, in a newly built biocontainment centre, prior to its commissioning. Prior to 2021, patients presenting at the study site with a suspected or confirmed high consequence infectious disease (HCID) would be cared for in two dedicated high-level isolation rooms in the ICU. During the 2014 West African Ebola outbreak, radiographers at the site developed and published a protocol for mobile chest imaging of patients with viral haemorrhagic fever.[44] This protocol involved a wireless digital radiography mobile X-ray machine, which remained in the clean quarantine anteroom, with the radiograph taken through the glass window into the contaminated patient room. The Medical Physics department was also consulted, to ensure that appropriate parameters were determined, that would accommodate the attenuation effect of the X-ray beam when projected through the glass. The aim was to minimise exposure of radiology staff to pathogens and prevent equipment becoming a vector for pathogen transmission. This process was accepted as best practice, throughout Australia, in anticipation of patients presenting with Ebola or other HCID and was adapted at the study site when the COVID-19 pandemic began.[45]

To enhance preparedness for future pandemics or HCID outbreaks, a purpose-built high-level isolation unit, with all the features of modern biocontainment, was completed in early 2021 to replace the existing ICU rooms and expand capacity. The biocontainment unit layout includes a footprint of 16 beds, 6 of which can be 'locked down' in containment mode. These six beds include two quarantine (Q) class and four negative pressure (N-class) rooms. In design consultation meetings, senior radiographers (SRs) had stressed the importance of clear glass walls/windows into these rooms, free from obstructions, to ensure X-ray imaging could be performed as per protocol. However, during a precommissioning inspection in December 2020, radiographers

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Figure 1 Screenshot showing a radiographer simulating taking a mobile X-ray image outside an N-class room, with labels indicating the door to small anteroom and the non-retractable aluminium slats in the glass doors.

noted several structural features of the N-class rooms and their surroundings that could compromise staff and patient safety and the X-ray image quality, even with significant modifications to the previously developed and tested protocol. Subsequently, this study was planned and conducted by a team including radiography and biocontainment unit nursing and medical staff, and researchers (one of whom was a biocontainment nurse).

Aim

Our aim was to explore and improve the safety and effectiveness of the existing radiography protocol in the new space, using video-reflexive methods.[39] Our primary objective was to identify safety and quality issues that could arise, as well as potential solutions, that could be implemented for improvement. Our secondary objective was to communicate our findings to hospital management, in order to implement changes for improvement. These objectives were achieved by: (1) videoing simulations of mobile X-ray examinations being performed in one of the N-class rooms; (2) engaging radiography and biocontainment staff in group debriefs ('video-reflexive sessions') facilitated by researchers, to collaboratively analyse video footage, identify potential problems and devise solutions; and (3) collating and communicating these problems and their solutions to the hospital executive, to be endorsed and actioned where possible.

Our study questions, aligned with our primary objective, were: (1) what are the safety and quality issues arising from use of the existing protocol in the new space; and (2) what are potential solutions to mitigate or prevent those safety and quality issues? We recorded both issues and solutions identified by participants as qualitative outcomes measured for this study.

METHODS

Participant characteristics and setting

This study was nested within a larger multimethod 3-year project, which used a three-stage qualitative design, across two tertiary hospitals and several primary care locations across New South Wales (NSW), Australia, to explore the experiences of healthcare workers (HCWs) regarding infection prevention and control during the COVID-19 pandemic (see online supplemental file 1). The first stage employed interviews, the results of which informed stage 2, in which video-reflexive methods were used to explore, in more depth, particular practices of concern that were raised during interview, including the current study. It was conducted at the newly completed NSW biocontainment centre, at a large Sydney teaching hospital, in March 2021, before the centre was commissioned. Five radiographers, a biocontainment nurse and a biocontainment physician consented to participate. These participants were selected as they would be the HCWs most likely to carry out this procedure should a patient be admitted. The participants gave written consent before the study commenced and verbal consent before activities were recorded.

