

## ORIGINAL RESEARCH

# Global catastrophe of hospital disasters: a retrospective analysis (1976–2023)

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**Abstract**

Hospitals are critical infrastructures that must remain operational during disasters, yet they often become disaster targets themselves. This study offers a global retrospective analysis of hospital disasters from 1976 to 2023, drawing on data from the Emergency Events Database (EM-DAT). Our methodology combines a historical data review with an evaluation of the impact of technological advancements, community awareness, governmental policies, and psychological support mechanisms on disaster mitigation. By categorizing disasters into collapses, explosions, and fires, we specifically examine incidents leading to significant human casualties and property damage. This retrospective study employs quantitative analysis to identify trends and patterns in hospital disasters, utilizing statistical methods to assess data categorization by EM-DAT and to evaluate the frequency, severity and geographical disparities of these incidents. A notable increase in hospital fires highlights an urgent need for improved safety standards and preparedness. Our analysis also reveals significant regional differences in hospital safety protocols, advocating for tailored preparedness strategies. Enhanced safety standards and disaster preparedness within healthcare facilities are imperative. We propose the development of comprehensive, region-specific preparedness strategies, informed by our findings, to mitigate the impact of future hospital disasters. Addressing these challenges necessitates a global, collaborative approach, emphasizing the role of international cooperation in fostering safer healthcare environments.

**Keywords**

Hospital disasters; Safety standards; Emergency preparedness; Fire safety; Healthcare facilities; Disaster management; Global health; Resilience planning

## 1. Introduction

While hospitals are a significant part of disaster management, they may become the target of disasters. Hospital disasters, encompassing a range of emergencies from structural failures to technological hazards, pose significant threats to global healthcare systems [1, 2]. These catastrophes not only result in loss of life but also disrupt essential healthcare services, impacting communities and economies worldwide [3]. The study of hospital disasters is critical yet underrepresented in current research. This gap highlights the need for a detailed examination of their types, impacts, and the dynamics shaping their occurrence.

Hospital disasters are defined as events that significantly disrupt hospital operations, encompassing structural failures, technological hazards, fires, natural disasters, and other emergencies that compromise the safety and functioning of healthcare facilities. The multifaceted nature of these disasters poses complex challenges to healthcare systems worldwide, threat-

ening not only the structural integrity of hospital buildings but also the safety of patients and healthcare professionals, and the continuity of critical medical services. The ability of hospitals to respond to and recover from such disasters is crucial to minimizing the impact on public health and community well-being. Despite their critical importance, the comprehensive understanding of hospital disasters—ranging from their causative factors to effective mitigation strategies—remains underexplored. This research problem underscores the need to investigate the various forms of hospital disasters and assess their broad implications on global healthcare delivery.

Globally, the frequency and severity of hospital disasters have shown a worrying increase, affecting millions of people worldwide, and causing significant disruptions in healthcare services in the last decades [4]. This rise is attributed to factors such as urbanization, climate change, and increasing dependency on complex technological systems within healthcare facilities [5, 6]. These global trends necessitate a thorough understanding of hospital disasters, and various factors

contributing to their occurrence.

Are these incidents a result of inadequate planning and preparedness, technological failures, or are there other underlying causes? Exploring these aspects enables researchers to fill a crucial gap in the existing literature and provide valuable insights for improving disaster preparedness and response. Traversing a wide spectrum of hospital disasters, the incidents inflicting significant human casualties and infrastructure damage could be identified, narrating the evolving scenarios of hospital safety and disaster response, and demonstrating how these events have influenced and been influenced by the global healthcare landscape.

The theoretical underpinnings of this study are rooted in disaster management theories and healthcare resilience models, emphasizing the capacity of healthcare systems to prepare for, respond to, and recover from hospital disasters. These theories advocate for a multi-faceted approach to disaster readiness, incorporating elements of risk assessment, emergency planning, and community engagement. By applying these theoretical frameworks, our study aims to shed light on the critical components of hospital disaster resilience and identify gaps in current practices.

The necessity of this study arises from the observed increase in hospital disasters and the evolving nature of threats to healthcare facilities. Current research gaps, including a lack of comprehensive global analysis and limited understanding of the effectiveness of existing disaster preparedness protocols, underscore the urgent need for this investigation. By exploring the intricacies of hospital disasters in the context of modern challenges such as urbanization and climate change, this study endeavors to provide a foundational analysis that supports future research and policy development.

The Emergency Events Database (EM-DAT), managed by the Centre for Research on the Epidemiology of Disasters (CRED) and the World Health Organization (WHO) [7, 8], offers a global perspective, enabling the analysis of trends and patterns in hospital disasters since 1976. However, statistical analysis may not explain the socio-economic and environmental contexts of these events. Nevertheless, the mixed approach allows us to delve into the “why” behind these disasters, exploring potential mitigation strategies and contributing to a more nuanced understanding of the issue.

After defining the scope of hospital disasters, it is imperative to consider their global magnitude and the epidemiological data underpinning these events. The World Health Organization reports that hospital disasters affect millions annually, with varying degrees of severity ranging from complete operational shutdowns to partial service disruptions. The impact extends beyond immediate patient care, affecting long-term public health outcomes and economic stability in affected regions. Specifically, the last decade has seen an alarming rise in the number of these disasters, with fire-related incidents alone causing over a thousand fatalities and highlighting the acute vulnerability of healthcare infrastructures to such crises.

