



KEY POINT SUMMARY

OBJECTIVES

This study reviews existing research concerning the integration of technology into healthcare environments and explores the impact technology has on the physical environment and patient outcomes.

Technology integration in complex healthcare environments: A systematic literature review

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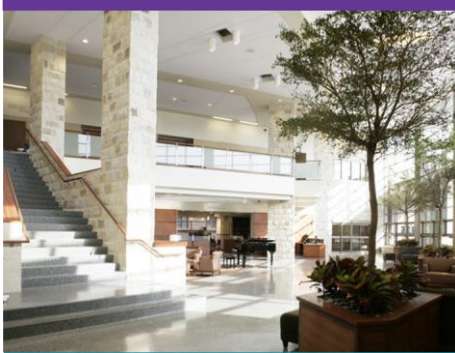
Key Concepts/Context

Previous research shows that the way in which information displays and imaging technology are integrated into healthcare environments can impact staff workflows, patient safety, and perceptions of care. Caregivers working in trauma rooms, intensive care units (ICUs), and operating rooms (ORs) require frequent access to imaging technology; when these resources are located far away from patients, issues may arise with communication, coordination, and interruptions. Floorplans and room designs balancing technological access with patient-centered care are ideal.

Methods

This systematic literature review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. The databases PsycINFO, PubMed, and Web of Science were searched for articles dating from 2005 and onwards. The search protocol included a list of keywords and used advanced search options to locate articles that were specifically related to technology, the physical and built environment, and ICUs, critical care units (CCUs), ORs, hybrid ORs, neonatal intensive care units (NICUs), and trauma rooms. Further manual searches were conducted through the JAMA Network, ScienceDirect, and SAGE Journals using the same search protocol. Google Scholar was used to scan the citation sections of certain articles for additional relevant research.

After removing any duplicate articles found through the search, all remaining research was screened using the following criteria: 1) published in a peer-reviewed journal, 2) written in English, 3) published during or after 2005, 4) contents were specifically related to technology, 5) contents were specifically focused on complex healthcare environments such as ICUs, ORs, CCUs, or trauma rooms. Articles were excluded that were not comprised of original research, did not address physical aspects of the built environment, or that focused on simulated environments.



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Two researchers reviewed the resulting articles to assess final eligibility and discussed any discrepancies over nine discussion meetings. The Mixed Methods Appraisal Tool (MMAT) 2018 was used to assess the remaining articles for quality of study design, reliability, sampling, and data analysis. Out of 1,001 articles screened, 24 were eligible. After applying the MMAT for quality appraisal, 20 articles yielded a score of 60% or above and thus were included in this study.

Findings

Through the relevant literature that was available, five primary themes were extracted and explored:

- **The technological environment:** Multiple studies found that the highly technological atmosphere of complex health environments significantly impacted patients and staff. In ICUs, high levels of light and noise disrupted patient sleeping patterns, and alarm sounds distracted nurses from high priority tasks. In CCUs, nurses noted that the abundance of technical equipment such as short tubes and dialysis catheters complicated daily tasks such as turning patients and changing sheets.
- **Robot-assisted procedures:** One study focused on the use of robots within ORs, revealing that their presence created congestion that disrupted staff workflows. Suggested solutions included establishing more appropriate adjacencies for the robot prior to installation and utilizing wireless technology to reduce clutter wherever possible.
- **Information technology:** Multiple studies explored the use of large customizable interactive monitors (LCIMs) from caregiver perspectives in pediatric ICUs. The LCIM made visual data more accessible and improved interactions between caregivers and family members. However, the LCIM also provoked anxiety by using the color red to indicate neutral values while potentially revealing private information through large font sizes.
- **Integrated environments:** One study examined how an integrated OR, which used a ceiling-mounted boom arm with three monitors, compared to a conventional OR using a cart with two monitors. The number of disturbances in surgical flow was not significant between the two types of ORs, nor were there significant differences in the procedure time or operating time.
- **Hybrid settings:** Eight studies described hybrid settings (e.g., ORs and trauma rooms equipped with imaging technology). OR patients described having reduced anxiety due to the presence of the imaging technology. Multiple studies examined “dual rooms”, which are architectural solutions for mitigating the high costs associated with hybrid settings where imaging equipment can be transferred between rooms using sliding fixtures. In ORs and ERs, dual rooms resulted in reduced time between procedures.



Limitations

The authors acknowledge that the amount of research specifically concerning technological integration into the physical environments of complex medical settings is notably low, which results in relatively limited interpretations. Since this review only included research from scholarly journals, relevant gray literature was not eligible for inclusion, thus some insights from non-scholarly outlets may have been neglected. The hand search of empirical studies may have resulted in some articles being overlooked. Only articles written in English were included in this study. Most studies featured limited sample sizes, and none were randomized controlled trials.

Design Implications

Positioning of equipment, layout design, and technological ambiance all influence patient and staff perceptions of new technologies within complex medical environments, as well as the efficacy of care delivery. Informational displays can help improve communications between patients and staff but should be integrated in a way that promotes privacy and interpersonal interaction. Placement of robots should be planned thoroughly, and wireless technology should be employed where possible. Dual rooms may help mitigate costs associated with hybrid settings.

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