Study design

Simulation scenarios

Performance of mobile X-ray imaging was simulated in an N-class room. A researcher played the part of the patient. This researcher did not have a clinical background. Participants were asked to follow current hospital protocol to the best of their ability in the new space. Two different scenarios were simulated: one with the patient standing and holding the detector, and one with the patient in bed. Because the aluminium slats in the large, double-glazed

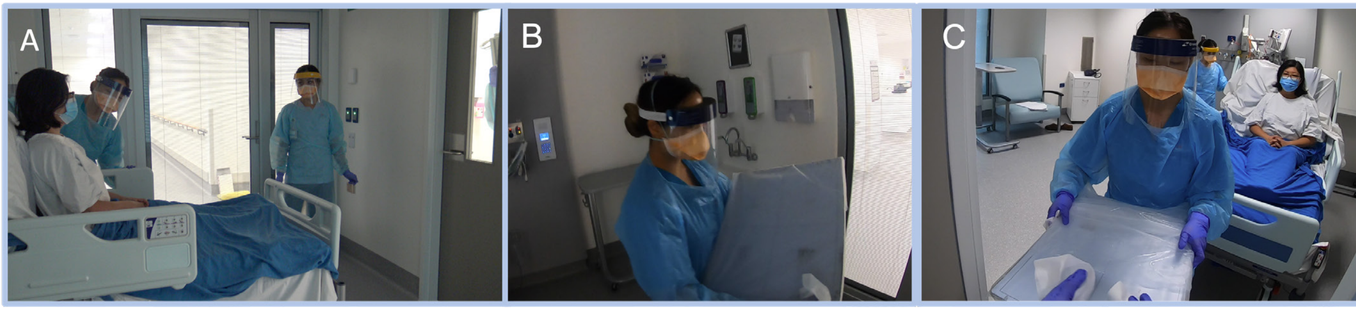

Figure 2 (A) Screenshot showing mobile X-ray image being taken, of a patient in bed, through anteroom window of an N-class room. (B) Post X-ray—radiographer has removed triple bagged detector from patient and cleans it with a disinfectant wipe. (C) Transfer of detector from patient room to radiographer in anteroom—the first layer of plastic is removed and discarded in the patient's room.

doors (figure 1) would cause artefact on the image, a decision was made by radiographers to trial taking the mobile X-ray images through the anteroom window (figure 2). A handheld digital camera was used by a researcher to collect wide shots. This researcher was also a biocontainment nurse, whose understanding of the procedure and issue at hand meant she was able to collect appropriate footage. A head strap-mounted GoPro camera was used by both the 'patient' and the radiographer taking the mobile X-ray images, to provide point-of-view footage.

Video-reflexive sessions

Two video-reflexive sessions were conducted, at which simulation footage was shown back to participants. The first was a group session held immediately after the simulation, when unedited footage was shown to the staff who had been videoed. The second was held 2 days later in the radiology department, attended by two SRs, who had not been involved in the simulations. In this session, an edited 6-min clip was shown, combining both handheld and GoPro footage. The purpose of both sessions was for participants to scrutinise the footage and identify any barriers to implementing the hospital protocol safely and effectively in the new environment, and to discuss potential solutions. These sessions were audio recorded.

Analysis

Two methods of analysis were used. The first was the cointerpretation of the video footage between researchers and participants. The minimal time between videoing and the reflexive session increased the accuracy and trustworthiness of responses. Second, the audio-recorded discussions were transcribed and entered into NVivo (QSR International Pty Ltd. V.20.6.2), a software program used for the analysis of unstructured text. Starting with a deductive approach, an initial coding framework based on the research aim was applied to the data, independently by two researchers, to identify issues and solutions raised during the reflexive sessions. Codes were compared and finalised. Subsequently, through an inductive process of thematic analysis,[46] these issues and solutions were further categorised into four themes/areas of risk, and confirmed through discussion between the research team.

The identified areas of risk and solutions were collated, then presented to the hospital executive for discussion, with representative footage. As executive members were not enrolled as participants in the study, that discussion was not recorded.

Patient and public involvement

None.

RESULTS

Video-reflexive findings

In this section, we present a selection of images and quotes, to illustrate how the video-reflexive discussions contributed, over and above those recognised before and during the simulation, to the identification of themes. The themes each encompass several issues, that share a common solution.

Theme 1: infection exposure risks

Our first theme describes the infection exposure risks identified by participants (table 1). For instance, junior radiographers (JRs) pointed out that, when moving around the mobile X-ray machine in the small anteroom, they might touch it when disinfecting the detector plate or doffing contaminated personal protective equipment (PPE) (figure 3A). The footage also clarified the need for PPE to be worn by the radiographer in the anteroom to avoid being contaminated by the X-ray detector before it is cleaned (figure 3B). SRs also noted that the limited space in the anteroom would increase the risk of contamination if a larger mobile unit were used and/or the radiographer were a larger person.

Theme 2: occupational health and radiation exposure risks

In our second theme, we found that both JRs and SRs watching the footage identified occupational risks—not considered prior to or during the simulation—that were associated with trying to project the X-ray beam through the small anteroom window (table 2). First was the risk of physical injury (figure 4A and B) in the cramped anteroom, which was a breach of the hospital work health and safety policy. Second were radiation exposure risks.

