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Strengthening Health Security in Hospitals to Confront Epidemics and Public Health Emergencies- A comprehensive, integrated framework for preparedness, response, and resilience

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1Health Security, Asir Health Cluster
2Health security, Asir Health Cluster
3Health Security, Asir Health Cluster
4Health security, Asir Health Cluster
5Health Security, Jeddah Second Health Cluster
6Health Assistant, Health Security, Asir Health Complex
7Health Assistant, Health Security, Asir Health Complex
8Health security, Madinah health cluster

Abstract

Epidemics and public health emergencies repeatedly test the limits of hospital systems, exposing gaps in infection prevention and control, surge capacity, workforce protection, logistics, and governance. Hospitals are not only sites of care but also potential amplifiers of transmission when preparedness is weak. This scientific paper synthesizes international guidance and peer-reviewed evidence to propose an integrated hospital health security framework for preventing, detecting, and responding to epidemics while maintaining essential services. Key domains include infection prevention and control (IPC), surveillance and early warning, workforce safety and well-being, operational readiness and incident management, supply chain resilience, infrastructure and engineering controls, clinical pathways for high-consequence infections, risk communication, and digital and cyber resilience. The paper highlights practical implementation steps—governance structures, readiness assessments, training and drills, performance indicators, and continuous improvement cycles—aimed at strengthening hospital resilience before, during, and after health emergencies.

Keywords- Health security; hospitals; epidemics; public health emergencies; pandemic preparedness; infection prevention and control; surge capacity; hospital resilience; incident management.

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1. Introduction

Hospitals sit at the center of epidemic response. They provide diagnosis, isolation, clinical management, and supportive care, while also serving as sentinel sites for early detection of unusual clusters of illness. During large outbreaks, hospitals must scale up capacity rapidly, protect staff from occupational exposure, and maintain continuity of essential services such as emergency surgery, obstetric care, dialysis, and oncology. When these functions falter, avoidable morbidity and mortality rise—not only from the epidemic pathogen but also from disruptions to routine care.

Recent experience has reinforced a critical lesson: preparedness cannot be improvised during a crisis. Epidemics are characterized by uncertainty, rapid change, and cascading operational pressures. Shortages of personal protective equipment (PPE), oxygen, medicines, and trained staff can occur simultaneously. Hospitals may face sudden surges in patient volume and the need to redesign workflows (triage, zoning, cohorting, and visitor policies) within days. If a hospital's systems for infection prevention and control (IPC) and operational readiness are not mature, the facility may become a locus of transmission among patients, visitors, and healthcare workers.

Health security in hospitals refers to the capacity to prevent, detect, and respond effectively to health threats while protecting patients, healthcare workers, and healthcare infrastructure. It is a multidimensional concept that integrates IPC, occupational health, emergency management, engineering and environmental controls, supply chain and logistics, information systems, and governance. This paper provides an integrated, practical framework for strengthening hospital health security to confront epidemics and public health emergencies, with emphasis on implementable actions, measurable indicators, and continuous improvement.

2. Aim, Objectives, and Scope

The aim of this paper is to describe evidence-informed strategies that strengthen health security in hospitals for epidemic and public health emergency response. The specific objectives are to: (1) define the core domains of hospital health security relevant to epidemics; (2) summarize international guidance and best practices for hospital preparedness and readiness; (3) propose an integrated framework that links clinical, operational, and infrastructure measures; and (4) offer a practical implementation roadmap with monitoring indicators.

The scope of this paper focuses on acute care hospitals and large health facilities that deliver inpatient and emergency services. The primary hazard class is communicable disease outbreaks (e.g., influenza, coronavirus infections, measles, mpox, viral hemorrhagic fevers, and other emerging pathogens). However, the framework also applies to broader public

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health emergencies that disrupt healthcare operations, including mass casualty events with infectious components, disruptions to utilities, and compounded crises (e.g., an outbreak following flooding).

This paper does not provide disease-specific clinical guidelines for any single pathogen. Instead, it emphasizes capabilities and systems that are adaptable across different epidemic scenarios, and that align with international concepts of preparedness, readiness, and response. The paper is intended for hospital leaders, infection control professionals, emergency preparedness coordinators, quality and patient safety teams, and policymakers responsible for healthcare facility readiness.

