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Assessment of Early Warning Systems for Emergencies and Disasters in Hospitals of Mazandaran, Iran, in 2024: A Cross-Sectional Study

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ABSTRACT

Objective: This study aimed to assess the status of early warning systems (EWS) for disaster and emergency response in hospitals affiliated with Mazandaran University of Medical Sciences in 2024.
Methods: This descriptive-analytical study was conducted from April to December 2024 across all affiliated hospitals with Mazandaran University of Medical Sciences. Data were collected using a validated 55-item EWS checklist evaluating preparedness in both pre-incident and during-incident phases. Overall hospital preparedness was categorized as good (≥75%), moderate (50–74%), or poor (<50%).
Results: In the pre-incident phase, 28 out of 32 hospitals (87.5%) demonstrated good preparedness score (mean±SD: 74.8±12.1). During the incident phase, overall preparedness declined, with only 25 hospitals (78.1%) classified as good (mean±SD: 61.7±14.9). Based on total performance scores, Hospital No. 29 and 30 ranked the highest, while Hospital No. 4 demonstrated the weakest overall preparedness across both phases.
Conclusion: While most hospitals exhibited adequate preparedness in key EWS components, such as warning dissemination and response readiness, notable weaknesses were identified in hazard identification, hazard monitoring, and documentation. Strengthening targeted training programs, establishing integrated monitoring systems, and conducting regular simulation exercises are essential for enhancing operational effectiveness.

Keywords: Early warning system; Emergencies; Disasters; Hospital preparedness; Disaster management.

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Introduction

In recent decades, the world has increasingly confronted diverse hazards that threaten both material and human resources [1]. Disasters and emergencies, defined as incidents that disrupt daily life and surpass local response capabilities [2], pose a significant challenge. Iran, a developing nation, is among the world's most disaster-prone countries. It ranks within the top 10 countries most affected by natural hazards, with approximately 90% of its population exposed to these risks. In addition to recurrent floods, local storms, and minor earthquakes, the country has experienced at least one major national catastrophe per decade [3].

Globally, disaster management efforts in prone countries are guided by the motto "Preparedness for Unforeseen Events" [4]. Rapid access to healthcare is essential for survival during such events [5]. Nonetheless, hospitals frequently experience delays in achieving full prepared and in mounting an effective response, primarily due to financial constraints and an insufficient recognition of their crucial role in disaster management [4].

"Response time" is a critical factor in reducing the irreversible consequences for disaster victims [5]. Hospitals, as fixed, specialized healthcare facilities, constitute the cornerstone of an effective disaster response—but only if they are adequately prepared to function under crisis conditions. Without pre-established plans, operational disorder and confusion are inevitable [6].

According to the United Nations International Strategy for Disaster Reduction, an Early Warning System (EWS) delivers timely and practical information through designated authorities, enabling at-risk individuals to take preventive or mitigativeactions againsthazards and to prepare for an effective response [7]. An EWS is designed to identify imminent hazards and to communicate clear, precise, and unambiguous signals that ensure an appropriate disaster response [8]. Implementing an effective EWS can significantly reduce vulnerability, mortality, and economic losses, thereby strengthening community resilience. Moreover, adopting optimized frameworks and models that incorporate the most effective EWS components can further reduce disaster risks and enhance operational performance [9].

In healthcare settings, EWS are crucial for eliminating confusion, preventing uncoordinated actions, shortening response times, and minimizing the impact of incidents. These systems are applicable to hospitals of all sizes and care capacities. A unified, all-hazards EWS approach facilitates integrated planning and response across a wide range of risks [4].

Given the rising frequency of emergencies and natural disasters worldwide, the implementation of EWS is recognized as a critical components of disaster risk management [9]. Building effective EWS frameworks—supported by adequate preparedness and well-structured national and local response plans—has become an urgent necessity, particularly in light of concurrent global challenges such as the COVID-19 pandemic and climate change [10, 11].

Despite the established importance of EWS for hospital disaster preparedness and its prioritization in healthcare system policies, few studies have assessed its operational status and the barriers to its implementation in hospitals affiliated with Mazandaran University of Medical Sciences (MUMS) [12, 13] . Accordingly, this study aimed to evaluate the current status of EWS for emergency and disaster response across all affiliated with MUMS. The evaluation was conducted from April to December 2024.

Materials and Methods

This descriptive-analytical study was conducted between April and December in 2024 to evaluate the performance of the EWS in hospitals affiliated with Mazandaran University of Medical Sciences (MUMS). The study assessed preparedness in the pre-incident and during-incident phases using a standardized, validated cheklist specifically developed for hospital EWS evaluation.