Table 1 Issues and illustrative quotes related to infection exposure risks

Issues identified before/ during simulation	Identified during reflexive 1 (junior radiographers (JR), medical and nursing staff)	Identified during reflexive 2 (senior radiographers (SR))
► Mobile X-ray machine could be contaminated in the small anteroom. ► Lack of cleaning products in anterooms for cleaning bagged X-ray detector ► Cleaning products could damage machine ► Protective machine covers could overheat the machine ► Question: is it necessary for radiographer in the anteroom to wear PPE?	► Radiographer in the anteroom could be contaminated by used detector plate. "See how she's sort of bracing [the detector] against her body? So, she needs to have the PPE on." (figure 3B). Junior Radiographer#4 (JR)	► The mobile machine and the radiographer in the footage were relatively small. A larger machine, or a larger person who would find it harder to move around, is more likely to be contaminated. "That's probably our smallest mobile … Some of the other ones are bigger than that. The [JR in footage] is probably one of our smaller staff members. We've got a couple of young fellas that are …six foot four and big burly guys." (figure 3). Senior Radiographer#2 (SR)

PPE, personal protective equipment.

It would be difficult for the radiographer to move 1.5–2 m from the radiation source and so would risk radiation exposure, which is reportable to the environmental protection authority (EPA) (figure 4A). There was also a risk that radiation could scatter from the patient's room into the public corridor, which is also reportable to the EPA (figure 5A). Third was the fact that radiographers losing sight of the patient would risk the X-ray image exposure having to be repeated.

Theme 3: communication

Our third theme identifies issues around communication, which threatened the safety and X-Ray image quality (table 3). JRs discussed why communication is important to ensure (1) the X-ray examination is performed correctly, such as by correctly positioning the detector and instructing the patient when to breathe in; and (2) to alert staff inside the room when to move away from radiation source.

When watching the footage, participants could see how communication could be hindered between those inside (nurse, radiographer, patient) and outside (the radiographer taking the image) the room, due to the physical barrier of the door and inability to lip read (figure 6). Radiographers who worked together regularly often

