Disaster Medicine and Public Health Preparedness

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Beyond the Room: Bed-Level Isolation as Surge-Capable Infrastructure for Pandemics and Disasters—A Conceptual Framework

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Abstract

The COVID-19 pandemic exposed a structural limit of hospital isolation infrastructure: airborne infection isolation and protective-environment rooms are fixed assets that cannot be multiplied at the speed of a respiratory surge, and the constraint is more severe in field hospitals after disasters. Pandemic workarounds (ward conversion, portable negative-air machines, and modular container construction) each addressed part of the problem at the cost of bed capacity, sustained containment, or deployment speed. This concept paper aims to synthesize the failure modes of room-scale isolation into a device-agnostic set of clinical and engineering criteria for deployable bed-level single-patient isolation with switchable pressure polarity, in-enclosure air-quality monitoring, and on-board between-patient decontamination. These criteria are summarized in a requirements matrix, and one illustrative implementation is outlined. The intended contribution is a framework to guide future design, testing, and evaluation, not a validated solution; no validation data are presented, and none should be inferred.

Concepts in Disaster Medicine

Cite this article: Yalçın İG (2026). Beyond the Room: Bed-Level Isolation as Surge-Capable Infrastructure for Pandemics and Disasters—A Conceptual Framework. *Disaster Medicine and Public Health Preparedness*, **20**, e178, 1–6
https://doi.org/10.1017/dmp.2026.10446

Received: 14 May 2026 UTC
Revised: 19 August 2026 UTC
Accepted: 27 August 2026 UTC

Keywords:
patient isolation; surge capacity; infection control; pandemic preparedness; disaster planning

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Introduction

Hospital-acquired SARS-CoV-2 infection during the COVID-19 pandemic carried a mortality penalty that was not distributed evenly. A systematic review and meta-analysis of more than 8,000 admissions across 8 countries found that adults who acquired the virus in hospital were 1.3 times more likely to die than those admitted with community-acquired infection, and immunosuppressed patients with nosocomial COVID-19 were more than twice as likely to die as their community-acquired counterparts.[1] The health care workforce paid a parallel price. A worldwide systematic review documented more than 152,000 COVID-19 infections and over 1,400 deaths among health care workers within the first months of the pandemic alone, with physicians disproportionately represented among the dead.[2] Taken together, these figures describe a single system failure: hospitals could not reliably separate infectious patients from vulnerable patients and staff at the scale and speed the pandemic demanded.

The engineered solution for separating infectious patients from vulnerable patients and staff is represented by the airborne infection isolation room (AIIR), which is fixed infrastructure. The AIIR operates with negative pressure, 12 or more air changes per hour, and direct exhaust to the outdoors. Most hospitals operate with a small pre-pandemic AIIR inventory that is already occupied by routine cases of tuberculosis, measles, and varicella. The demand created by a respiratory pandemic rapidly outstripped that supply.[3] Ad-hoc strategies adopted during COVID-19—converting general wards with portable negative-air machines, rebalancing existing HVAC zones, or prefabricating modular container wards—partially closed the shortfall between isolation demand and isolation capacity.

Each strategy, however, resulted in documented limitations. Existing bed capacity had to be sacrificed, environmental sampling recovered SARS-CoV-2 RNA from surfaces in converted rooms in a substantial proportion of cases, and even purpose-built container wards required weeks of construction and substantial cost.[4,5]

The above-mentioned constraints are amplified, not relieved, in disaster and austere settings. Field hospitals deployed after the 2010 Haiti earthquake, the 2013 Lushan earthquake in China, and the 2023 earthquakes in Türkiye operated with tent or modular structures in which engineered airflow control, HEPA filtration, and anteroom architecture were limited or absent.[6] When a pandemic coincides with a disaster—a scenario that the COVID-19 era made concrete rather than hypothetical—the requirement for isolation rises precisely when the infrastructure to deliver it is most degraded.

A related, though not identical, constraint arises in any system that must protect severely immunocompromised patients (hematology, transplant, oncology) from a contaminated environment. Here the limitation is a chronic, fixed-capacity ceiling rather than a surge-driven collapse: the protective-environment (PE) room is also fixed infrastructure, and its availability

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is similarly finite. The 2 situations therefore share a dependence on limited built isolation infrastructure while representing different failure modes.