3. Methodology

A narrative (non-systematic) review methodology was used to synthesize evidence and guidance relevant to hospital epidemic preparedness and health security. Sources included international public health guidance, hospital readiness assessment tools, and infection prevention guidance for healthcare settings. Particular attention was given to documents designed to operationalize preparedness (e.g., checklists, catalogues of guidance and training tools, and core infection control practices).

The analysis proceeded in three steps. First, key domains of hospital health security were identified from global guidance and emergency preparedness literature. Second, recommended actions within each domain were extracted and organized into "before, during, and after" phases of a health emergency. Third, the paper integrated these actions into a practical framework including governance structures, implementation steps, and indicators for monitoring readiness and performance.

Because the review is narrative, it prioritizes clarity and applicability over exhaustive coverage of all possible sources. The recommended framework is designed to be adaptable to local context, hospital size, and resource availability, while remaining aligned with widely accepted standards and guidance.

4. Threat Landscape and Risk Assessment in Hospitals

Hospitals face a dynamic threat landscape during epidemics. Biological risks include respiratory pathogens that spread via droplets and aerosols, contact-transmitted infections, and high-consequence pathogens requiring specialized isolation and handling procedures. Non-biological risks—such as supply chain disruption, misinformation, and cyberattacks—can amplify the impact of an outbreak by interrupting care delivery and undermining trust.

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A foundational preparedness activity is an all-hazards risk assessment tailored to facility context. Hospitals should evaluate likely epidemic scenarios based on regional epidemiology, travel patterns, and historical outbreaks. Risk assessment should map vulnerabilities across: (1) clinical care pathways (triage, isolation, ICU care); (2) staffing and surge staffing; (3) physical environment (airflow, zoning, donning/doffing areas); (4) critical supplies and logistics; (5) laboratory capacity and turnaround times; and (6) governance and communications.

Risk assessment should also consider vulnerable patient groups and high-risk departments (emergency department, ICU, dialysis, oncology, neonatal care). Hospitals can operationalize risk assessment using structured readiness tools and checklists to identify gaps and prioritize investments. An effective risk assessment is not a one-time document; it is reviewed periodically and updated after drills, incident debriefings, and major changes in services or infrastructure.

Importantly, risk assessment must translate into actionable plans: updated standard operating procedures (SOPs), clear escalation triggers, and pre-identified surge spaces. Without this link, risk assessment remains theoretical and does not improve readiness.

5. Infection Prevention and Control as the First Line of Defense

Infection prevention and control is the cornerstone of hospital health security during epidemics. Strong IPC prevents healthcare-associated transmission, protects staff, and preserves capacity by reducing absenteeism and secondary outbreaks within the facility. IPC should be built on core practices applicable to all healthcare settings, including hand hygiene, standard precautions, environmental cleaning, respiratory hygiene, safe injection practices, and appropriate use of PPE, alongside transmission-based precautions when indicated.

During epidemics, hospitals must rapidly scale IPC functions: expand screening and triage, establish clear patient pathways, implement cohorting or zoning (clean, transition, and contaminated areas), and enforce donning and doffing protocols. Engineering controls such as ventilation optimization and negative-pressure areas (where feasible) provide additional protection, especially for airborne transmission risks.

Training is critical. Staff require repeated, competency-based training in PPE selection, fit, and sequence; safe specimen handling; and safe waste management. Hospitals should maintain simplified visual aids at points of care and provide real-time coaching (e.g., trained observers) during high-risk procedures. IPC teams should conduct audits (hand hygiene, PPE compliance, environmental cleaning) and provide rapid feedback.

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Hospitals can use structured readiness tools to evaluate IPC readiness domains, including governance, protocols, supplies, and staff competencies. When resource constraints exist, prioritized "high-impact, low-cost" actions (hand hygiene infrastructure, rapid triage, separation of symptomatic patients, and consistent standard precautions) can significantly reduce transmission.