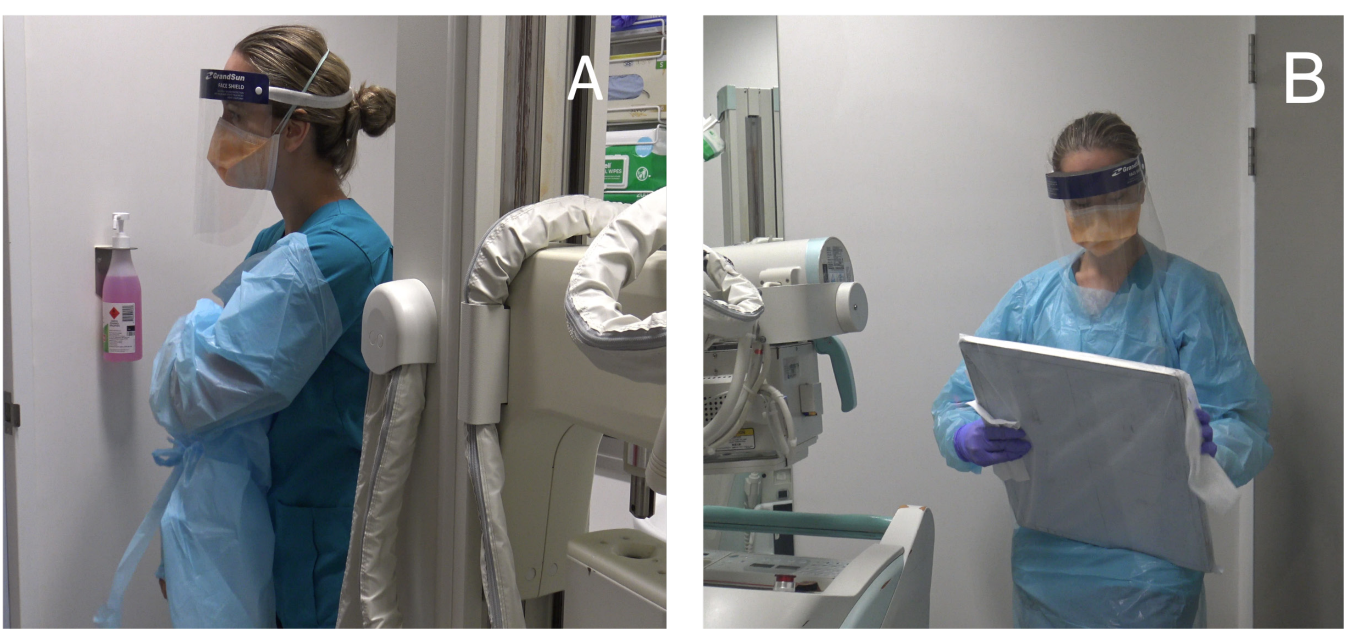

Figure 3 (A) Radiographer removing personal protective equipment (PPE) may inadvertently contaminate mobile X-ray machine (foreground) while moving around the cramped anteroom. (B) Potentially contaminated X-ray detector in contact with 'clean' radiographer while being cleaned, necessitating PPE.

Table 2 Issues and illustrative quotes related to occupational health and radiation exposure risks

Issues identified before/during simulation	Issues identified during reflexive 1	Issues identified during reflexive 2
▶ At the walk through prior to simulation the senior radiographers recognised the need for the radiographer to step outside the anteroom to avoid exposure to X-ray—and the subsequent potential for the control cord to be damaged in the closing door	▶ Risk of ergonomic injury to radiographer when taking the X-ray in the cramped anteroom (figure 4) "… if I come from the side of my machine, as I would anywhere else, I can't see the patient. So, I had to go from underneath. #JR1 "We're twisting our bodies in the wrong way. So, you're going to have back problems. You're asking for the radiographer to get injured. Can you imagine a poor, sole radiographer, or a couple of radiographers doing that for 10 beds?" #JR2 ▶ To keep sight of the patient through the narrow window, the radiographer cannot step 2 metres away from the machine, so is exposed to radiation (figure 4) ▶ Due to the direction of the X-ray beam from anteroom into the patient room, radiation scatter could leak into public corridor (figure 5A) ▶ If staff step away from the machine and lose sight of patient, the X-ray image capture may not be optimal, and the patient may need to be exposed again. "The biggest issue is squeezing us in the anteroom where we can't move away from the radiation source." #JR2	▶ Ergonomic issues are a breach of WHS policy (figure 4) "That's a work health and safety issue straight out, the fact that she's crouching to get into that. Because normally she would be over to the side [standing]". #SR2 ▶ Potential radiation exposure of staff is an EPA reportable issue. "[Taking an X-ray from the anteroom] is a radiation incident. You have to be a minimum of one-and-a-half metres away. She's directly underneath. Medical physics would be all over that. That would be an EPA reportable issue" (figure 4) #SR2 ▶ Additional radiation exposure for patient"[The radiographer] wouldn't have direct line of sight of the patient … They've got to watch whilst [the patient is] doing the breath hold …to be sure that they've taken a big breath in. Because if you've got them on expiration, … you've got to repeat [the X-ray exposure]. So, there's another unnecessary [exposure for the patient]" (figure 4) #SR2 ▶ Radiation scatter could leak into public corridor (figure 5) "If we pause [the footage] there … so, that's the [door to the] outside… because we're shooting [from anteroom], there's scatter coming out here [into the corridor] (figure 5A) … people outside that glass, if they were walking by, there's a potential that they could be exposed … Whereas if we were shooting directly through the glass [into the room], [the scatter] is going into the wall." (figure 5B) #SR2

EPA, Environment Protection Authority; WHS, work health and safety.

relied on agreed signals, and this shared understanding gave them a sense of confidence. However, nursing and medical staff watching the footage expressed a lack of confidence with the procedure.

Communicating from the anteroom was also difficult because of the narrow window (figure 6), compared with the glass door from the corridor, which offered a better view of the movements of everyone inside the patient room (figure 1).

Theme 4: X-ray image quality

In our final theme, participants discussed how achieving an adequate X-ray image though the narrow anteroom window was challenging (table 4), as it was difficult to navigate the bed into the X-ray beam, or close enough to the source (figure 7). The further the patient is away from the source, the higher the X-ray tube must be placed to correctly angle over the patient's diaphragm. The anteroom window would not allow for significant height increase of tube. The tube/patient distance will also affect the exposure factors required to compensate for increased distance.