Beyond the acute hospital, several distinct preparedness contexts also depend on scarce isolation capacity. These can be grouped into 3 broad domains: surge triage of respiratory patients in field hospitals; single-patient containment within shared mobile intensive-care units; and protective sheltering of immunosuppressed evacuees, alongside isolation of suspected high-consequence-infectious-disease cases in austere environments where built isolation is unavailable. What these settings have in common is that isolation must be provided at the level of the individual patient, often where fixed rooms do not exist.

Therefore, a different design logic is worth exploring. Rather than continuing to engineer the room around the patient, the failure modes reviewed above point toward engineering a controlled microenvironment directly around the hospital bed. Such a microenvironment would need to be deployable in days rather than weeks, able to switch between containment of an infectious patient and protection of a vulnerable one, and capable of being decontaminated and turned over rapidly between occupants.

This concept paper synthesizes the clinical criteria that a bed-level isolation infrastructure would have to satisfy, considers where existing devices and standards leave the concept underdeveloped, and outlines one illustrative implementation as an example of how those criteria might be addressed. Consistent with the concept-paper format, the aim is not to advance a specific commercial device, nor to derive a definitive or fully validated set of requirements, but to organize existing knowledge and open a structured discussion about a category of surge-capable isolation infrastructure that has received little systematic attention in the literature considered here.

Discussion

Limitations of Room-Level Isolation in Pandemic Surge and Disaster Settings

The fundamental constraint of the AIIR is its dependence on fixed built infrastructure. Compliance with ANSI/ASHRAE/ASHE Standard 170 requires negative pressure relative to adjacent spaces, a minimum of 12 air changes per hour, direct exhaust to the outdoors, supply diffusers positioned above the patient bed, and continuous pressure-differential monitoring with visual indication.[7,8] These requirements are met by fixed mechanical infrastructure—dedicated ductwork, fans, exhaust pathways, and controls—that must be designed into the building envelope. Retrofitting them into wards that were not designed for them is possible but slow and expensive, and constructing them from scratch is slower still. The COVID-19 experience supplied concrete numbers: a Singaporean prefabricated container ward, an explicitly rapid solution, still required 50 days and 100 workers to deliver 50 beds.[4] A respiratory pathogen with a doubling time of 5 to 7 days can therefore outpace even a construction program designed for speed.

The faster alternatives that hospitals actually deployed during the pandemic were compromises. Converting general wards to negative-pressure zones using portable HEPA machines and rebalanced HVAC sacrificed existing bed capacity at the moment surge demanded more of it, and the converted rooms did not always perform as expected once in use. In an environmental sampling study of temporary isolation wards constructed from prefabricated containers and converted general wards, SARS-CoV-2 RNA was recovered from environmental surfaces in nearly a quarter of patient rooms, and clusters of health care-associated infection among staff working in these areas were investigated by whole-genome sequencing.[5] Containment therefore remained incomplete even after construction was complete—a finding that should temper enthusiasm for any temporary-AIIR strategy that relies on retrofitted HVAC alone.

A separate ventilation pathway protects the opposite patient. Severely immunocompromised patients—bone marrow transplant recipients, neutropenic oncology patients, and selected solid-organ recipients—are placed in PE rooms maintained at positive pressure with HEPA-filtered supply and laminar-flow diffusers above the bed.[8] PE rooms share the AIIR's structural problem: they are fixed, finite, and built into the building. A hospital that exhausts its PE capacity cannot add further capacity within the timeframe of a clinical decision.