IPC is not isolated from other domains: it depends on supply chains (PPE availability), workforce planning (trained staff), and infrastructure (space and airflow). Therefore, IPC must be integrated into overall incident management and operational readiness.

6. Surveillance, Early Warning, and Laboratory Integration

Hospitals contribute to epidemic control by detecting and reporting unusual patterns of disease. Early warning depends on effective clinical surveillance at triage points, robust case definitions, and timely communication with public health authorities. Hospitals should integrate surveillance into daily operations, using triage algorithms that flag symptoms, travel history, exposure risks, and clusters.

Laboratory capability is central to detection and clinical management. Preparedness includes ensuring appropriate specimen collection protocols, transport, biosafety procedures, and clear communication pathways for results. During surges, laboratories require surge staffing, extended operating hours, and contingency plans for reagent shortages and equipment downtime.

Digital health systems can strengthen surveillance by enabling real-time dashboards for admissions, test results, bed capacity, and staff infections. Where electronic systems are limited, standardized manual line lists and rapid reporting protocols are essential. Surveillance should include healthcare worker infections, which serve as indicators of IPC effectiveness and can forecast staffing shortages.

Hospitals should participate in regional surveillance networks when available. Collaboration supports consistent case definitions, shared situational awareness, and coordinated escalation of care. Preparedness also requires clear triggers for activating incident management structures (e.g., increased influenza-like illness presentations, rising positivity rates, or a cluster among staff).

Surveillance is most effective when linked to action: reinforcing triage, adjusting visitor policies, increasing PPE requirements, opening surge wards, and revising staffing plans. A strong surveillance system turns data into decisions, reducing delays that can lead to uncontrolled transmission.

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7. Workforce Protection, Occupational Health, and Psychological Resilience

Healthcare workers are the most critical resource during epidemics, yet they are at increased risk of infection, fatigue, moral distress, and burnout. Protecting the workforce is therefore a core health security objective. Hospitals should establish robust occupational health services that monitor exposures, manage testing and vaccination programs, and implement return-to-work policies that balance safety with staffing needs.

Preparedness includes ensuring routine training and competency verification for high-risk tasks (airway management, aerosol-generating procedures, isolation transport). Vaccination policies for vaccine-preventable diseases and annual influenza campaigns reduce outbreak risk. During epidemics, hospitals should implement structured exposure assessment tools, provide post-exposure guidance, and ensure confidential reporting channels.

Psychological resilience should be treated as an operational priority. Sustained surges and high mortality environments can increase anxiety, sleep disruption, and depression among staff. Hospitals should offer tiered support: peer support programs, access to counseling services, rest areas, hydration and nutrition support, and scheduling practices that minimize unsafe fatigue. Transparent communication from leadership, recognition of staff efforts, and clear ethical guidance on triage decisions reduce moral distress.

Workforce planning should include surge staffing strategies, cross-training, and flexible redeployment. Maintaining a reserve roster of trained staff and agreements for mutual aid between hospitals can mitigate shortages. Importantly, workforce protection also includes preventing workplace violence and ensuring security measures, as fear and stress during epidemics may increase aggression in clinical areas.

A resilient workforce sustains continuity of care. Hospitals that invest in occupational health and psychological support are better prepared to maintain function under prolonged epidemic pressure.

8. Operational Readiness, Incident Management, and Surge Capacity

Operational readiness is the ability to activate coordinated response structures rapidly and sustain them throughout a crisis. Hospitals should establish an incident management system (IMS) or incident command structure with defined roles, reporting lines, and decision-making authority. The IMS should integrate clinical operations, IPC, logistics, communications, human resources, and security.

Surge capacity planning is a core function of operational readiness. Hospitals should map "4S" surge domains: staff, space, supplies, and systems. For space, this includes

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pre-identifying surge wards, step-down units, and areas for triage expansion. For staff, surge plans include cross-training, task shifting, and rapid onboarding procedures. For supplies, hospitals should define minimum stock levels, re-ordering triggers, and conservation strategies for critical items.

Triage protocols must be clear and ethically grounded. During high demand, hospitals may need to implement crisis standards of care, prioritizing resources based on clinical criteria. Ethical preparedness includes establishing triage committees, documentation procedures, and communication plans with families.