Solutions

In both video-reflexive sessions, participants found that the optimal solution to all four identified risks was essentially the same. *Infection exposure risks* due to contamination of equipment or personnel would be avoided if use

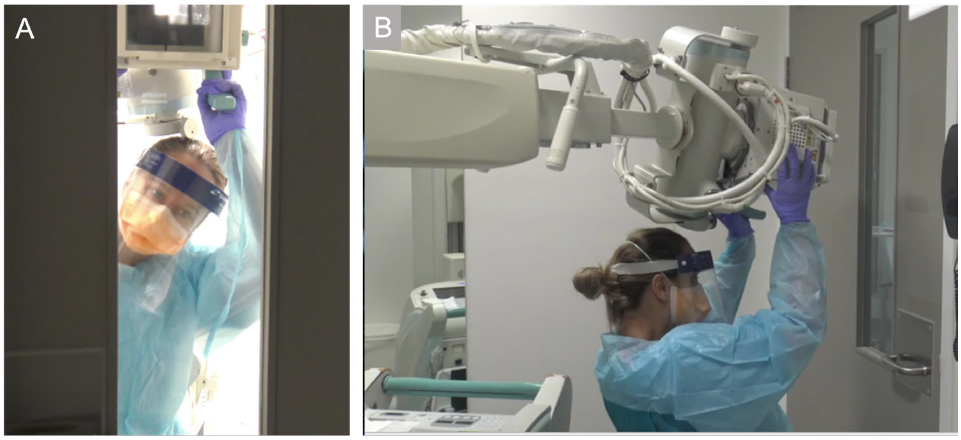

Figure 4 Radiographer in ante room crouching below X-ray machine. (A) View from patient room towards anteroom. (B) View from inside anteroom.

of the anteroom for mobile X-ray imaging was avoided. Use of the anteroom could be avoided by performing X-ray imaging through the glass door into the corridor. This would require replacing the aluminium slats on the door with retractable slats, radiolucent opacifying glass or plain glass with a retractable curtain.

Performing X-ray imaging through the glass door in the corridor would also resolve *occupational health and radiation exposure risks* by: allowing the radiographer to move about freely, keep the patient in sight and step away from the source of radiation scatter. It would ensure that the X-ray beam was directed into the patient's room and avoid radiation scatter into the public thoroughfare. *Communication* by visual cues, between staff outside, and staff and patient inside the patient's room, would be improved. The mobile X-ray machine being closer to, and more appropriately positioned in relation to the patient would optimise *X-ray image quality*.

The risks and solution suggested by participants were collated and taken to a special meeting with the hospital executive to put forward a case for changes to existing glass doors in the corridor. The video footage was used at this meeting to illustrate the issues. The significance of the issues was understood by those present at the meeting, who agreed that the aluminium stats would be replaced by retractable blinds. This took place in December 2021. This meeting was not recorded and did not form part of the research data.

DISCUSSION

Our study showed that in situ video-reflexive simulation and debrief assisted HCWs to identify serious latent safety threats when performing mobile X-ray imaging on patients with HCID, in a new biocontainment unit. These included, increased risks of exposure to infection, occupational injury and radiation, and interference with communication and X-ray image quality. As with other studies, by conducting this investigation prior to the rooms being commissioned, it was possible to minimise the risks of endangering staff and patients.[1 9] While some of the issues were identified prior to, or during, the in situ simulation, several unforeseen but important issues,