Disaster and austere settings sharpen each of these limits. Field hospitals deployed after major earthquakes have repeatedly operated under tent or modular shelters in which engineered airflow, anteroom architecture, and reliable filtration were limited or absent, even when isolation requirements were anticipated by planners.[9] In a review of mobile-hospital design after major Chinese disaster responses, the authors explicitly identified intelligent control, rapid deployment, and modular isolation as the principal unmet requirements for the next generation of field facilities.[6] The compound scenario of a pandemic occurring within a disaster—already plausible enough to merit planning, and demonstrated during the 2023 earthquake response in Türkiye, when respiratory infections continued to be managed alongside trauma—is precisely the scenario for which fixed AIIR and PE infrastructure offers the least. In such mass-casualty scenarios with respiratory pathogen co-circulation, existing isolation infrastructure is underprovisioned at the moment of greatest demand. The comparative profile of currently available strategies under these conditions, together with the conceptual bed-level enclosure discussed below, is summarized in Table 1.

Design Requirements for Bed-Level Isolation in Surge Settings

If a bed-level enclosure is to function as genuine surge infrastructure rather than as an aerosol-attenuating accessory, the clinical requirements it must satisfy can be specified independently of any particular device. Six requirements recur when the failure modes described above are analyzed in turn—that is, when each documented failure of room-scale isolation is read as an implicit specification for what an adequate alternative would have to achieve.

First, the enclosure must produce a controlled pressure differential relative to the surrounding room, of sufficient magnitude and stability to contain or exclude airborne particles during ordinary care activities, including the brief openings required for procedural access.[7] Second, that pressure differential should be switchable in polarity according to the patient inside: negative when the patient is infectious to others, positive when the patient must be protected from a contaminated room. Third, the enclosure must allow routine clinical access—examination, drug administration, line and tubing management, and basic procedures—without breaching containment for the duration of the contact, and it must additionally permit immediate full access for life-saving intervention, including airway management, cardiopulmonary resuscitation, and defibrillation, through a rapid full-panel release that accepts a deliberate, controlled loss of containment when clinical need demands it. Fourth, the air leaving the enclosure must be filtered and, where

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Table 1. Comparative profile of single-patient isolation strategies during pandemic surge or disaster response

Isolation strategy	Deployment time	Per-bed scalability	Containment integrity	Patient access mode	Between-patient turnover	Validation maturity
Fixed AIIR/PE room	Weeks to months	Low; fixed infrastructure	High when standards met	Direct bedside	Hours of cleaning	Mature (ASHRAE 170, CDC)
Temporary ward conversion	Days to weeks	Medium, at cost of other beds	Variable; environmental leakage reported	Direct bedside	Hours to a day	Limited; operational evidence only
Modular container ward	Weeks (≥50 days reported)	Medium (parallel build)	Verified in published series	Direct bedside, with footprint constraints	Hours	Emerging (post-COVID–19 series)
Bed-level enclosure (conceptual)	Potentially rapid if pre-positioned; not yet characterized	Potentially high (per-bed unit)	Not yet validated	Ports plus partial direct access	Not yet validated	Conceptual only

Notes. Color coding indicates the relative favorability of each attribute for surge and disaster use: green = favorable or established; yellow/amber = intermediate or context-dependent; orange = unfavorable; gray = unknown, uncharacterized, or conceptual. The color scale is a qualitative reading aid only and does not represent quantitative scoring. The bed-level enclosure row represents a hypothesized operational profile derived from the requirements matrix in Table 2, not measured performance. All entries in that row should be interpreted as conceptual until supported by bench, simulation, and clinical validation studies. References for the other rows appear in the main text.

appropriate, disinfected to a standard equivalent to that of an engineered isolation room, so that the surrounding ward is not made dirtier by the device's operation.[10] Fifth, the enclosure must be turned over rapidly and reliably between occupants, because surge capacity is wasted if room change-over takes hours.[11] Sixth, the enclosure must be operable by clinical staff under realistic workload, which means automated monitoring and alarms for the parameters that determine whether the device is actually doing what it claims. These 6 criteria, together with their disaster-medicine rationale, candidate technical responses, validation endpoints, and dominant failure modes, are summarized in the requirements matrix presented in Table 2.