Regular drills and exercises test readiness. Scenario-based simulations should include surges, PPE shortages, oxygen system stress tests, and staff infection clusters. After each drill or real incident, hospitals should conduct structured debriefings and implement corrective actions. Operational readiness is strengthened through continuous improvement cycles rather than static plans stored on shelves.

Hospitals can use rapid readiness checklists to assess governance, plans, and operational capacity and to monitor progress over time. The use of standardized checklists supports objective benchmarking and prioritization of improvements.

9. Supply Chain Resilience and Critical Logistics

Epidemics stress supply chains, often causing simultaneous global demand spikes and transportation disruptions. Hospitals must therefore strengthen supply chain resilience to secure PPE, oxygen, essential medicines, disinfectants, and laboratory consumables. A resilient supply chain includes diversified suppliers, transparent inventory tracking, and contingency procurement pathways.

Hospitals should maintain a list of critical items and calculate burn rates under different surge scenarios. Stockpiling strategies should be risk-based: items with long shelf life and high criticality (e.g., respirators, gloves, disinfectants) are prioritized. For items with limited shelf life, rotating stock through routine consumption reduces waste and ensures readiness.

Logistics includes distribution within the hospital. During epidemics, clear processes for issuing PPE, managing re-supply, and preventing theft or misuse are essential. Hospitals should also plan for safe waste management (including increased volumes of infectious waste) and linen handling protocols.

Oxygen availability is frequently a limiting factor during respiratory epidemics. Preparedness includes assessing oxygen generation and storage systems, ensuring backup supplies, and maintaining oxygen delivery equipment. Similarly, pharmaceutical supply resilience requires

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coordination with national procurement systems and pharmacy teams to monitor shortages and implement therapeutic alternatives when needed.

Supply chain resilience is not solely a purchasing function; it is a clinical safety function. Shortages can force unsafe practices (e.g., prolonged reuse of PPE beyond safe limits) and compromise IPC. Therefore, logistics leadership must be integrated into the hospital's incident management structure and decision-making during health emergencies.

10. Infrastructure, Engineering Controls, and Environmental Safety

Hospital infrastructure influences transmission risk and operational stability. Engineering controls—ventilation, air filtration, pressure differentials, and spatial design—reduce exposure risk, particularly for airborne pathogens. Preparedness includes evaluating ventilation performance, ensuring maintenance of heating, ventilation, and air conditioning (HVAC) systems, and planning feasible upgrades for high-risk areas such as emergency departments and isolation rooms.

Hospitals should establish safe patient flow and zoning. Clear physical separation between suspected infectious patients and non-infectious patients reduces cross-transmission. Wayfinding signage, dedicated elevators or corridors (where feasible), and designated donning/doffing areas improve safety. Environmental cleaning protocols should be evidence-based and adaptable to pathogen characteristics, with defined responsibilities and monitoring (e.g., checklists, ATP testing when available).

Infrastructure resilience also includes utilities: electricity, water supply, information technology networks, and medical gases. Epidemics can coincide with disasters that threaten utilities, so hospitals require redundancy (generators, fuel plans, water storage, and maintenance contracts). Facilities should conduct stress testing of critical systems under surge scenarios, including oxygen system capacity and ICU electrical load.

Environmental safety extends to waste management, safe handling of sharps, and appropriate decontamination processes. During epidemics, increased volumes of PPE and contaminated materials can overwhelm standard waste systems. Preparedness includes contingency plans, contracts with waste disposal providers, and staff training in safe disposal practices.

Investing in infrastructure and engineering controls yields long-term benefits by improving routine infection prevention and reducing outbreak amplification. Even in resource-limited settings, practical interventions—improving natural ventilation, reducing crowding, and enhancing environmental cleaning—can significantly improve safety.

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11. Communication, Coordination, and Community Trust

Risk communication is essential during epidemics. Hospitals must communicate clearly and consistently with staff, patients, families, and the broader community. Poor communication can lead to confusion about visitation policies, fear-driven behaviors, and misinformation that undermines compliance with public health measures.