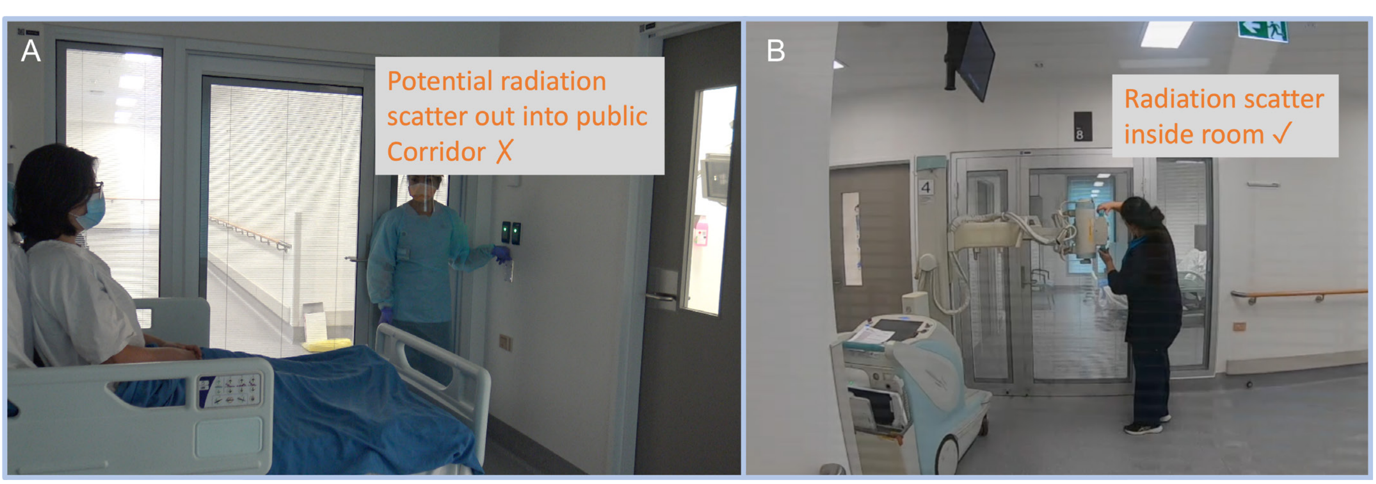

Figure 5 Radiation scatter. (A) Potential radiation incident if radiation scatter bounces off patient and bed out into public corridor. (B) Preferred option for X-ray via corridor. Scatter mostly directed inside room.

Table 3 Issues and illustrative quotes related to communication

Identified before/during simulation	Identified during reflexive 1	Identified during reflexive 2
► Communication between staff inside and outside the room is important to ensure that: – the detector is placed correctly; – staff inside the room know when to move away from the radiation source; – patient can be given instructions during the X-ray procedure ► Communication is hindered: – by the glass in the door – by everyone wearing facial protection, which muffles sounds and prevents lip reading	► Communication in this setting requires: – a shared understanding, between experienced radiographers, of what is required for optimum X-ray image capture; – agreed sign or body language, for example, thumbs up; – trust that your colleagues know what they are doing ► This may be more difficult with casual or agency staff, who are unfamiliar with the setting "Look, if that was my first time, I wouldn't be comfortable to do it. I think that if you were going to get a nurse to do it, they need to go through some sort of workshop or at least … training by a radiographer for them to understand." #RN [Registered Nurse] ► The window of the anteroom door is not wide enough to see what is going on in the patient room or exchange visual cues "You're always going to have to shout really loud. But at least [through a larger window or glass door] she can see where I'm going." #JR4	► Communication barriers can cause mistakes; for example, an inexperienced nurse inside the room may not do correct checks, and the wrong patient could be exposed to X-ray in error.

across all four areas of risk, were identified and articulated only during reviews of video footage.

Central to the four video-reflexive methodological principles is acknowledgement of the expertise of frontline clinicians and of the need to *collaborate* with them to find ways to improve healthcare, or in this case—healthcare environments. Rather than relying on researchers or simulation experts to analyse the footage, our study enabled clinicians, who have the most at stake, to identify and collate user-specific safety risks, and suggest changes most appropriate to their use of the space. This also speaks to the principle of *care,* in that clinicians are valued and respected for their expertise.[47] Our approach also promoted *exnovation,* enabling clinicians to gain awareness of their existing competencies and increase their agency and control over what needs to change.[24]

Video-reflexive methodology also values *reflexivity*; collaborative, thoughtful deliberation that allows people to raise and negotiate different viewpoints and position themselves in relation to visual evidence of their practices and relationships.[48] The footage allowed viewing by a wider audience than those involved in the simulation. Even those who were a part of the simulation could not experience all aspects of the X-ray examination process; the staff in the patient's room did not experience what it was like for the radiographer in the anteroom, and the radiographers did not experience what it was like for the nurse. Having people from different disciplines—who perform different roles and with differing expertise—view and discuss the entire process from all points of view, enabled them to understand the complex interconnected issues and design appropriate improvements collaboratively. Importantly, the experienced radiographers, who could not attend the simulation, identified different issues from those identified by the JRs, including issues relating to policy and legal concerns, such as that radiation breaches were reportable to the EPA.

Video is critical to engendering reflexivity. In our study, as found by Krammer *et al*,[9] analysis of the video footage not only confirmed problems anticipated by radiographers prior to, and during the simulation, it also shed light on many additional issues. This is because video connects people to their ways of working in new ways, allowing them to see things in a different light.[24] For the radiographers, watching themselves perform taken-as-given activities in a new environment helped them to understand the complexity of performing a safe and effective mobile X-ray imaging and the potential consequences of workarounds (eg, potential scatter of radiation into public spaces). Having video footage to refer to meant that viewers did not have to rely on memory or recall.[24] Furthermore, the footage could be paused for in-depth