Epidemiologically, hospital disasters are not uniformly distributed across the globe. Developed regions with stringent safety standards experience fewer catastrophic outcomes compared to developing areas where such regulations may be lax or inconsistently enforced. For instance, in Riyadh’s tertiary

hospitals, Saudi Arabia, the frequency and impact of hospital disasters provide a microcosm of broader challenges faced by healthcare facilities in similarly situated regions. This discrepancy underscores the importance of a comprehensive study that not only maps the geographical distribution of hospital disasters but also delves into the types of incidents most prevalent and their respective outcomes.

The rising complexity of healthcare systems and emerging global challenges, such as climate change, demand a reevaluation of hospital disaster preparedness [4, 9], to not only review historical data but also considers future scenarios, thereby serving as a vital reference for contemporary and future strategies in hospital disaster management.

This study seeks to answer critical questions pertinent to policymakers, healthcare practitioners, and disaster response teams, aiming to identify prevalent types of hospital disasters, their geographical distribution, and any shifts in their frequency or severity over time. The findings are intended to inform global policies and practices, ultimately enhancing hospital safety, and reinforcing healthcare infrastructure against potential disasters.

## 2. Materials and methods

### 2.1 Study design

This research employs a retrospective analysis to investigate the patterns and magnitudes of hospital disasters worldwide from 1976 to 2023. We utilized the EM-DAT database for its comprehensive documentation of significant disaster events. Its extensive range of disaster-related data, validated through a process involving multiple credible sources, aligns with our study’s objectives, ensuring the reliability and accuracy of our analysis.

### 2.2 Data collection

For our study, we utilized the EM-DAT database for the period from 1976 to 2023, focusing on hospital disasters. EM-DAT classifies these disasters into several categories, including collapses, explosions and fires. We specifically concentrated on incidents categorized under these three types, particularly those resulting in significant human casualties and property damage. This approach allowed us to examine the most impactful hospital disasters, as defined by the categorization standards of EM-DAT.

### 2.3 Scoring methodology for hospital disaster incidents

In categorizing hospital disasters into collapses, explosions and fires, we developed a scoring methodology to quantitatively assess the impact of each incident. This involved evaluating the scale of human casualties and property damage using predefined criteria. For instance, incidents were scored based on the number of fatalities, injuries, and the extent of infrastructure damage reported. Each disaster type was then classified according to these scores, allowing for a systematic comparison across categories and identification of the most severe incidents. This scoring process was crucial for filtering

the data to focus on the most impactful disasters, thereby ensuring our analysis addressed those events with significant implications for healthcare systems and emergency preparedness. For a detailed description of the scoring criteria and methodology, see **Supplementary material 1**.

## 2.4 Validation of EM-DAT as a study tool

To validate the EM-DAT database as a study tool, we reviewed its criteria for disaster inclusion, focusing on its comprehensive coverage of natural and man-made disasters affecting healthcare facilities. EM-DAT's inclusion criteria are based on a combination of factors, including the number of deaths, the number of affected individuals, and the declaration of a state of emergency. To ensure the accuracy and reliability of the data used in our analysis, we cross-verified selected EM-DAT entries against independent reports from governmental and non-governmental organizations, as well as academic studies focusing on similar incidents. This cross-verification process helped to confirm the consistency and comprehensiveness of the EM-DAT records, reinforcing the database's historical data integrity. Furthermore, the database's systematic approach to documenting and categorizing disasters provided a solid foundation for our retrospective analysis, enabling us to trace patterns and trends in hospital disasters with confidence.

## 2.5 Data preparation

Once extracted from EM-DAT, the data were transferred to a Microsoft Excel environment for organization and preliminary analysis. This step involved structuring the data into readable formats and performing a first audit to identify any inconsistencies or outliers. Where anomalies were found, we cross-referenced with other reliable data sources or made informed estimations to maintain data integrity.

## 2.6 Data analysis

In our study, we employed a two-tiered approach to data analysis to comprehensively understand the patterns of global hospital disasters. Initially, we utilized descriptive statistics to provide a foundational overview of the data. This involved summarizing the data in terms of frequency counts, percentages, measures of central tendency (mean, median), and measures of dispersion. These descriptive statistics offered a clear and straightforward depiction of the data, allowing us to establish basic patterns and trends in hospital disasters over the studied period.

Building upon this initial analysis, we then applied advanced statistical techniques to delve deeper into the data and uncover more intricate relationships and patterns. This included correlation analysis to explore potential relationships between different variables and frequency distribution analysis to understand the distribution and occurrence of hospital disaster types over time. By employing these advanced techniques, we could offer a more nuanced and detailed exploration of the data, going beyond basic descriptive insights.

Our data analysis, therefore, combined the simplicity and clarity of descriptive statistics with the depth and rigor of more advanced statistical methods. This dual approach enabled a

comprehensive understanding of the complex dynamics of hospital disasters, ensuring both accessibility and sophistication in our analysis.

## 2.7 Univariate analysis

During our study, we encountered several challenges, particularly in the standardization of data across different countries and periods. Discrepancies in reporting standards and the evolution of hospital safety protocols over time required careful consideration to ensure data comparability. To address these issues, we implemented normalization techniques and consulted historical records to contextualize the data within specific time frames and regional settings. This step was crucial in maintaining the integrity of our analysis and ensuring that the conclusions drawn were reflective of the true nature of hospital disasters globally.