Internally, hospitals should establish a single source of truth for updates: standardized briefings, daily situation reports, and accessible policy repositories. Leadership communication should be transparent about uncertainty, rationale for decisions, and expected changes. Communication should also include feedback mechanisms so that frontline staff can report barriers, shortages, and safety concerns.

Externally, hospitals should coordinate with public health authorities on case reporting, referral pathways, and community guidance. Partnerships with emergency medical services and other hospitals support load balancing and interfacility transfer protocols. When hospitals are overwhelmed, coordination mechanisms can ensure that patients are directed to appropriate levels of care.

Community trust is strengthened through culturally competent messaging, respect for privacy, and patient-centered policies. During epidemics, restrictions such as limited visitation can be distressing; compassionate alternatives (virtual visits, structured updates) can mitigate harm. Communication strategies should also address stigma, which can discourage early care seeking and lead to concealment of symptoms.

Ultimately, communication is part of health security because it influences behavior, adherence to IPC, staff morale, and the public's willingness to follow guidance. Hospitals that build trust before crises are better positioned to mobilize cooperation during emergencies.

12. Digital Health, Cyber Resilience, and Information Security

Epidemic response increasingly depends on digital systems: electronic health records, laboratory information systems, imaging platforms, and connected medical devices. These systems support surveillance, decision-making, and operational coordination. However, reliance on digital infrastructure introduces cyber risk. Cyberattacks such as ransomware can disrupt care delivery at the worst possible time.

Hospitals should integrate cybersecurity into health security planning. Preparedness includes routine patching, network segmentation, multi-factor authentication, staff training to reduce phishing risk, and data backup and recovery plans. During emergencies, changes in

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workflows (rapid onboarding, remote access, telemedicine expansion) can increase vulnerabilities, so security measures must adapt without blocking clinical operations.

Digital health can enhance epidemic response through tele-triage, teleconsultation, and remote monitoring. These tools reduce unnecessary hospital exposure and preserve resources. Hospitals should develop governance for telehealth, including privacy protections and clinical protocols.

Information governance includes protecting patient confidentiality while supporting timely public health reporting. Clear policies are required for data sharing with authorities, research use of clinical data, and communication of results to patients.

A resilient digital environment ensures that critical hospital functions continue despite cyber incidents and supports the data-driven coordination required during epidemics. Digital resilience should be tested through tabletop exercises and integrated into incident management planning.

13. Quality Improvement, Training, and Readiness Measurement

Health security capability improves when hospitals treat preparedness as a measurable quality domain rather than a periodic compliance exercise. Readiness measurement starts with baseline assessments of governance, IPC, surge systems, and supply resilience, followed by regular monitoring using indicators. International guidance emphasizes the use of structured readiness checklists and assessment tools to identify gaps and guide improvement planning.

Training should be competency-based. Hospitals need a training matrix that specifies required competencies by role (e.g., triage nurse, ICU clinician, environmental services worker, laboratory technician) and tracks completion and assessment. Short, frequent refreshers (microlearning) are often more effective than annual lectures, especially for PPE donning and doffing, specimen handling, and cleaning protocols. Training should also include leadership and coordination skills, such as incident command roles and communications.

Drills and exercises should cover realistic stressors: rapid influx of suspected cases, oxygen system strain, laboratory backlogs, staff exposure clusters, and simultaneous cyber or utility disruptions. Tabletop exercises test decision-making, while functional drills test workflows (triage to isolation, transport routes, and waste disposal). After each exercise, hospitals should perform an after-action review, identify root causes, assign corrective actions, and re-test changes.

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Quality improvement methods such as Plan–Do–Study–Act cycles can turn lessons into sustained capability. For example, if audits show delayed isolation, hospitals can redesign triage space, refine screening questions, and monitor the effect. A culture of safety—where staff can report hazards without blame—accelerates learning and reduces hidden risks.

Finally, readiness must connect to patient outcomes and staff safety. Monitoring healthcare worker infection rates, outbreak clusters linked to the hospital, and continuity indicators (e.g., delayed elective cancer care) helps leaders understand whether preparedness measures are effective in real-world conditions.