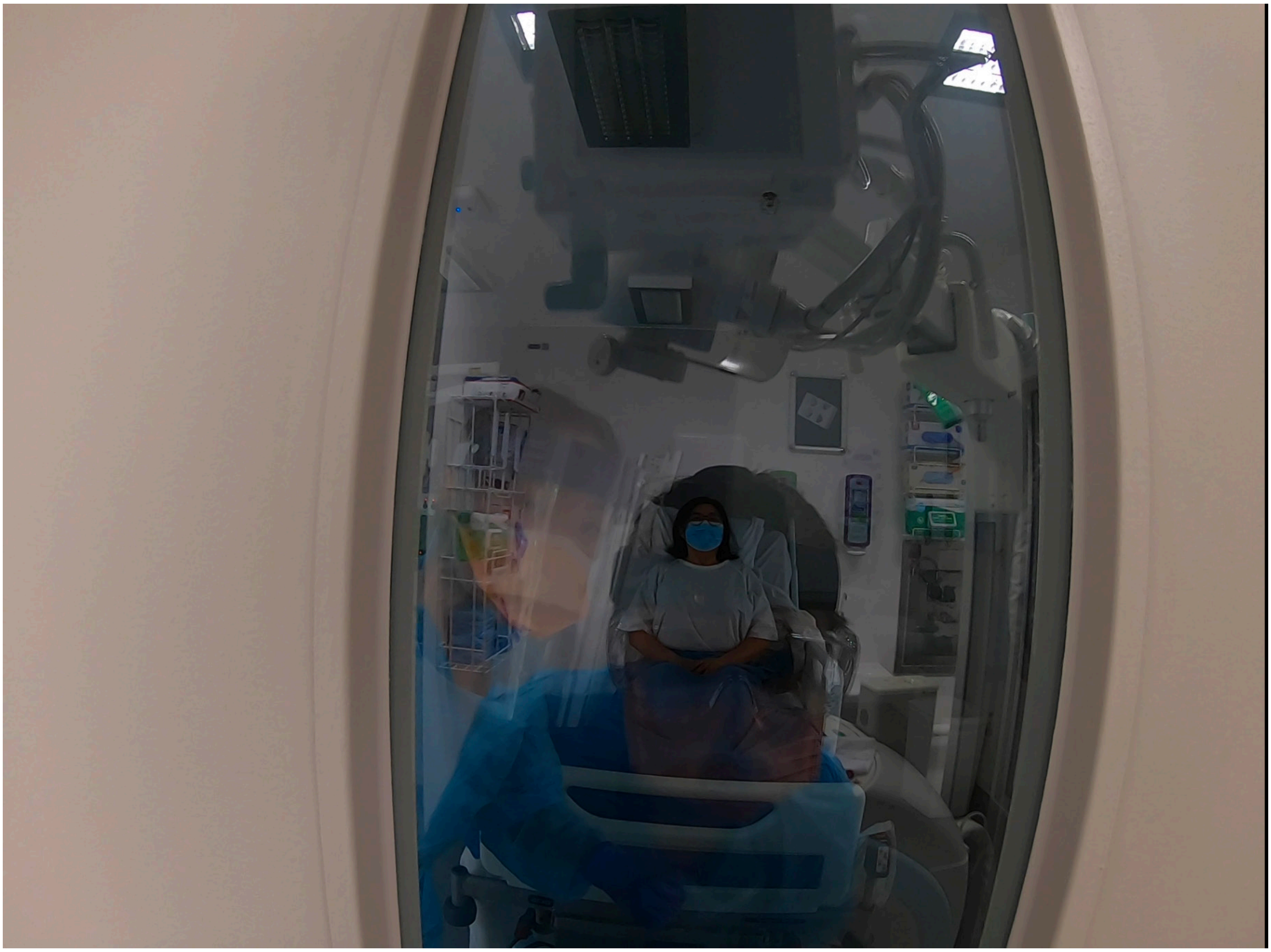

Figure 6 View from anteroom into patient room showing the healthcare worker giving the 'thumbs up'. Barriers to communication include the narrow visual field, darkness and masks.

analysis: for example, when one of the SRs requests that the video be paused to point out the potential for radiation scatter into the corridor. As well as the practical/technical aspects of work, video can connect people to meanings and feelings embedded in their work practices, and reflexive sessions create a space for discussion and sharing.[24] For example, when the biocontainment nurse explains her feelings around her inexperience with the procedure, or when the JR expresses her concern about performing repetitive actions that cause personal physical injury.

