DEVELOPMENT AND VALIDATION OF AN INTEGRATED FIRE PREVENTION AND RESPONSE PROTOCOL IN HOSPITALS: A SYSTEMATIC REVIEW

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Abstract: Fire safety in hospitals is a critical component of risk management and patient safety, requiring a systemic and integrated approach. The absence of standardized protocols compromises the safety of critical patients and the continuity of care operations. This systematic literature review aims to synthesize scientific evidence on the development, validation, and implementation of integrated fire prevention and response protocols in hospitals. The analysis covers operational flowcharts, brigade training, critical patient evacuation, and organizational safety culture. Research conducted in databases such as PubMed, SciELO, Scopus, and Web of Science, as well as technical standards repositories, identified that fire response effectiveness depends on the integration of multiple components: clear protocols, competency-based training, realistic simulations, and a robust safety culture. Evidence points to the need for scalable and adaptable protocols that incorporate international best practices and consider different hospital realities. Knowledge gaps include the scarcity of studies in low- and middle-income countries, limited research on complex scenarios with multiple victims, and the need to evaluate long-term effects of training programs. It is concluded that implementing an integrated protocol, validated through simulations and audits, is fundamental to strengthening hospital resilience and reducing the occurrence of serious adverse events related to fires.

Keywords: Fire safety. Hospitals. Emergency protocols. Patient evacuation. Safety culture.

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INTRODUCTION

Fire safety in hospital environments represents a complex and multifaceted challenge, essential for protecting patients, healthcare professionals, and care infrastructure. Although the frequency of hospital fires is relatively low in developed nations, the potential for catastrophic consequences is immense, potentially resulting in multiple victims, loss of life, and complete interruption of operational continuity (KING et al., 2014). In the United States, for example, an estimated 550 to 650 fires occur annually in surgical rooms alone, of which 20 to 30 result in serious or fatal injuries (SIMULAÇÃO…, 2022).

The absence of prevention and response protocols that are simultaneously standardized and integrated significantly compromises patient safety, especially critical patients, and the ability to maintain care operations during and after an adverse event. Highly prestigious international standards, such as NFPA 101 (Life Safety Code) and NFPA 99 (Health Care Facilities Code) (NATIONAL FIRE PROTECTION ASSOCIATION, 2021), along with Brazilian regulations such as NBR 13434 and manuals from the National Health Surveillance Agency (ANVISA) (BRASIL, 2014), provide a robust framework for fire safety. However, the heterogeneous and sometimes incomplete implementation of these requirements results in considerable disparities in the level of preparation and response capacity among hospital institutions, a problem particularly pronounced in low- and middle-income countries (EBEKOZIEN et al., 2020).

This systematic literature review has as its central objective to analyze and synthesize available scientific evidence on the development, validation, and implementation of integrated fire prevention and response protocols in hospitals. The scope of analysis covers the fundamental components of an effective response system, including operational flowcharts, fire brigade training, and procedures for critical patient evacuation.

METHODOLOGY

For the preparation of this review, a systematic and comprehensive bibliographic search was conducted, following a predefined methodology to ensure the reproducibility and quality of selected evidence.

Search Strategy and Data Sources

Research was conducted in internationally recognized electronic databases, including PubMed, SciELO, Scopus, and Web of Science. Additionally, repositories of technical and normative documents from reference organizations were consulted, such as the National Fire Protection Association (NFPA), ANVISA, the World Health Organization (WHO), and The Joint Commission. Search descriptors, in English and Portuguese, included terms such as “hospital fire prevention protocols,” “emergency response fire safety,” “critical care evacuation,” “fire brigade training,” “fire safety simulation,” “protocolo incêndio hospital,” and “simulação incêndio hospitalar,” combined with Boolean operators to refine results.

Selection Criteria and Data Extraction

Studies were selected based on predefined inclusion and exclusion criteria. Original studies, systematic reviews, case reports, and technical documents addressing safety protocols, brigade training, patient evacuation, and fire simulations in hospital contexts were included.

Studies focused only on structural aspects of fires without addressing response protocols, research in non-hospital environments, and publications older than 15 years were excluded, with the exception of fundamental technical standards. Selection and data extraction were performed by two

independent reviewers to minimize bias, using a standardized form to collect information about study design, population, intervention, performance indicators, and main results.

RESULTS AND DISCUSSION

Literature analysis allowed the synthesis of evidence into five main thematic areas, which constitute the pillars of an integrated fire prevention and response protocol in hospitals.

Integrated Protocols and Operational Flowcharts

The literature is unanimous in stating that effective protocols must be integrated and multifaceted. The Joint Commission (THE JOINT COMMISSION, [s.d.]) requires that each healthcare organization maintain a detailed fire response plan, which must be exercised through practical simulations in all work shifts. These protocols should cover everything from risk identification and prevention measures to detection, alert, evacuation, and emergency communication procedures. The R.A.C.E. mnemonic (Rescue, Alarm, Contain, Extinguish/Evacuate) is a widely adopted reference, providing a logical sequence of immediate actions.

