XR in the Operating Room: Participatory Identification of Resilient Use Cases for Surgical Instrument Logistics

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Abstract

The operating room is among the most demanding deployment contexts for Extended Reality: sterile, noisy, time-critical, and reliant on fragmented information systems. In this position paper, we report on participatory workshops with surgical assistant staff (OTAs) at a German university hospital, conducted as part of the BMFTR- and ESF Plus-funded ERTRAG project. Drawing on a *problem-first* design philosophy [1] and utilizing the *MTO* (human-technology-organisation) framework as our analytical lens, we collaboratively identified two Mixed Reality use cases for instrument logistics that address genuine user needs rather than imposing technology for its own sake. We discuss how these use cases surface concrete design challenges around calibrated trust, resilience by design, and situated explainability, contributing a practitioner-grounded perspective to the XR4CE workshop's research agenda.

Keywords

Extended Reality, Mixed Reality, Operating Room, Participatory Design, Challenging Environments, Healthcare, Surgical Instrument Logistics

1. Introduction

Extended Reality in surgery is typically discussed from the surgeon's perspective: pre-operative planning, anatomical overlays during navigation, or training simulations [2]. In this paper, we turn to a less visible but equally critical group: surgical assistant staff (Operationstechnische Assistent*innen, OTAs), who manage instrument logistics, documentation, and coordination in the operating room (OR). Their work is shaped by time pressure, strict hygiene protocols, and fragmented information systems, making the OR a prototypical *challenging environment* that fully aligns with the scope of the XR4CE workshop.

We present findings from the ERTRAG project[1], an initiative funded by the German Federal Ministry of Research, Technology and Space (BMFTR) and the European Union through the European Social Fund Plus (ESF Plus), exploring XR for healthcare transformation. Through a series of participatory workshops [3, 4] with OTAs at a German university hospital, we identified two concrete MR use cases for instrument logistics. Crucially, these emerged from user-identified pain points rather than from a technology-first approach, which we argue is essential when designing XR for mission-critical work.

2. Approach: From Pain Points to XR Scenarios

A core principle of ERTRAG is that XR must not be forced into workflows. We employed a three-stage participatory workshop series with OTAs at a German university hospital, building on the MTO (Mensch-Technik-Organisation) approach to participatory work system design [3, 4]. In the first session, a moderated employee workshop, we explored the OTAs' general work context and pain points without mentioning XR. In the second session, an MTO workshop, we applied the MTO framework to model the current instrument logistics process in detail, examining the interplay of

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people, tools, and organisational structures to identify friction points. Only in the third session, a Requirements-Engineering (RE) workshop, did we introduce XR as a possible intervention, letting participants co-design scenarios based on the previously identified bottlenecks. This staged approach ensured that the resulting use cases reflect genuine needs rather than researcher assumptions about where XR might be useful.

3. Findings: Two Use Cases from the Workshops

3.1. Tray Inspection and Instrument Search

The most pressing problem identified by OTAs concerns locating specific instruments during surgeries. Instruments are stored in standardised sterilisation containers, each holding trays with defined instrument sets. In the OR, all objects and personnel are classified as either sterile or non-sterile, and crossing this boundary risks contamination. Two types of OTAs reflect this division: the sterile OTA assists the surgeon directly at the operating table, while the non-sterile OTA, known as the "runner," retrieves sealed containers and other materials from outside the sterile zone. When an instrument is needed that is not in the pre-prepared set, for instance because it was dropped or an unexpected situation arose, the runner must find the right container from the storage area.

The information systems tracking container contents are fragmented, slow, and do not support searching for individual instruments. Runners rely on printed lists, experience, or trial and error, opening containers until they find what they need. Each opened container breaks the sterile seal, rendering its contents unusable for other procedures until re-sterilised. Participants reported opening four to five containers for a single instrument, wasting sterile resources, time, and cost. A further complication is identification: OTAs often use colloquial instrument names that differ from manufacturer or sterilisation databases, and surgeons may not name an instrument at all but instead describe its shape or function, leaving the runner to interpret the request. Many surgical instruments are small and visually similar, making this interpretation error-prone. The co-designed scenario envisions an MR application on a head-mounted display that aggregates container content data from the existing (fragmented) systems and supports multiple search modalities: voice input (potentially LLM-supported to bridge the terminology gap), visual recognition of an instrument or reference image, or even freehand gesture sketching in mid-air to outline an instrument shape that is then matched against a 3D model database. The system would show which container holds the needed instrument, whether it has already been opened, and whether it is scheduled for another procedure, all *before* the container is opened.