The meeting at which clinicians' findings were presented to the health service executives responsible for approving changes to the built environment did not form part of the research. However, showing the video footage at this meeting, alongside a summary of the issues brought up at reflexive sessions, led to a greater understanding by the executive as to why the cost of replacing the aluminium slats was outweighed by staff, patient and public safety risks. As a result, the doors were replaced, allowing utility of the novel 'through glass' X-ray techniques.[44 45] This did not happen until after patients had already been admitted to the unit, which caused some disruption. In future, time to make changes should be factored in to postconstruction simulations and testing, before opening for patient care.[1]

Limitations to this study include the small number of participants involved in the review of only two simulations. It would be preferable to have included an even wider range of stakeholders in the reflexive sessions, such as a member of the public (rather than a researcher) to provide a patient experience component. We make no claims regarding data saturation, as it is possible that including more participants and other perspectives could have identified even more issues and solutions. Instead, we draw on the criteria of information power[49] which recognises that this is a study with aims that are highly context specific, using methods that provide appropriate richness in information power through the use of video and collaboration with participants who are experts in the setting.

However, even with these limitations, we showed that in situ simulation and video feedback are crucial to ensuring that a new healthcare facility is ready to function safely

Table 4 Issues and illustrative quotes related to X-ray quality

Identified before/during simulation	Identified during reflexive 1	Identified during reflexive 2
► The glass door in the corridor is the best place from which to take the X-ray image, but the aluminium slats would distort the image ► X-ray image quality is also affected by – The distance between the X-ray tube and patient – Thickness of the glass, which attenuates X-ray beam's energy as it passes through – Placement of detector – Whether patient can follow instructions – Radiographer performing the X-ray exam keeping sight of the patient to ensure they do not move ► The patient in the bed must be moved into the line of the X-ray beam as it passes through the glass	► The window in the anteroom is so narrow that it is difficult to navigate the bed into a good line of sight of patient "Forcing us to align our X-ray [beam] through a … tiny slit, which is about, what, eight centimetres wide? That's a nightmare" (figure 4) #JR2	► It is difficult to get the bed close enough to the anteroom window. This affects the source-to-image receptive distance, between X-ray tube and patient's chest, required for adequate image "From a technical perspective, we would want to have what we call the… source to image receptive distance, between 150 and 180 centimetres. So here, [the bed] is probably, I'd say, about three metres [from the source]. So, we would need to bring the bed closer." #SR1 ► The top of the window in the anteroom was too low to angle the X-ray tube correctly over the patient's diaphragm from their bed position (figure 7) "When you're doing an AP [antero-posterior X-ray], you need to … angle to the patient's sternum to get over the top of their diaphragm. So, the further away you are, the higher the tube needs to be…You're at the top of the [window] … You couldn't get it in any further." #SR2

and effectively. We have since taken this approach in preparation for commissioning of the biocontainment Q-rooms, by simulating and videoing a range of patient care and diagnostic activities and analysing the footage. This approach could be used in other biocontainment settings, both existing and new, to enhance and maintain biopreparedness; particularly given that patient presentations of HCID in many countries are relatively

Figure 7 The further the patient is away, the higher the X-ray tube must be placed to angle over the patient's diaphragm and may affect the dose required to compensate for increased distance.

rare. It is also worth keeping in mind that the facilitation of video reflexivity need not always be researcher led. This is evidenced by a growing number of healthcare professionals who have embraced the method for quality improvement in their hospitals/units.[50 51]

CONCLUSIONS

This study demonstrated the critical importance of in situ exploration and evaluation of a new facility before its commissioning. In situ simulation is increasingly used to evaluate and improve healthcare practices. This study confirmed the added value of video-reflexive methods, which provide experienced participants with a richer view of a familiar protocol, in a new setting. Video footage can be examined immediately or later, if required, and by a broader group of stakeholders with different experience or expertise. Using video reflexivity, clinicians were able to identify, collate and present latent environmental and safety threats to those who could endorse and implement the modifications.

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Acknowledgements The authors thank the healthcare workers who participated in this study for providing insights that will contribute to future improvements in facility design. We also thank Faith Yong for formatting documents for the submission of this manuscript.

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Funding This work was supported by the National Health and Medical Research Council Centre of Research Excellence (NHMRC CRE), the Australian Partnership for Preparedness Research on Infectious Disease Emergencies (APPRISE AppID 1116530) and in-kind support by the University of Technology, Sydney; The NSW Biocontainment Centre, Sydney; and the Westmead Hospital Radiology Department, Sydney.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Ethics approval for this study was granted by the Western Sydney Local Health District Human Research Ethics Committee (2020/ETH01803). The participants gave written consent before the study commenced and verbal consent before activities were recorded. All research were performed in accordance with relevant guidelines and regulations. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The datasets generated and/or analysed during the current study are not publicly available for privacy reasons, but are available from the corresponding author on reasonable request.

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