14. Policy Alignment, IHR Linkages, and Equity Considerations

Hospitals do not operate in isolation; their readiness depends on alignment with national public health systems and legal frameworks. The International Health Regulations (IHR 2005) provide a global framework for preventing, preparing for, and responding to the international spread of disease. At the facility level, IHR principles translate into timely event detection, standardized reporting channels, and coordination mechanisms that support national decision-making. Hospitals should therefore formalize relationships with public health authorities, define reporting responsibilities, and ensure that frontline teams understand notification pathways for unusual events.

Policy alignment also includes harmonizing hospital preparedness plans with national emergency operations, referral pathways, and stockpile strategies. During epidemics, inconsistent policies between facilities can create confusion and lead to unsafe patient movement. Regional coordination and mutual aid agreements help distribute load, move supplies, and share specialized expertise (e.g., high-consequence isolation capability).

Equity is a practical health security concern, not only an ethical one. Epidemics disproportionately affect vulnerable populations, including older adults, people with chronic diseases, migrants, and those with limited access to information. Hospitals should design triage, communication, and care pathways that reduce barriers—providing multilingual information, accessible signage, and patient navigation support. Equity also applies to the workforce: contract staff, cleaners, and support workers often face high exposure risk and require the same protections, training, and access to PPE as clinical staff.

Finally, policy alignment should be supported by transparent governance and accountability. Hospitals can publish readiness goals, track key indicators, and report improvements to oversight bodies. When gaps are identified—such as insufficient isolation capacity or weak ventilation—leadership should advocate for capital investments and support from health authorities. Aligning hospital practice with national and international expectations increases

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coherence, improves trust, and strengthens system-wide resilience during public health emergencies.

15. Integrated Framework and Implementation Roadmap

Strengthening hospital health security requires integration across domains rather than isolated projects. This paper proposes an integrated framework with five operational layers: (1) governance and leadership; (2) core clinical and IPC capabilities; (3) workforce protection and surge staffing; (4) infrastructure, supplies, and logistics; and (5) information systems and communication. Each layer includes actions across the emergency cycle: preparedness (before), response (during), and recovery and learning (after).

Implementation can begin with a structured readiness assessment using standardized tools and checklists to identify gaps in governance, protocols, and capacity. Based on gaps, hospitals should develop a prioritized improvement plan with clear owners, timelines, and budgets. Governance should include a multidisciplinary health security committee that meets routinely and reports to executive leadership.

Key preparedness actions include: establishing an incident management system; ensuring updated IPC policies and training; building a surveillance dashboard; pre-identifying surge spaces; maintaining critical stock levels; conducting drills; and implementing staff well-being programs. During response, hospitals activate incident management, implement surge plans, intensify IPC audits, and communicate daily with staff and partners. During recovery, hospitals debrief, analyze data (including staff infection rates and patient outcomes), and implement system improvements.

Monitoring is essential. Suggested indicators include: hand hygiene compliance; time from triage to isolation of suspected cases; PPE stock days on hand; percentage of staff trained and competency-checked; staff infection incidence; bed occupancy and ICU surge capacity; laboratory turnaround times; and completion of drills with corrective actions tracked.

By institutionalizing continuous improvement—Plan-Do-Study-Act cycles and after-action reviews—hospitals can convert epidemic experience into sustained resilience and stronger health security.

16. Conclusion

Epidemics and public health emergencies are inevitable, but their impact on hospital systems can be mitigated through deliberate, integrated health security strategies. Hospitals must build capabilities that prevent transmission within facilities, protect healthcare workers, sustain essential services, and maintain trust through transparent communication. Strong IPC

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programs, surveillance and laboratory integration, workforce support, incident management, surge capacity, supply chain resilience, and robust infrastructure are interdependent pillars of hospital health security.

This paper provides a practical framework and roadmap to strengthen hospital readiness across the emergency cycle. The central message is that preparedness is not a one-time plan but an ongoing institutional commitment, assessed through structured tools, refined through training and drills, and strengthened through continuous improvement after real events. Investing in hospital health security improves outcomes during epidemics and enhances everyday patient safety, making it a high-value priority for health systems seeking resilience in an increasingly complex risk environment.

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