## 3. Results

### 3.1 Types and distribution of hospital disasters

In analyzing hospital disasters from the EM-DAT database across the categories of collapses, explosions and fires, our findings reveal significant insights into the distribution and severity of these incidents. Notably, fire-related disasters emerged as the most prevalent, with a total of 1259 deaths across 25 countries, underscoring the substantial impact of these events on healthcare facilities and their capacity to manage emergencies. Our analysis indicates that the highest number of fire-related casualties occurred in countries with significant infrastructure challenges, such as Russia, India and the United States.

Our study delved into the unique challenges and consequences associated with each disaster type. For instance, collapses were often triggered by structural failures or natural disasters such as earthquakes, highlighting the need for stringent building codes and regular structural assessments in hospital design. Explosions frequently resulted from gas leaks or mishandling of hazardous materials, pointing to the critical importance of chemical safety protocols and regular safety drills. The prevalence and severity of fire-related incidents particularly call for an urgent review of fire safety standards in hospitals. These incidents not only caused high casualty rates but also indicated systemic vulnerabilities in emergency preparedness and response mechanisms. The repeated occurrence of such disasters suggests a global need to enhance fire safety protocols, including the installation of comprehensive fire detection and suppression systems and regular safety audits.

**Supplementary Fig. 1** provides a comprehensive comparative analysis of the different types of incidents depending on the country. This appendix allows for a focused narrative in the main text, which emphasizes the geographical variations and the impact of different disaster types on hospital safety and emergency preparedness.

This analysis not only helps to identify the most impactful types of hospital disasters but also serves as a basis for recommending changes in safety standards and handling protocols. By understanding the root causes of these incidents, healthcare

facilities can implement more targeted and effective measures to prevent future occurrences and mitigate their impacts. In light of these findings, it is imperative that hospital administrators and policymakers revise existing safety protocols and disaster response strategies. This revision should aim at bolstering hospital resilience against specific types of disasters, enhancing structural integrity, improving chemical safety, and upgrading fire safety measures to safeguard against the predominant risks identified in our study.

## 3.2 Geographical distribution

Russia emerges as a significant case, having experienced a disturbing frequency of hospital disasters. These incidents have led to considerable loss of life and property, highlighting the urgent need for enhanced safety measures and emergency preparedness. The nature and causes of these disasters in Russia offer valuable lessons for the global healthcare community.

Similarly, India's vast and varied healthcare system has been tested by numerous hospital disasters. The analysis of these incidents in India sheds light on the challenges faced in densely populated and resource-constrained settings, emphasizing the need for tailored safety protocols and robust disaster management strategies.

China and Iraq have also witnessed their share of hospital disasters. Each incident in these countries contributes to a growing understanding of the risk factors and effective mitigation strategies. These cases are particularly instructive for understanding how different cultural and infrastructural contexts influence the nature and impact of hospital disasters.

Contrasting these examples is the United States, which, despite its advanced healthcare infrastructure, is not immune to such calamities. The frequency and impact of hospital disasters in the USA offer a different perspective, especially in terms of established safety standards and emergency response mechanisms.

For a more detailed understanding of the historical trends and specific data on the frequency and casualties of hospital disasters in these countries, Table 1 in the article serves as an essential reference. This comprehensive table not only provides quantitative data but also aids in grasping the broader implications of these disasters on global healthcare safety.

## 3.3 Trends and patterns

### 3.3.1 Yearly analysis

A longitudinal examination of hospital disasters over the years sheds light on significant trends and patterns. This analysis reveals changes in the frequency of such incidents, providing insights into the evolving nature of hospital safety and risk factors. A key observation is the fluctuation in the number of disasters, which can be linked to various factors like advancements in safety protocols, changes in healthcare infrastructure, and external environmental factors.

The data suggests an evolving trend in the occurrence of these disasters. In some periods, there's a noticeable spike in incidents, while in others, a relative decline is observed. This fluctuation demands a deeper exploration to understand the underlying causes and to implement more effective preventive

measures.

To visually represent these trends, **Supplementary Fig. 2** has been created, mapping the frequency of hospital disasters from 1976 to 2023. This appendix provides a clear and immediate grasp of the temporal distribution and changes in the frequency of these incidents over the years. The peaks and troughs in the graph are indicative of the periods with higher and lower incident rates, respectively. Such a visual depiction not only enhances the understanding of these trends but also serves as a tool for identifying potential periods of increased risk and the effectiveness of implemented safety measures.

### 3.3.2 Impact analysis

The impact of hospital disasters transcends beyond immediate destruction, leaving behind a trail of human suffering and infrastructural damage. A comprehensive analysis of the casualties, including both deaths and injuries, is indispensable to grasp the extent of these calamities. Our study unveils the harsh reality of these events: a significant toll on human life, with thousands perishing and many more suffering injuries, alongside the devastating loss of healthcare infrastructure.

The data presents a clear differentiation in the human toll of these disasters, with variations observable across different regions and types of healthcare facilities. Such disparities underscore the critical influence of localized factors, including the robustness of hospital construction, the proficiency of emergency responses, and the rigidity of implemented safety protocols.

For a detailed account of the impact of hospital disasters, including specific data on deaths and injuries, Table 1 in the article is referenced. This table not only enumerates the casualties but also provides a contextual background, allowing for a comprehensive understanding of the consequences of these disasters.

Building upon the narrative of hospital disaster impacts, Table 2 presents a granular view of the frequency and severity of various disaster types. For instance, the table reveals that fire-related incidents, while being the most frequent type of hospital disaster, also account for the highest number of casualties, as seen in Russia. This aligns with our earlier observations on the oscillating nature of casualties over time and highlights the specific challenges posed by different disaster types.