The second criterion reported in the requirements matrix (Table 2), switchable polarity, requires additional consideration, because it is the point on which current room-level practice has explicitly retreated. Recent editions of ANSI/ASHRAE/ASHE

Table 2. Requirements matrix: clinical and engineering criteria for deployable bed-level isolation infrastructure

Requirement	Disaster/pandemic rationale	Candidate technical response	Required validation endpoint	Dominant failure mode
Stable pressure differential	Containment must persist during routine care, including brief panel openings	Closed-loop motor control with differential-pressure sensing and panel-state interlocks	Pressure stability re-established within seconds of panel events; quantified leak rate	Loss of differential during procedure-related panel openings
Switchable pressure polarity	Same platform must serve infectious-patient containment and immunosuppressed-patient protection during surges	Independent supply and exhaust paths with software-mediated mode transitions and decontamination between modes	Mode confirmation logging; verified decontamination cycle between polarity changes	Cross-contamination during mode transitions; staff confusion over the active mode
Routine and emergency clinical access	Bedside care, line management, and brief procedures must proceed without removing isolation; life-saving intervention (airway management, CPR, defibrillation) must remain immediately possible	Glove ports with sealed cuffs; planned panel openings with compensating airflow; rapid full-panel release for emergency full access	Particle clearance after access events; ergonomic acceptability for typical care tasks; time-to-full-access for emergency intervention	Port seal degradation; staff workaround due to ergonomic strain; delay in life-saving intervention
On-board filtration to room-equivalent standard	Surrounding ward must not be made dirtier by the enclosure operating within it	HEPA-class filtration on exhaust; particulate monitoring at outlet	Outlet particulate counts within applicable airborne-infection-isolation benchmarks	Filter loading without alert; bypass leakage
Rapid in-situ between-patient turnover	Surge capacity is wasted if room change-over takes hours	Sealed-volume decontamination (gaseous ozone, hydrogen-peroxide vapor, or ultraviolet-C) with sensor-confirmed clearance	Microbiological reduction validated against surrogate organisms; residual measurement below safety thresholds	Incomplete decontamination; staff or patient exposure to residual agent
Operability under realistic staff workload	Surge conditions reduce supervisory attention and increase error risk	Continuous parameter monitoring, automated alerts, and a visible operating-mode indicator	Human-factors evaluation under simulated surge conditions	Alarm fatigue; misinterpretation of active mode during shift change

Notes. Each requirement is paired with the disaster-medicine rationale that motivates it, a candidate technical response, the validation endpoint that would establish whether the response is adequate, and the dominant failure mode that validation must rule out. The matrix is device-agnostic: any candidate platform should be assessed against all 6 criteria. Beyond these clinical and engineering requirements, deployment additionally depends on cross-cutting operational-feasibility criteria—uninterrupted power and a tolerable temperature range, consumable filter and decontaminant resupply, transport weight and footprint, set-up time, and patient tolerance—discussed under operational implications and feasibility across settings.

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Standard 170 restrict reversible airflow between airborne infection isolation (AII) and PE functions in built rooms, because safe mode switching, decontamination between modes, and operational verification of the active mode are difficult to assure at building scale.[8] The current solution at room scale is a combined AII/PE room paired with an anteroom; that is, a more elaborate build rather than a simpler one. A bed-level enclosure occupies a different regulatory and physical category from a built room, in that it is a medical device with a defined internal volume and dedicated supply and exhaust pathways. This category difference does not automatically resolve the underlying concerns. Any candidate bed-level platform with reversible polarity would still have to demonstrate adequate mode confirmation, between-mode decontamination, and operational safety under device-specific validation and regulatory review before it could be considered for clinical use. The argument here is therefore not that reduced scale dissolves the regulatory question, but that the smaller, dedicated volume changes which engineering responses become tractable.

The remaining requirements summarized in the matrix (Table 2) follow a similar logic. Continuous monitoring of pressure, oxygen, carbon dioxide, temperature, humidity, and particulate matter inside the enclosure is feasible at the scale of a cubic-meter internal volume in a way that it is not feasible at the scale of a ward.[7] Rapid in-situ surface and air decontamination after a patient leaves may be approached using gaseous ozone, hydrogen-peroxide vapor, or UV-C irradiation, and becomes simpler and faster in a sealed bed-level volume than in a ward. Published evidence supports ozone activity against SARS-CoV-2 surrogates at room scale[11,12]; the comparative efficacy of hydrogen-peroxide vapor and UV-C irradiation for a sealed bed-level enclosure remains to be established. The appropriate choice between these technologies depends on residual safety profile, material compatibility, and turnover time, and would have to be determined for any given platform. What appears to be a regulatory obstacle at room scale is, in part, a scale problem. Reducing the enclosed volume does not by itself create a safe device, but it does change which engineering choices become tractable.