3.2. AR-Supported Instrument Preparation

The second scenario addresses instrument table preparation. OTAs arrange instruments on sterile tables according to standardised layouts before each procedure. While in principle, instrument manufacturers, such as our project partner Stryker, provide pre-defined tray compositions, in practice surgeons routinely customise their setups: they combine instruments from different vendors and rearrange trays based on personal preference and perceived efficiency rather than manufacturer logic. As a result, the tray layouts actually in use at a given hospital bear little resemblance to any vendor-provided specification and vary between institutions, departments, and even individual surgeons. Currently, these hospital-specific layouts are documented on laminated reference images stored in binders at the back of the preparation room. These are difficult to update when layouts change, can get lost, and require the OTA to leave the sterile preparation area to consult them. Despite the obvious need for a digital alternative, none is currently in use. AR-guided assembly is well-established in manufacturing, where projected layouts reduce errors and training time for complex tasks [5], yet this approach has not been transferred to surgical instrument preparation. Correspondingly, our participants proposed that AR-interfaces could be employed to project these layouts directly onto the preparation surface, with outlines and reference markers indicating correct instrument positions. They argued this would particularly benefit less experienced staff, substitute personnel, or rare procedure types where the layout is not routine.

4. The OR as a Challenging Environment for XR

Our participatory workshops revealed already that the OR challenges XR deployment in ways that demand the *resilience-by-design* thinking this XR4CE workshop advocates.

Environmental realities. The OR defies the clinical calm one might imagine. Noise levels are substantial, with suction devices, monitors, conversations, and sometimes background music competing for attention [6]. Space can be tight, temperatures unreliable, and the environment physically messy. Voice interaction may be drowned out; gesture interaction is impractical with gloved or occupied hands. Any XR system must perform reliably under these adverse conditions, not just in a controlled lab setting.

Sterility and device handling. Runners move between the OR and non-sterile corridors. Head-mounted displays must be cleanable to sufficient standards, and practical questions around storage, charging, and handoff between staff remain unresolved.

Intermittent vs. continuous use. Instrument search is episodic; documentation could benefit from continuous HMD availability. Should runners wear devices full-time, requiring additional use cases to justify the overhead? Or on-demand, requiring instant boot times and accessible storage?

Network and data access. Hospital networks in OR areas can be unreliable. The application needs real-time access to inventory systems that may link to patient data, raising both connectivity and security concerns. A system that fails silently or becomes unavailable is worse than the current manual approach.

Integration, not addition. OTAs already manage multiple disconnected digital systems alongside paper-based documentation. An XR layer that does not replace existing burdens will be rejected. The participatory approach was essential for surfacing this risk: users themselves articulated that technology must *reduce* their workload, not add to it.

5. Discussion

Our findings connect directly to the three shifts proposed by the XR4CE workshop.

Calibrated trust is critical: a single incorrect container recommendation could waste sterile resources and erode team-wide adoption. The terminology mismatch adds complexity, as the system must reliably interpret queries in the OTAs' vocabulary, not just the catalogue language. Trust must be earned through consistent accuracy in a context where errors have immediate, visible consequences.

Resilience by design is non-negotiable in the OR. Network drops, device failures, or software errors cannot leave a runner stranded. The manual fallback of walking to storage and checking physically must always remain viable. This means designing the XR system as an enhancement layer that degrades gracefully [7], not as a replacement for existing capabilities.

Situated explainability shapes the entire interaction design. A runner looking for an instrument mid-surgery needs information at a glance: which container, where, is it available. There is no room for multi-step navigation, abstract dashboards, or explanations that demand cognitive investment. The co-designed scenarios consistently emphasise spatially anchored, minimal information rather than comprehensive data displays.

More broadly, our experience underscores the value of participatory methods for XR in challenging environments. Our staged workshop approach, consistent with participatory design principles in healthcare [8], prevented a technology-push approach and surfaced constraints (terminology gaps, documentation burden, environmental noise) that would have been difficult to anticipate from outside the domain.

We are planning to develop two functional prototypes: one for tray inspection and instrument search via head-mounted display, and one for MR-guided pre-operative instrument preparation. Both will operate with simulated inventory and scheduling data, since the hospital's fragmented system landscape, data protection requirements, and the sheer number of tray configurations in use preclude live integration at this stage. We plan to evaluate both prototypes with surgical assistant staff in a simulated OR environment at Universitätsklinikum Heidelberg, combining task-based sessions with interviews and standardised questionnaires. This will allow us to probe the workshop's core themes empirically: calibrated trust through participants' reliance on system recommendations versus manual fallback, resilience through responses to simulated system degradation, and situated explainability through the effectiveness of minimal, spatially anchored displays under realistic task pressure. Further evaluation activities with international partners are being planned to broaden the perspective beyond a single institutional context.

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Declaration on Generative AI

During the preparation of this work, the author used Claude (Anthropic) in order to: Grammar and spelling check, Paraphrase and reword. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the publication's content.

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