All hospitals officially affiliated with MUMS were included in the study. This comprised a total of 32 hospitals: 24 public (75%), 3 private (9.4%), and 5 affiliated with the Social Security Organization (15.6%). At each hospital, the crisis-management committee and designated EWS focal points served as the primary respondents for completing the cheklist.

Inclusion criteria included: 1) official affiliation with MUMS; 2) the presence of an active disaster risk-management or crisis-management committee; and 3) willingness to participate in both pre-incident and during the incident assessments.

Hospitals lacking documented disaster-management plans, those that failed to complete both phases of data collection, and centers undergoing restructuring or temporary closure during the study period were excluded.

The early warning system evaluation checklist was developed based on international EWS frameworks, national disaster management guidelines, and findings from a prior qualitative study conducted in Iran [14].

The instrument for assessing the status of the EWS consisted of 55 items covering the following domains:

A. Pre-incident phase

1. Hazard identification (items 1-6)
2. Hazard monitoring (items 7-9)
3. Warning dissemination (items 17-21)
4. Response preparedness (items 22-30)

B. During incident phase

5. Warning dissemination (items 1-11)
6. Response preparedness (items 12-25)

Each checklist item was rated on a three-point scale: low (1 point), moderate (2 points) and high (3 points). Based on the evaluators' judgment, the low option was assigned 1 point, the moderate option 2 points, and the high option 3 points.

For the pre-incident phase, the total score ranged from 30 to 90, categorized as follows: 30–45=poor**,** 46–60=moderate and 61-90=good.

The during-incident phase evaluated the EWS based on documented evidence from previous hospital incidents. In this phase, the cheklist consisted of 25 items, with a total score range of 25-75: 25-35=poor, 36-50=moderate, and 51-75=good.

An overall final percentage score was also calculated and classified as: good: ≥75%; moderate: 50–74% and weak: <50%.

Hospital rankings were generated for both phases to facilitate performance across facilities.

Face Validity: Established through a review by 10 experts from the Emergency Operations Center (EOC). They evaluated the checklist for readability, clarity, transparency, ease of comprehension, appropriateness of response categories, ease of completion, and grammatical correctness [15].

Content Validity: Quantitative content validity was assessed using the content validity ratio (CVR) and content validity index (CVI) [16].

CVR: Fifteen disaster and emergency health specialists rated the necessity of each item on a 3-point scale, including (1) not necessary, (2) useful but not necessary, and (3) necessary. The purpose of CVR is to ensure that the most important and relevant items are retained. Using Lawshe's method [17], a CVR value greater than 0.49 (for 15 raters) indicatesitem necessity ($p < 0.05$). In this study, the calculated CVR was 0.99, demonstrating excellent content validity by Lawshe's criterion.

CVI: Five PhD students in Disaster and Emergency Health evaluated each item for simplicity, relevance, and clarity on a 4-point Likert scale (1=not relevant, 4=highly relevant) [18]. The resulting CVI score was 0.86, which is considered acceptable..

Reliability: Internal consistency was evaluated using Cronbach's alpha coefficient. The checklist was administered twice to six members of the a hospital crisis management committee with a two-week interval between the assessments. nalysis in SPSS yielded a Cronbach's alpha of 0.83, indicating strong level of reliability.

Table 1. Status of EWS assessment domains in the pre-incident phase in hospitals

Hospital Type	Hospital	Hazard Identification	Hazard Monitoring	Warning Dissemination	Response Preparedness	Total Preparedness (Pre-Incident phase)
Academic	1	14	12	20	15	61
Academic	2	17	14	22	25	78
Academic	3	17	18	22	15	72
Academic	4	8	7	9	9	33
Academic	5	15	18	18	21	72
Academic	6	17	18	21	24	80
Academic	7	14	12	19	16	61
Academic	8	16	14	20	26	76
Academic	9	15	17	23	25	80
Academic	10	17	17	25	22	81
Academic	11	17	14	20	19	70
Academic	12	16	18	26	22	82
Academic	13	16	17	21	23	77
Academic	14	15	17	22	21	75
Academic	15	16	14	19	16	65
Academic	16	16	15	21	23	75
Academic	17	13	10	14	16	53
Academic	18	10	8	16	14	48
Academic	19	18	18	25	27	88
Academic	20	16	18	25	21	80
Academic	21	11	15	21	16	63
Academic	22	18	17	21	21	77
Academic	23	17	18	26	25	86
Academic	24	9	16	15	15	55
(Tamin [Social Security])	25	18	18	27	27	90
(Tamin [Social Security])	26	15	17	24	25	81
(Tamin [Social Security])	27	15	14	20	17	66
(Tamin [Social Security])	28	17	15	18	25	75
(Tamin [Social Security])	29	18	17	24	26	85
Private	30	17	17	26	22	82
Private	31	16	17	22	21	76
Private	32	18	18	27	27	90

A scenario simulating a 5.6-magnitude earthquake near Sari was used. Key elements included: structural damage to nearby facilities, a mass-casualty influx, partial communication failure, temporary disruptions, and the activation of hospital surge-capacity protocols.