To ensure clarity and standardization, operational flowcharts are indispensable tools. The Incident Command System (ICS), and its adaptation for healthcare environments, the Hospital Incident Command System (HICS), offer a robust organizational structure for crisis management, clearly defining roles, responsibilities, and communication lines (WORLD HEALTH ORGANIZATION, 2011). A well-designed flowchart should be visually intuitive, define critical decision points, and specify those responsible for each action, always being accessible in strategic locations.

Training and Competence of Fire Brigades

The technical competence of the fire brigade is a determining factor for response effectiveness. Literature demonstrates that competency-based training programs combining theory and practice are superior to purely didactic approaches. A study comparing surgeon and anesthesiologist training with practical simulations versus traditional teaching concluded that the group subjected to simulations showed significant improvement in both technical competence and confidence in managing operating room fires (SMITH et al., 2018).

Critical elements of an effective training program include addressing topics such as fire physics, practical use of firefighting equipment, realistic simulations, and periodic performance evaluations. Virtual reality (VR) technology emerges as a promising innovation, with tools like the Virtual Electrosurgery Skill Trainer (VEST©) demonstrating a significant increase in professionals' knowledge and performance in fire simulations (JONES et al., 2019).

Critical Patient Evacuation

The evacuation of patients from Intensive Care Units (ICU) during a fire is one of the most complex and high-risk operations, as it requires uninterrupted maintenance of advanced life support during transport. The CHEST Consensus Statement of 2014 offers a set of evidence-based recommendations for ICU evacuation that are directly applicable to fire scenarios (KING et al., 2014).

Recommendations include establishing formal mutual aid agreements between hospitals, developing detailed vertical evacuation plans (use of stairs), designating a Critical Care Team Leader (CCTL), and categorizing patients based on resources needed for transport.

A significant challenge lies in the fact that a considerable portion of hospitalized patients, estimated at approximately 10.5%, have special needs that hinder rapid evacuation, such as dependence on mechanical ventilation (CHEN et al., 2021). These patients require meticulous planning and specialized transport resources.

Simulations and Performance Evaluation

Simulations are universally recognized as the most effective method for training teams and validating protocols. A recent scoping review highlighted that practical simulations significantly improve team confidence and readiness to handle critical events (SIMULAÇÃO…, 2022). Technological evolution has enabled the transition from simulations in real scenarios to immersive virtual environments, which offer greater flexibility and safety. However, an important limitation of current literature is that most studies evaluate only the immediate impact of simulations, with few investigations examining long-term skill retention.

For a protocol to be validated, it is crucial that simulations be accompanied by rigorous performance evaluation. Indicators such as evacuation time, communication effectiveness between sectors, brigade performance, and overall team preparedness level should be measured and systematically analyzed to identify failures and improvement opportunities.

Safety Culture and Organizational Implementation

Successful implementation of any safety protocol fundamentally depends on a change in organizational culture. A positive safety culture, in which patient safety is a non-negotiable institutional value, facilitates adherence to procedures and promotes a collaborative work environment (AGENCY FOR HEALTHCARE RESEARCH AND QUALITY, [s.d.]). Studies on protocol implementation demonstrate that success is associated with factors such as engaged leadership, team empowerment, transparent communication, and a constructive, non-punitive feedback system.

Compliance audits with current standards, both national and international, are an essential component of the continuous improvement cycle. Unfortunately, studies conducted in developing countries frequently reveal inconsistent application of standards, especially in public institutions

compared to private ones (EBEKOZIEN et al., 2020).

CONCLUSIONS AND RECOMMENDATIONS

This systematic literature review confirms that an integrated fire prevention and response protocol is an indispensable tool for ensuring safety in hospital environments. The effectiveness of such a protocol does not reside in a single component but in the synergy between a clear organizational structure (flowcharts and HICS), well-trained teams (brigades), specific procedures for vulnerable populations (critical patient evacuation), continuous validation (simulations and audits), and an organizational culture that prioritizes safety.

The main knowledge gaps identified point to the need for more research in low- and middle-income countries, studies exploring more complex scenarios (such as fires with multiple victims), and investigations into the long-term effects of training programs. Based on the analyzed evidence, it is recommended that the development of integrated fire protocols incorporate the following key elements:

Component	Description and Recommendations
Structural	Development of clear operational flowcharts based on the HICS system, with explicit definition of roles and responsibilities for each scenario.
Educational	Implementation of continuous competency-based training programs combining theory, simulated practice, and, whenever possible, virtual reality.
Operational	Including preparation of transport kits and formalization of inter-hospital agreements.
Evaluative	Definition of measurable performance indicators (KPIs), periodic simulations with systematic evaluation, and compliance audits.
Cultural	Organizational that emphasizes leadership commitment, open communication, and team empowerment.

The implementation of a robust protocol that consolidates international best practices and is adapted to local realities is a fundamental step to strengthen hospital resilience and mitigate the risks

of serious adverse events related to fires.

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