In particular, the average casualties per incident, as shown in the table, provide critical insights into the lethality of each disaster type. For example, while explosions have occurred less frequently, their average casualties per incident are significantly high. This information is crucial for tailoring disaster response strategies to the specific risks associated with each type of disaster.

The analysis is further enriched by a detailed visual representation—Fig. 1 that chronicles the number of deaths and injuries from 1976 to 2023. This graph elucidates the oscillating nature of casualties over time, marking periods of intense loss and drawing attention to the grave human repercussions. Moreover, it underscores the necessity of steadfast advancements in preventive measures and safety standards to mitigate the impact of such disasters.

Through this examination, we recognize not only the importance of robust physical infrastructure but also the need



**TABLE 1. Historical analysis of hospitals' disasters.**

| Disaster Type                   | Country                               | Year | Sum of Total Deaths | Sum of No. Injured |
|---------------------------------|---------------------------------------|------|---------------------|--------------------|
| Collapse (Miscellaneous)        | India                                 | 1988 | 14                  | 50                 |
| Explosion (Miscellaneous)       | China                                 | 2006 | 33                  | 7                  |
|                                 | Myanmar                               | 2011 | 15                  | 65                 |
|                                 | North Macedonia                       | 2021 | 14                  | 47                 |
|                                 | Syrian Arab Republic                  | 2015 | 27                  | 30                 |
|                                 | Ukraine                               | 2010 | 16                  | 47                 |
| Explosion (Miscellaneous) Total |                                       |      | 105                 | 196                |
| Fire (Miscellaneous)            | Argentina                             | 1985 | 79                  | 247                |
|                                 | Azerbaijan                            | 2018 | 25                  | 4                  |
|                                 | Brazil                                | 2019 | 11                  | 77                 |
|                                 | Canada                                | 1976 | 21                  | 47                 |
|                                 | Canada                                | 1980 | 21                  | 35                 |
|                                 | Canada Total                          |      | 42                  | 82                 |
|                                 | China                                 | 2005 | 39                  | 24                 |
|                                 | China                                 | 2015 | 38                  | 6                  |
|                                 | China                                 | 2023 | 29                  | 39                 |
|                                 | China Total                           |      | 106                 | 69                 |
|                                 | Costa Rica                            | 2005 | 15                  | 47                 |
|                                 | Democratic People's Republic of Korea | 1993 | 34                  | 2                  |
|                                 | Ecuador                               | 2019 | 17                  | 12                 |
|                                 | Germany                               | 1995 | 0                   | 47                 |
|                                 | India                                 | 2001 | 25                  | 53                 |
|                                 | India                                 | 2011 | 89                  | 47                 |
|                                 | India                                 | 2016 | 21                  | 100                |
|                                 | India                                 | 2021 | 39                  | 142                |
|                                 | India Total                           |      | 174                 | 342                |
|                                 | Iraq                                  | 2005 | 14                  | 75                 |
|                                 | Iraq                                  | 2016 | 11                  | 47                 |
|                                 | Iraq                                  | 2021 | 174                 | 220                |
|                                 | Iraq Total                            |      | 199                 | 342                |
|                                 | Italy                                 | 1997 | 11                  | 47                 |
|                                 | Italy                                 | 2001 | 19                  | 7                  |
|                                 | Italy Total                           |      | 30                  | 54                 |
|                                 | Japan                                 | 2013 | 10                  | 47                 |
|                                 | Japan                                 | 2021 | 24                  | 3                  |
|                                 | Japan Total                           |      | 34                  | 50                 |
|                                 | Philippines                           | 1998 | 25                  | 100                |
|                                 | Poland                                | 1980 | 55                  | 47                 |
|                                 | Republic of Korea                     | 2014 | 21                  | 47                 |
|                                 | Republic of Korea                     | 2018 | 37                  | 130                |
|                                 | Republic of Korea Total               |      | 58                  | 177                |
|                                 | Romania                               | 2020 | 10                  | 7                  |

TABLE 1. Continued.

| Disaster Type                    | Country                             | Year | Sum of Total Deaths | Sum of No. Injured |
|----------------------------------|-------------------------------------|------|---------------------|--------------------|
|                                  |                                     | 1999 | 37                  | 15                 |
|                                  |                                     | 2006 | 42                  | 2                  |
|                                  | Russian Federation                  | 2009 | 23                  | 3                  |
|                                  |                                     | 2013 | 75                  | 94                 |
|                                  |                                     | 2015 | 23                  | 24                 |
|                                  |                                     | 2022 | 22                  | 6                  |
|                                  | Russian Federation Total            |      | 222                 | 144                |
|                                  | Saudi Arabia                        | 1996 | 13                  | 33                 |
|                                  |                                     | 2015 | 24                  | 123                |
|                                  | Saudi Arabia Total                  |      | 37                  | 156                |
|                                  | Senegal                             | 2022 | 11                  | 47                 |
|                                  | South Africa                        | 2011 | 22                  | 27                 |
|                                  | Taiwan                              | 2012 | 12                  | 60                 |
|                                  | Turkey                              | 2020 | 10                  | 47                 |
|                                  | United Kingdom and Northern Ireland | 1990 | 22                  | 94                 |
|                                  | United States of America            | 1976 | 20                  | 47                 |
|                                  |                                     | 2003 | 11                  | 20                 |
|                                  | United States of America Total      |      | 31                  | 67                 |
| Fire (Miscellaneous) Total       |                                     |      | 1281                | 2415               |
| Miscellaneous accident (General) | India                               | 2017 | 85                  | 47                 |
| Grand Total                      |                                     |      | 1366                | 2562               |