Statistical Analysis

Data were analyzed using SPSS version 22. Descriptive statistics (mean, SD, percentage) were used to summarize the preparedness levels. The Kolmogorov–Smirnov test indicated non-normal data distribution. Therefore, non-parametric tests (Kruskal–Wallis and Mann–Whitney U) were applied. The Friedman test was used to rank the hospitals based on calculated scores across sections [19].

Results

This study assessed the status of the EWS for disaster and emergency response in hospitals affiliated with MUMS. Table 1 reports the status scores for the pre-incidentEWS domains across the hospitals.

Table 2 presents the status scores for the EWS domains during the incident phase.

Table 3 compares the scores for different EWS domains across the pre-incident and during-incident phases by hospital type. The results indicated no statistically significant difference among the three hospital types— academic, social security, and private—across all domains ($p>0.05$).

Table 4 demonstrates the overall EWS performance classification. In the pre-incident phase, of the 32 hosptials, 1 (3.1%) hospital was classified as poor, 3 (9.4%) hospitals as moderate, and 28 (87.5%) hospitals as good. In the incident phase, 4 hospitals (12.5%) were rated as poor, 3 hospitals (9.4%) as moderate, and 25 hospitals (78.1%) as good. The frequency distribution of EWS status in both phases, stratified by hospital type, showed no statistically significant difference among the three types ($p>0.05$).

Table 5 provides an overview of the mean rankings for EWS capabilities by hospital type. Total scores for each hospital were evaluated for three scenarios: a combined pre- and during-incident score, a pre-incident score, and a during-incident score. Academic hospitals demonstrated higher mean rankings than Social Security (Tamin) and private hospitals. Hospital 23 had the highest combined score (16.96), indicating strong overall EWS implementation.

Table 2. Status score of EWS domains during the incident phase in the hospital

Hospital Type	Hospital	Warning Dissemination	Response Preparedness	Total Preparedness (During-Incident)
Academic	1	29	28	57
Academic	2	32	39	71
Academic	3	26	28	54
Academic	4	14	14	28
Academic	5	19	14	33
Academic	6	32	42	74
Academic	7	17	14	31
Academic	8	30	42	72
Academic	9	31	33	64
Academic	10	27	38	65
Academic	11	28	33	61
Academic	12	33	28	61
Academic	13	23	14	37
Academic	14	31	26	57
Academic	15	33	34	67
Academic	16	30	31	61
Academic	17	14	20	34
Academic	18	12	24	36
Academic	19	33	24	57
Academic	20	27	40	67
Academic	21	32	42	74
Academic	22	31	42	73
Academic	23	31	40	71
Academic	24	31	39	70
(Social Security)	25	33	42	75
(Social Security)	26	29	28	57
(Social Security)	27	27	20	47
(Social Security)	28	32	32	64
(Social Security)	29	30	39	69
Private	30	27	38	65
Private	31	26	38	64
Private	32	33	42	75

Table 3. Comparison of EWS domain scores in different phases by hospital type

Phase	Domain	Academic	(Tamin [Social Security])	Private	*p*-value
Pre-Incident Phase	Hazard Identification	14.92±2.80	17.20±0.84	16.00±1.73	0.19
	Hazard Monitoring	15.08±3.26	16.80±1.09	16.33±2.08	0.44
	Warning Dissemination	20.46±4.02	23.40±3.58	23.67±3.51	0.18
	Response Preparedness	19.87±4.67	24.20±2.59	23.00±5.29	0.11
	Total Preparedness (Pre-Incident)	70.33±13.19	81.60±6.27	79.00±12.12	0.13
During Incident Phase	Warning Dissemination	26.92±6.69	29.60±3.05	29.67±3.05	0.56
	Response Preparedness	30.37±9.91	37.80±3.63	30.00±11.13	0.27
	Total Preparedness (During Incident)	57.29±15.39	67.40±4.72	59.67±14.19	0.36