An Illustrative Implementation

The requirements above are device-agnostic, and more than one engineering configuration could in principle satisfy them. To make the requirements concrete, and solely as one worked example, this section summarizes a single illustrative implementation reported in the patent literature.[13] The author is a named co-inventor on that application, and the competing interest is disclosed in full below; the example is included to show how the requirements matrix translates into hardware decisions and where the difficult trade-offs lie, not to advocate for this or any particular system.

In this example, a sealed bed-level enclosure is connected to a separate filtration-and-control unit by short ducts. The enclosure provides direct visual monitoring through transparent panels. Routine bedside care is supported through glove-like iris ports distributed across its surface, and larger panels open for patient placement and for procedures that require full access. The pressure function is software-controlled and bidirectional: paired air-handling motors maintain a configured pressure differential—negative for an infectious patient, positive for an immunosuppressed patient—and adjust when panels are opened. A visible interior indicator displays the active mode to staff as a safeguard against errors during shift changes. A sensor array continuously measures pressure differential, particulate matter, oxygen, carbon dioxide, temperature, humidity, and ozone, and between patients the enclosure is decontaminated in place through an automated cycle that operates only while the enclosure is sealed and unoccupied, with sensor-confirmed clearance required before reopening. Gaseous ozone is only one of several candidate technologies for between-patient decontamination at this scale; alternatives include hydrogen-peroxide vapor, UV-C irradiation, and HEPA filtration combined with manual surface cleaning, each with distinct efficacy, residual, and material-compatibility profiles that would have to be evaluated for any candidate platform.[12]

The purpose of this single example is limited: it demonstrates that the 6 requirements can be mapped onto concrete engineering choices, and it exposes where the hardest trade-offs lie, without implying that this configuration is optimal or validated. The same implementation shares its bidirectional-pressure operation with the single-patient transport isolation unit reported in the high-consequence-infectious-disease literature, which is also operable at negative or positive pressure but is designed for inter-facility transport rather than sustained bedside care, and currently relies on hydrogen-peroxide vapor fumigation in a separate sealed chamber for full decontamination.[14] The 2 device categories address adjacent rather than overlapping problems, and a credible isolation infrastructure during pandemic surge or disaster response would arguably draw on both. The comparative profile of these strategies, alongside existing room-scale options, is summarized in Table 1.

Human Factors and Operational Workflow

Practical feasibility depends not only on containment performance but also on whether clinical teams can deliver care through the enclosure under realistic conditions. Several human-factors and workflow determinants are therefore central to feasibility rather than peripheral to it. Emergency bedside access is the most acute concern: any enclosure must permit immediate intervention for cardiopulmonary resuscitation, airway management, and defibrillation without a delay that would compromise the patient, which implies rapid full-opening mechanisms and unambiguous procedures for abandoning containment when life-saving care requires it. Complex positioning maneuvers, including prone positioning of a hypoxemic patient, and routine but space-intensive tasks such as line and drain management must remain achievable through the available access ports or planned panel openings. Working through iris ports rather than at the open bedside may also impose an ergonomic and cognitive burden on nursing and medical staff—restricted reach, altered tactile feedback, and slower task completion—that can accumulate over a shift and, if unaddressed, drive workarounds that defeat containment. From the patient's perspective, tolerability of an enclosed microenvironment, claustrophobia, the effect on family contact and communication, and the psychological impact of visible confinement are material determinants of whether the approach is acceptable at all. None of these determinants can be assumed to be favorable, and each would require explicit human-factors evaluation under simulated surge conditions before any clinical role could be claimed.