TABLE 2. Comprehensive overview of hospital disaster types since 1976.

| Disaster Type          | Number of Incidents | Total Casualties | Most Affected Country | Avg. Casualties/Incident | Frequency per year |
|------------------------|---------------------|------------------|-----------------------|--------------------------|--------------------|
| Collapse               | 1                   | 50               | IND                   | 50.0                     | 0.02               |
| Explosion              | 5                   | 196              | CHN                   | 39.2                     | 0.10               |
| Fire                   | 44                  | 1259             | RUS                   | 29.1                     | 0.98               |
| Miscellaneous accident | 1                   | 85               | IND                   | 85.0                     | 0.02               |

for comprehensive disaster management plans that prioritize human life and well-being. The data and trends call for an unwavering commitment to enhancing hospital safety and for an international dialogue on improving disaster readiness and response.

### 3.4 Case Studies of significant incidents

In our analysis of significant hospital disaster incidents, we delve into detailed examinations of specific cases, each offering unique insights into the nature of these disasters. These case studies not only illuminate individual events but also reflect the broader trends and patterns identified in our earlier analysis.

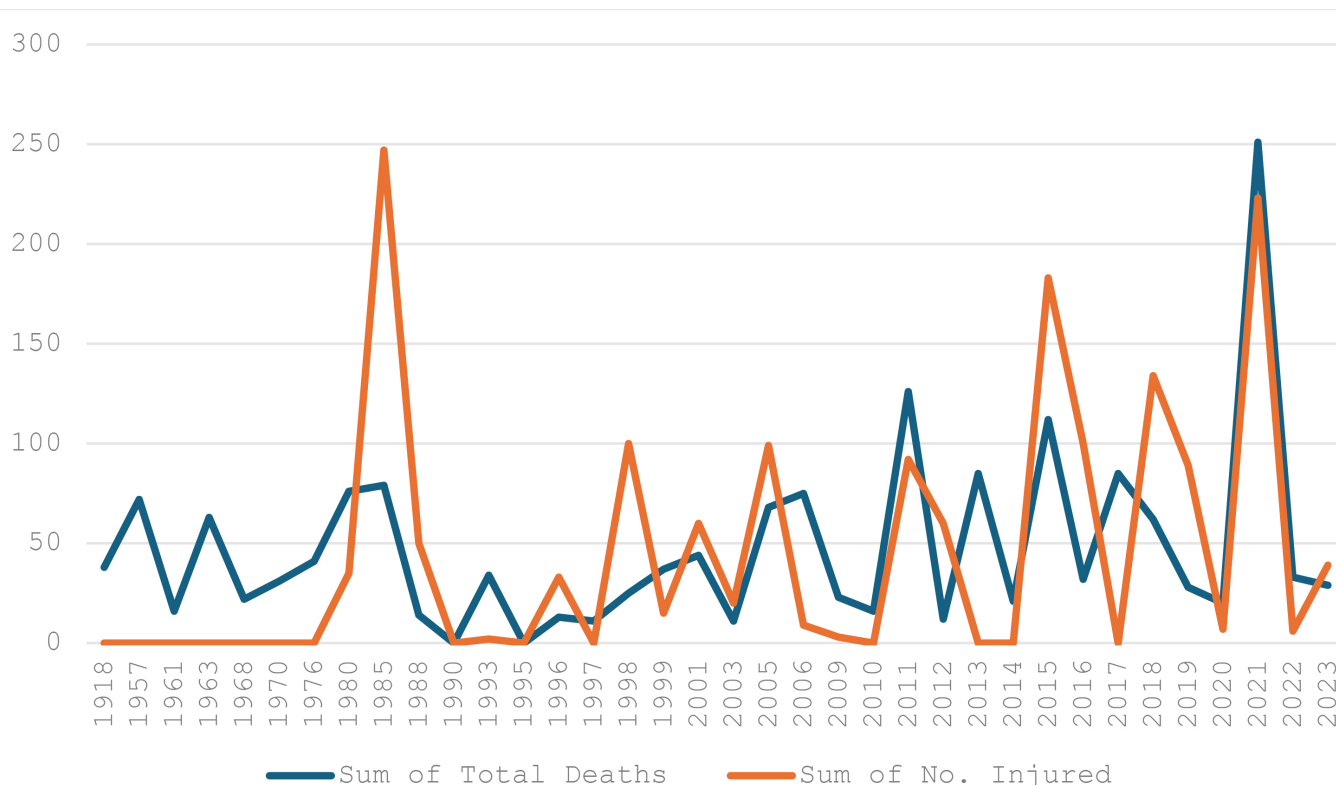
#### 3.4.1 Hospital fires in Russia

One notable area of concern is hospital fires in Russia. The country experienced a series of such incidents, with six major fires recorded in 1999, 2006, 2009, 2013, 2015 and 2022.

These fires collectively resulted in 222 deaths and 144 injuries. The recurrent nature of these fire-related disasters in Russian hospitals mirrors the global trend of increasing frequency and severity of hospital fires. This correlation suggests systemic issues in fire safety and emergency response protocols in Russia, echoing similar challenges observed in other parts of the world. It underlines the need for rigorous safety measures and regular reassessments of emergency preparedness, aligning with global calls for enhanced disaster management in healthcare settings [10].