Table 4. Comparison of EWS domain levels in different phases by hospital type

Phase	Level	Academic	(Tamin [Social Security])	Private	*p*-value
Pre-Incident Phase	Poor	1 (4.2)	0	0	0.99
	Moderate	3 (12.5)	0	0	
	Good	20 (83.3)	5 (100)	3 (100)	
During Incident Phase	Poor	4 (16.7)	0	0	0.39
	Moderate	2 (8.3)	0	1 (33.3)	
	Good	18 (75.0)	5 (100)	2 (66.7)	

Table 5. Mean ranking of EWS domain levels in hospitals of Mazandaran Province by hospital type

Hospital Type	Hospital	Total Scores (Combined Pre- and Incident)	Total Scores (Pre-Incident)	Total Scores (During Incident)
Academic	1	10.4^{19}	9.8^{20}	11.23^{18}
	2	15.37^{7}	14.48^{9}	16.57^{6}
	3	12.37^{16}	13.03^{15}	11.45^{17}
	4	3.63^{24}	3.32^{24}	4.05^{24}
	5	10.15^{20}	13.18^{14}	6.02^{20}
	6	16.21^{2}	15.13^{7}	17.68^{2}
	7	7.7^{21}	9.92^{19}	4.68^{23}
	8	15.38^{6}	13.77^{11}	17.57^{4}
	9	15.09^{8}	15.23^{6}	14.89^{10}
	10	15.02^{9}	15.53^{4}	14.32^{11}
	11	12.43^{15}	12.05^{16}	12.95^{12}
	12	14.64^{10}	15.93^{3}	12.89^{13}
	13	10.43^{18}	14.22^{10}	5.27^{22}
	14	12.93^{14}	13.6^{12}	12.02^{16}
	15	13.2^{13}	10.92^{17}	16.32^{8}
	16	13.22^{12}	13.48^{13}	12.86^{14}
	17	6.36^{22}	7.03^{22}	5.43^{21}
	18	6.25^{23}	6.25^{23}	6.25^{19}
	19	15.44^{5}	17.63^{1}	12.45^{15}
	20	15.68^{4}	15.35^{5}	16.14^{9}
	21	13.63^{11}	10.38^{18}	18.07^{1}
	22	15.81^{3}	14.52^{8}	17.57^{3}
	23	16.96^{1}	17.1^{2}	16.77^{5}
	24	11.69^{17}	8.13^{21}	16.55^{7}
Tamin (Social Security)	25	2.67^{4}	2.62^{4}	2.73^{5}
	26	3.19^{2}	3.27^{2}	3.1^{2}
	27	2.9^{3}	3^{3}	2.77^{4}
	28	2.66^{5}	2.52^{5}	2.83^{3}
	29	3.58^{1}	3.6^{1}	3.56^{1}
Private	30	2.58^{1}	2.45^{1}	2.74^{1}
	31	1.95^{2}	2.03^{2}	1.84^{2}
	32	1.47^{3}	1.52^{3}	1.42^{3}

The numbers in the table are the mean ranks (ranks) for each hospital.

In contrast, Hospital 4 had the lowest score within the academic category during incidents (3.63), suggesting specific vulnerabilities in emergency situations.

Social Security (Tamin) hospitals had consistently low ranking, with Hospital 28 achieving the lowest rank (2.66), indicating a need for enhanced EWS capabilities, particularly in emergencies.

Private hospitals had the lowest overall rankings. Hospital 32 scored the lowest (1.47), suggesting that private facilities may be less equipped regarding EWS compared to academic and Social Security hospitals, highlighting a need for greater readiness and improved response systems.

Discussion

The EWS is an essential pillars of crisis management within healthcare systems, enabling the timely anticipation, detection, and coordinated response to potential hazards. By facilitating rapid information flow and enhancing organizational coordination, an effective EWS can reduce human and economic losses and accelerate the restoration of normal operations in healthcare facilities [13, 20]. Numerous international frameworks emphasize that an effective EWS design requires a robust technological infrastructure, trained personnel, rapid-response protocols, and well-defined communication pathways [21, 22].

Findings from the present study in Mazandaran Province revealed that overall hospital preparedness in the pre-incident phase was superior to preparedness during the incident phase. Consistent with the ranking results in Tables 5, academic hospitals demonstrated higher mean EWS performance compared to both Social Security (Tamin) and Private hospitals. For instance, Hospital 23 achieved the highest combined score (16.96), indicating a strong EWS implementation. In contrast, Hospital 28 records the lowest score within the academic category (2.96) during incidents, suggesting vulnerabilities in emergency situations.

Social Security (Tamin) hospitals showed consistently low rankings, with Hospital 28 achieving the lowest rank (2.66). These performance differences align with previous studies indicating that well-established communication pathways, functional Emergency Operations Centers (EOCs), and routine training significantly enhance EWS effectiveness [12]. Conversely, hospitals lacking dedicated hazard-monitoring mechanisms, documented risk analyses, or adequately trained crisis-management staff remain vulnerable to operational delays and inconsistent responses during emergencies.