Operational Implications and Feasibility Across Settings

The operational role of a bed-level enclosure would differ markedly by setting, and it is more useful to describe a spectrum than a single use case. In a tertiary facility with intact building services, biomedical-engineering support, and a reliable supply of consumables and power, such an enclosure is best understood as a surge

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supplement to existing AIIR and PE capacity—a way to add single-patient isolation quickly when fixed rooms are exhausted, while the hospital's own infrastructure continues to provide the baseline. In this context, the dominant feasibility questions are integration with existing workflows, staff training, and turnover logistics rather than basic viability. In austere or field settings, by contrast, the same device would be operating where no fixed isolation exists, and its feasibility is governed by more elementary constraints: uninterrupted electrical power, a tolerable ambient temperature range, resupply of filter elements and decontamination consumables, transport weight and footprint, and set-up time. A configuration that is straightforward to support in a tertiary hospital may be impractical at the resource-limited periphery of a disaster response, and the reverse trade-offs—ruggedness and self-sufficiency against sophistication—would have to be made explicitly. Any claim about deployability in disaster response should therefore be qualified by the specific setting envisaged, and, at present, these operational parameters have not been characterized for the concept.

Limitations

The 4 limitations discussed below relate directly to the 2 principal contributions of this concept paper, in that each constrains their validation and practical substantiation. The first contribution is the device-agnostic set of clinical and engineering criteria summarized in the requirements matrix; the second is the single illustrative implementation used to make those criteria concrete. Accordingly, this paper should be regarded as a critical synthesis of existing evidence and a conceptual framework for bed-level isolation as surge-capable disaster infrastructure, rather than as a validated set of design guidelines. The limitations that follow encompass the absence of empirical validation data, the staged validation pathway still to be completed, open questions that sit beyond the device itself, and constraints specific to disaster and austere settings.

Absence of validation data

The principal limitation of this concept paper is also its premise. The illustrative implementation described above has not been subjected to bench validation, simulated clinical evaluation, or any form of patient-facing study. Several claims are made for it: that the pressure differential is maintained during panel openings; that the filter train delivers the intended containment; that the in-situ decontamination cycle reliably clears the enclosed volume below safe residual thresholds before reopening; and that the operating-mode indicator reduces error during shift change. At this stage, these are design intentions rather than measured outcomes. Accordingly, they cannot be cited in support of clinical use, and this paper should not be read as recommending such use. What the paper does offer is methodological: a device-agnostic framework of clinical requirements, validation endpoints, and failure modes against which any candidate platform can be assessed, together with a worked example of how that framework maps onto engineering decisions.

A staged validation pathway

A defensible validation pathway has at least three sequential stages. Bench testing should establish whether the device meets the engineering specifications already used for room-scale isolation: maintenance of pressure differential under panel-opening conditions, particle clearance rates expressed in air changes per hour, and leak rate under realistic occupancy. Particle-image-velocimetry and particle-count studies of similar bed-level negative-pressure hoods have shown that visual clarity is a poor proxy for fine-particle containment, and that quantitative particle counting is required to distinguish a functioning enclosure from a leaky one.[15] Simulated clinical evaluation, using manikins and standardized aerosol-generating procedures, should then assess whether routine bedside care can in fact be delivered through iris ports without breaches, and whether the human-factors burden on staff is acceptable. Only after these stages should patient-facing studies be considered, beginning with low-acuity cohorts in which an enclosure failure would not change clinical outcome.

Open questions beyond the device

Several questions sit outside the device itself. Gaseous ozone is useful against respiratory virus surrogates but is also a respiratory toxicant, and its use in a health care environment requires regulated residual measurement and material-compatibility assessment that the literature explicitly identifies as incomplete.[16] Comparative validation against alternative decontamination technologies—hydrogen-peroxide vapor, UV-C irradiation, and manual cleaning combined with HEPA filtration—should be considered a prerequisite to clinical deployment rather than an afterthought, because the appropriate choice may depend on patient population, turnover frequency, and the materials present in the enclosure. Regulatory classification of any bed-level enclosure as a medical device, with the corresponding evidence requirements for CE marking or comparable approval, has not been mapped for this category. Cost-effectiveness against alternative surge strategies—temporary AIIR conversion, modular container wards, and patient cohorting—has not been modelled and would be expected to vary substantially by health system. Patient-facing and workforce concerns, discussed under Human factors above, remain equally underexplored.