#### 3.4.2 Hospital collapse in India, 1988

Another significant incident occurred in India in 1988, where a hospital collapse led to 14 deaths and 50 injuries. This event is indicative of the broader trend of structural vulnerabilities in hospital infrastructure, a concern that has been consistently highlighted in various global regions. It underscores the critical need for enhanced safety standards and regular maintenance protocols in such essential public buildings, especially



**FIGURE 1. Trends in hospital disaster casualties.**

in areas prone to natural disasters or burdened with aging infrastructure. This case study reinforces the global pattern of infrastructural risks in healthcare facilities and the imperative for proactive measures to address these vulnerabilities [11].

**3.4.3 Hospital fires in the United States**

In contrast, the United States presents a different narrative. Our analysis highlights significant hospital fires, particularly focusing on notable incidents in 1976 and 2003, which collectively resulted in a considerable number of deaths and injuries. The absence of major hospital fires post-2003 underscores the effectiveness of improved safety and disaster management measures in the U.S. This case study illustrates the positive impact of stringent safety regulations and proactive disaster management strategies, contributing to a decrease in hospital fire incidents and aligning with global trends towards enhanced healthcare safety standards [12].

**3.4.4 The 2021 Baghdad hospital fire**

The 2021 Baghdad hospital fire represents a critical incident in the landscape of hospital disasters, marked by devastating consequences. On the night of 24–25 April 2021, the Ibn al-Khatib hospital in Baghdad, Iraq, experienced a tragic fire, resulting in 82 deaths and 110 injuries. This incident was triggered by an explosion of oxygen tanks designated for COVID-19 patients, compounded by a lack of fire detection and suppression systems. The situation was dire, as many victims were COVID-19 patients, forcibly taken off ventilators in a desperate attempt to escape [13]. The hospital, serving a poor neighborhood and recently renovated for coronavirus patients, was ill-equipped for such a disaster.

The aftermath of the fire led to widespread public outcry, underscoring the consequences of negligence and systemic issues in healthcare safety and emergency response. The Iraqi government’s response, including suspending the Health Minister and initiating a rapid investigation, highlighted the urgent need for accountability and reform in healthcare safety standards. This case epitomizes the critical vulnerabilities in hospital infrastructure during times of crisis, such as a pandemic, and emphasizes the necessity of robust safety protocols and disaster preparedness in healthcare settings globally.

**3.4.5 Hospital fire in Saudi Arabia, 2015**

In 2015, a tragic fire in Jazan General Hospital, Saudi Arabia, stands as a notable case of hospital disasters. On 24 December 2015, a blaze in the hospital’s intensive care unit and maternity ward led to at least 24 deaths and 123 injuries. The fire, which broke out in the early hours, caused significant damage and panic. Initial reports indicated the fire might have been electrical in nature and spread rapidly, engulfing the hospital [14].

The response to the fire involved at least 20 brigades from the civil defense directorate. The incident prompted an investigation to determine the cause and raised critical questions about safety standards in healthcare facilities. It also led to widespread criticism of the hospital’s management and the broader healthcare system in Saudi Arabia, particularly regarding fire safety protocols and emergency response preparedness. This case highlights the importance of robust fire safety measures and the need for continuous evaluation and improvement of disaster management strategies in healthcare settings.

## 4. Discussion

The findings from our comprehensive analysis of hospital disasters from 1976 to 2023 open a window into the complex and evolving nature of these catastrophes. The stark increase in the frequency and severity of hospital disasters, particularly fires, demands urgent attention and action. This pattern, observed globally, is especially pronounced in countries like Russia, where systemic issues in fire safety protocols appear prevalent. These findings echo the concerns raised by many studies that stress the necessity of stringent safety standards in healthcare facilities [15–23].

Advancements in technology and innovation play a crucial role in enhancing hospital disaster management. The integration of sophisticated fire alarm systems, automated sprinklers, and state-of-the-art emergency response equipment has shown promising results in mitigating the impact of fires, as highlighted by Diaz *et al.* [24]. These technological solutions, coupled with comprehensive training programs for hospital staff, are vital for ensuring a rapid and effective response to disasters. The disparity in technological adoption across countries, as observed in our study, calls for a global initiative to bridge this gap, ensuring all healthcare facilities are equipped with the necessary tools to handle emergencies. However, their dependence on electricity, mobile net, internet, *etc.*, should be well addressed.

The effectiveness of technological advancements in disaster management has highlighted the significant impact of modern safety systems in reducing hospital fire incidents [25]. However, their study also points to the gap in technology adoption between developed and developing countries, a concern that our study corroborates. This emphasizes the need for a more equitable distribution of resources and knowledge to ensure that hospitals worldwide can benefit from these advancements.

Contrastingly, the United States presents a narrative of progress and adaptation. The decline in hospital fires post-2003 reflects the effective implementation of improved safety and disaster management measures, resonating with the conclusions drawn by Kahn *et al.* [26] regarding the success of such interventions in developed countries. This dichotomy between the situations in Russia and the United States underscores the disparity in healthcare safety standards across different geographical regions, a topic explored in depth by Shartova *et al.* [27]. Their work emphasizes the importance of region-specific disaster preparedness strategies, reinforcing the findings of our study.

The stark disparity in healthcare safety standards across different regions, as highlighted in our analysis, underscores a significant challenge in global health equity. This gap is not just a matter of resource availability but also involves equitable access to knowledge and best practices in disaster management. Studies like those conducted by Wagner *et al.* [28] have shown that implementing standardized safety protocols and providing access to advanced disaster management resources can significantly reduce the incidence of hospital disasters, especially in resource-limited settings. Therefore, enhancing global health equity in disaster preparedness must be a priority, ensuring that all countries, regardless of their economic status, have access to the tools and knowledge needed to protect their

healthcare facilities.