Within specific components of the EWS, the domains of alert dissemination and response preparedness achieved the highest scores. This finding was consistent with the work of Delshad *et al.,* who highlighted that establishing a functional EOC and implementing targeted training can significantly improve emergency-response performance [23]. Similarly, our findings indicated that hospitals with active and well-trained crisis management committees demonstrated superior performance in these functional domains.

Despite variations in ownership and administrative structures, no statistically significant differences in overall EWS performance were observed among academic, private, and Social Security Organization hospitals. This contrasted with the findings of Zaboli *et al.,* [8] who noted that managerial and resource-related disparities could influence preparedness levels. A potential explanation for this uniformity might be the standardized accreditation requirements mandated by the Ministry of Health, which could have reduced structural disparities and promoted greater consistency across hospital types.

While the study by Maftoohian *et al.,* [24] focused on a clinical Modified Early Warning Score (MEWS) rather than an organizational system, their findings highlighted the value of structured and standardized alerting tools in improving response speed. Although clinical and organizational EWS serve different purposes, their integration—particularly during large-scale disasters—could support more coordinated and effective hospital-wide responses.

The deficiencies in hazard monitoring and documentation observed in the present study were consistent with the findings of Zaboli *et al.,* [8], who attributed such gaps to a lack of integrated reporting systems and standardized data-analysis mechanisms. Strengthening these processes is essential for enhancing early warning capability and ensuring timely, evidence-based decision-making.

Overall, while hospitals in Mazandaran Province have made measurable progress in establishing the foundational components of EWS, a significant gap remains between documented preparedness and real-world operational performance. International models, such as the World Health Organization (WHO) Hospital Emergency Response checklist [21] and the Sendai Framework for Disaster Risk Reduction [25], emphasizing the importance of continuous monitoring, multi-hazard surveillance, and simulation-based evaluation. These components are crucial for translating written plans into actual operational capability.

Prior studies—including Moradian *et al.,* [26] and Blashki *et al.,* [27]—underscored the importance of public education, timely warning dissemination, and preparedness training. These factors enable both healthcare providers and the community respond effectively to emergencies. Strengthening knowledge transfer, communication systems, and human resources is therefore essential for enhancing the feasibility and effectiveness of EWS.

A key strength of the present study was its comprehensive evaluation of more than 30 hospitals with diverse ownership structures, using a standardized and validated cheklist. This breadth

provides a reliable evidence base for provincial-level disaster-management policymaking. To close the implementation gap and improve operational performance, future efforts should prioritize regular simulation drills, upgrades to communication and information infrastructures, the development of digital warning dashboards, and periodic performance re-evaluations—ideally conducted every 6 months—to ensure sustained responsiveness and continuous system improvement.

This study had several limitations. First, the performance of EWS was assessed via an observational cheklist and self-reported data from hospital crisis managers; it was not tested for operational effectiveness during an actual crisis. Second, the research was confined to a single province, which might limit the generalizability of the findings to other regions. Finally, the evaluation did not assess certain managerial and structural factors, such as the experience of crisis managers, the number of trained staff, and the technical availability of communication systems, which could influence preparedness.

The findings of this study demonstrated that while most hospitals in Mazandaran Province have established the basic structural components of an EWS, a substantial gap persists between documented preparedness and actual operational capability. Strengths were observed in alert dissemination and response readiness, reflecting progress in foundational disaster-preparedness efforts. However, persistent deficiencies in hazard identification, hazard monitoring, and systematic documentation reveal critical weaknesses that may limit the overall effectiveness of hospital response during emergencies.

Bridging this gap requires transitioning from predominantly paperwork-based preparedness to functional, drill-tested, and technology-supported systems. Regular simulation exercises, enhanced training for crisis-management teams, the establishment of integrated monitoring platforms, and improvements in interdepartmental communication pathways are essential steps to strengthen real-world performance.

Given the province's vulnerability to natural and technological hazards, investing in robust, integrated, and continuously updated early warning mechanisms is not only necessary but also urgent. Such advancements would improve provincial readiness and could also serve as a replicable model for strengthening EWS implementation in other regions of Iran.

Declaration

Ethics approval and consent to participate: This study was conducted in accordance with the principles of the revised Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Mazandaran University of Medical Sciences (Approval ID: IR.MAZUMS.REC.1402.421). Participation from all hospitals was coordinated through official correspondence, and institutional consent was obtained from the designated authorities.

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