Constraints specific to disaster and austere settings

A separate set of constraints applies to disaster and austere settings specifically, as outlined under Operational implications. Deployable bed-level enclosures require uninterrupted electrical power, a reasonable temperature range, and consumable filter elements, none of which can be assumed in the most resource-limited contexts. Transport weight, footprint, set-up time, and maintenance demands have not been characterized for the illustrative implementation discussed above, and would have to be modelled before any disaster-response role beyond the immediate periphery of a functioning hospital could be claimed.

None of these gaps is a reason to abandon the concept. Each, however, is a reason to be precise about what is currently known: a clinical requirement set that the COVID-19 pandemic and recent disaster responses have made visible, and a candidate engineering response that has not yet been tested against it.

Conclusions

The COVID-19 pandemic and the disaster responses of the past decade have made one fact difficult to ignore: room-scale isolation infrastructure, both negative-pressure for containment and positive-pressure for protection, is too slow to build, too expensive to multiply, and too dependent on intact building services to function reliably during surges. Each of the workaround strategies that hospitals adopted during COVID-19—ward conversion, portable negative-air machines, and modular container construction—addressed part of the problem at the cost of either existing capacity, sustained containment,

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or deployment speed. In general, field hospitals in disaster settings start from a position in which engineered airflow is largely unavailable, and the compound scenario of a pandemic occurring within a disaster collapses the available isolation options further.

The primary contribution of this concept paper was to develop a device-agnostic framework for a candidate infrastructure category: surge-capable, deployable, single-patient isolation that can be turned over within a clinical shift rather than within a construction project. The framework pairs clinical and engineering criteria with validation endpoints and dominant failure modes. A bed-level isolation enclosure with switchable pressure polarity, continuous in-enclosure air-quality monitoring, and on-board between-patient decontamination is not a replacement for the AIIR or the PE room, but a complementary category whose criteria can be provisionally articulated from existing failure modes.

Whether a platform integrating all of these functions for sustained bedside care can meet the proposed criteria remains unanswered. Answering that question will require bench validation, simulated clinical evaluation, cost-effectiveness modelling against established surge alternatives, and patient-facing assessment of tolerability. This work is well within the reach of existing methods, and the framework offered here is intended to structure it before the next surge, so that the concept can be tested rather than merely proposed.

Data availability statement. No new data were generated or analyzed in support of this article. All evidence cited is publicly available through the references listed.

Author contribution. The sole author conceived, drafted, revised, and approved the final version of this manuscript.

Funding statement. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing interests. The author is named as 1 of 5 inventors on a published international patent application (Reference 13) disclosing the illustrative implementation described in this article. The patent rights are jointly held by Süleyman Demirel University and Isparta University of Applied Sciences as institutional applicants; the author does not hold personal ownership rights and derives no current financial benefit from the application. The patent has been filed nationally with the Turkish Patent and Trademark Office and internationally via the Patent Cooperation Treaty (WO/2024/123271, published 13 June 2024); both filings are publicly accessible. The author had no role in any product development, manufacturing, or commercialization activity related to this concept, and no licensing arrangements exist at the time of submission. The decision to publish, the framing of clinical requirements, and the selection of supporting evidence were made independently of any potential commercial interest.

Ethical approval. This article is a conceptual analysis and does not involve human subjects, animal subjects, identifiable patient data, or interventional research. Institutional review board approval was therefore not applicable.

Use of artificial intelligence. The author used a large language model (Claude; Anthropic) as a writing-assistance tool during preparation of this manuscript, to support drafting, structural organization, and formatting of the text, tables, and references. The conceptual content, scientific argument, clinical framing, interpretation of the cited literature, and all editorial decisions are the author's own. The author reviewed, verified, and edited all AI-assisted output, independently confirmed all references and their sources, and takes full responsibility for the accuracy, integrity, and originality of the manuscript. The artificial intelligence tool does not meet authorship criteria and is not listed as an author, in accordance with the publisher's policy.

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