Community awareness and preparedness are also pivotal in mitigating the impact of hospital disasters. As argued by Madrigano *et al.* [29], community-based disaster preparedness programs can significantly enhance the overall resilience of healthcare facilities. These programs involve training local residents in basic fire safety and emergency response techniques, thereby creating a more informed and prepared community that can assist in times of crisis. This approach not only helps in immediate response but also fosters a culture of safety and preparedness, crucial for long-term disaster management.

The role of community engagement in enhancing the resilience of healthcare facilities against disasters is pivotal, as our study and others have found. For instance, Akbari *et al.* [30] observed that in regions where community involvement in disaster preparedness was high, the impact of hospital disasters was significantly mitigated. This aligns with our findings, suggesting that empowering local communities through education and training can be a powerful tool in disaster management. It highlights the need for culturally sensitive and locally informed approaches to community engagement, ensuring that disaster preparedness programs are effectively integrated into the local context.

The practical purpose of this study extends beyond academic inquiry. It seeks to directly inform and enhance disaster preparedness and safety protocols within healthcare facilities. By identifying prevalent types of hospital disasters and analyzing their geographical distribution and temporal trends, our findings aim to guide policymakers, healthcare practitioners, and disaster response teams in developing targeted strategies to bolster hospital safety and resilience. Ultimately, the study contributes to a global effort to reinforce healthcare infrastructure against the potential devastation of future disasters, ensuring that hospitals can continue to serve their communities even in the face of unprecedented challenges.

The grim reminder of the hospital collapse in India in 1988 brings to the fore the issue of structural vulnerabilities [31]. This case highlights the urgent need for resilient healthcare infrastructure, particularly in regions susceptible to natural disasters or burdened by aging buildings. The critical importance of robust infrastructure in healthcare facilities is further underscored in the work of AlDulijand *et al.* [32], who advocate for disaster preparedness in the face of climate change and other environmental challenges.

Reflecting on the historical trajectory of hospital disasters, it becomes evident that learning from past incidents is pivotal for building a resilient future. The backward-looking examination of these incidents, as recommended by numerous scholars, provides critical insights for strengthening the robustness of healthcare systems in the face of upcoming challenges [33–35].

The role of government and policymakers in shaping hospital disaster preparedness cannot be overstated. Legislative frameworks and policies play a critical role in enforcing safety standards and ensuring regular audits of healthcare facilities, as suggested by Epping-Jordan *et al.* [36]. Governments must prioritize funding and resources towards disaster resilience, especially in regions with high risks or outdated infrastructure. Moreover, international collaboration and sharing of best



practices can facilitate the development of more effective and universally applicable disaster management strategies.

The critical role of government and policy intervention in enhancing hospital disaster preparedness, as underscored in our study, aligns with the findings of Wilfond [37]. They emphasize the effectiveness of policy-driven initiatives in improving hospital safety standards, particularly in the context of developing countries. Our study extends this perspective by suggesting the need for international collaboration in policy formulation and implementation, ensuring a more unified and effective approach to hospital disaster management on a global scale.

The significant role of policymakers and government interventions in shaping hospital disaster preparedness, as emphasized in our study, finds resonance in the broader research landscape. For example, the work of Kabrah *et al.* [38] highlights how policy initiatives can lead to substantial improvements in hospital safety protocols, especially when they are backed by adequate funding and political commitment. These studies reinforce our suggestion that a collaborative approach to policy formulation, involving international agencies, can lead to more comprehensive and effective disaster management strategies. Such collaborative efforts could focus on standardizing safety protocols, sharing best practices, and ensuring that all regions, particularly those prone to disasters, have the necessary support and resources.

Building on these insights, specific recommendations emerge as pivotal for advancing hospital disaster preparedness. Firstly, the establishment of a global standard for fire safety in healthcare facilities, inspired by successful models in countries like the United States, could be a game-changer [39]. This standard would encompass not only the technological aspects but also the structural integrity and staff training components. Secondly, a global fund dedicated to supporting disaster resilience in healthcare facilities, particularly in low-resource settings, could address the disparity in technological and infrastructural adoption. Such initiatives, as recommended by the WHO [40–42], could significantly elevate the preparedness and response capabilities of hospitals worldwide.

Additionally, the psychological impact of hospital disasters on survivors, healthcare workers, and the community at large is an often-overlooked aspect that needs urgent attention. The trauma associated with such events can have long-lasting effects, as indicated by the work of Shakespeare-Finch *et al.* [43]. There is a pressing need for mental health support mechanisms and counseling services as part of the disaster response framework. Addressing the mental health repercussions is vital for the holistic recovery of affected individuals and for maintaining the morale and effectiveness of healthcare professionals in the aftermath of such tragedies.

Looking forward, several avenues for future research have been identified. There is a need to explore the long-term psychological impact of hospital disasters on healthcare workers and patients, a relatively uncharted domain that could yield crucial insights for post-disaster recovery strategies. Additionally, research into the effectiveness of different disaster preparedness training programs for hospital staff could inform best practices in this area. Further, studies assessing the impact of climate change on the frequency and severity of hospital

disasters could provide valuable data for future-proofing our healthcare facilities against environmental threats.

These avenues for further investigation, highlighted during the 2023 World Association for Disaster and Emergency Medicine (WADEM) Conference, are essential for broadening our knowledge and improving our proficiency in handling hospital disasters [44].

Comparatively, our findings resonate with global research that underscores the increasing trend of hospital disasters, particularly emphasizing the critical role of fire-related incidents. Studies by Salleh and Salim highlight similar observations regarding the prevalence of fire incidents in healthcare facilities and their devastating impact on hospital operations and patient safety [45]. These studies, like ours, advocate for a paradigm shift towards more robust disaster preparedness and mitigation strategies, further emphasizing the importance of integrating modern technological solutions and community engagement in disaster response protocols.

Furthermore, our analysis on the effectiveness of disaster preparedness measures aligns with the insights provided by Goniewicz *et al.* [46], who demonstrated the positive outcomes of comprehensive training programs and safety protocol implementations in reducing disaster impact. Their findings, along with our study, underscore the disparity in disaster management capabilities across different regions, echoing the urgent need for international collaboration to bridge this gap. The consensus among these studies showcases a critical global challenge that demands concerted efforts for improvement, reinforcing our call for enhanced safety standards and preparedness in healthcare facilities worldwide.

The findings from this study highlight the imperative for ongoing improvements in hospital safety standards and disaster preparedness strategies. The diversity in challenges and responses across different regions underscores the need for tailored approaches, informed by both historical data and current research. The path forward must involve collective action and a commitment to learning from past experiences to forge more resilient healthcare systems globally.

## 5. Limitations

This study, while providing a comprehensive retrospective analysis of hospital disasters worldwide from 1976 to 2023, encounters several limitations that merit consideration. The primary data source, the EM-DAT, offers an extensive dataset but also presents challenges in data standardization and reporting consistency across different countries and periods. These challenges arise from variations in hospital safety protocols and disaster reporting mechanisms, which could impact the comparability and uniformity of the data.

Another limitation arises from the geographical coverage and data availability within the EM-DAT database. While EM-DAT is comprehensive, there are disparities in the quality and quantity of data reported from different regions. Factors such as political stability, economic resources, and the presence of local data collection agencies can significantly affect the availability and accuracy of disaster reports. This uneven geographical coverage might have influenced our analysis, potentially leading to an underrepresentation of hospital dis-

asters in regions where data reporting mechanisms are less developed.

The study also acknowledges limitations due to temporal changes in reporting standards. Over the years, enhancements in disaster awareness, improvements in healthcare infrastructure, and the advent of more rigorous disaster management protocols have likely influenced the reporting and categorization of hospital disasters. These evolving standards may affect the longitudinal analysis of disaster trends, introducing challenges in directly comparing data across different time periods.

Potential biases in data reporting within the EM-DAT database also present a limitation. The database may exhibit a bias towards more severe or newsworthy disasters, possibly overlooking smaller-scale incidents that nonetheless have significant implications for local healthcare systems. This selection bias could skew the perceived magnitude and nature of hospital disasters, affecting the study's conclusions about their global impact and trends.

Lastly, the study's reliance on the categorization of disasters as provided by EM-DAT could limit the analysis. The categorization process may simplify the complex nature of some incidents, which could straddle the boundaries between defined disaster types. This simplification might obscure nuanced insights into the specific characteristics and impacts of certain disasters, impacting the depth and specificity of our findings.

The methodological approach, focusing on univariate analysis, allowed for a detailed examination of each disaster type. However, this approach may limit the scope of understanding complex interrelations and multifaceted impacts of hospital disasters. The study's emphasis on major disasters with substantial human casualties and property damage may inadvertently overlook smaller incidents. These smaller incidents, while individually less impactful, could collectively offer significant insights into the evolving nature of hospital safety and disaster preparedness.

The data preparation and preliminary analysis, conducted within a Microsoft Excel environment, involved necessary normalization techniques and cross-referencing with other data sources to address inconsistencies or outliers. While these steps were vital for maintaining data integrity, they also highlight the inherent challenges in dealing with historical data and diverse information sources.

## 6. Conclusions

Our analysis from 1976 to 2023 indicates a significant increase in the frequency and severity of hospital disasters, especially fires, emphasizing the urgent need for enhanced safety standards and preparedness worldwide. Notably, the contrast between the systemic fire safety issues observed in Russia and the effective disaster management strategies in the United States highlights the global disparity in healthcare safety standards. This underscores the importance of adopting region-specific disaster preparedness approaches.

Community involvement and improved preparedness are essential for enhancing the resilience of healthcare facilities. Effective disaster management practices informed by our findings can aid healthcare administrators in implementing robust

safety protocols, assist policymakers in developing targeted legislation, and enhance training programs for emergency response personnel. Such measures are crucial to make hospitals more resilient and capable of safeguarding patients and healthcare workers against future disasters.

This study serves as a valuable reference for developing global strategies to bolster hospital safety and resilience. Future research should focus on leveraging advanced predictive analytics and Artificial intelligence (AI) to enhance disaster responses, examining the psychological impacts on affected individuals, and assessing the role of climate change in influencing hospital disaster trends.

## AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## AUTHOR CONTRIBUTIONS

ZAM—conceptualization, methodology, investigation, data curation, visualization. HA—validation, formal analysis. ZAM and KG—writing—original draft preparation. AKM and KG—writing—review and editing. KG—supervision. All authors have read and agreed to the final version of the manuscript.

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest. Krzysztof Goniewicz is serving as one of the Guest editors of this journal. We declare that Krzysztof Goniewicz had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to TK.

## SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at <https://oss.signavitae>.

[com/mre-signavitae/article/1816739021807599616/attachment/Supplementary%20material.zip](https://com/mre-signavitae/article/1816739021807599616/attachment/Supplementary%20material.zip)

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