

Lassa fever: A review of three treatment centres in Nigeria

*Original*

Lassa fever: A review of three treatment centres in Nigeria / De Filippi, F., Pagano, F., Di Marco, M., Fontana, L., Silenzi, A.. - In: TECHNE. - ISSN 2239-0243. - ELETTRONICO. - 31:(2026), pp. 279-292. [10.36253/techne-18620]

*Availability:*

This version is available at: 11583/3013812 since: 2026-07-31T13:21:13Z

*Publisher:*

Firenze University Press

*Published*

DOI:10.36253/techne-18620

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**Abstract.** Durante le epidemie di febbre di Lassa, i Centri di Trattamento (CT) sono cruciali per la cura e il controllo della trasmissione, ma la loro progettazione resta poco esplorata. Lo studio analizza tre CT in Nigeria con approccio di reverse-engineering. I risultati mostrano differenze in capacità, zonizzazione e integrazione dei servizi, con effetti su controllo delle infezioni, sicurezza del personale e inclusività. Emergono tendenze ricorrenti e lacune critiche; viene proposto un set di indicatori spaziali e le evidenze cross-case sono tradotte in principi di design per i CT. Lo studio propone un quadro per standard progettuali a supporto della gestione dei focolai e richiama la necessità di strutture adattabili e ricerche che colleghino il design a esiti sanitari ed esperienza dei pazienti.

**Parole chiave:** Febbre di Lassa; Centri di trattamento; Design; Salute materna e neonatale; Reverse engineering.

## Introduzione

La febbre di Lassa (Lassa Fever, LF) è una malattia virale emorragica (Viral Hemorrhagic Fever, VHF) endemica dell'Africa occidentale, con un'incidenza annua stimata tra 100.000 e 300.000 casi e un tasso di letalità di circa il 15% tra i pazienti ospedalizzati (Naeem *et al.*, 2023).

I primi casi nell'uomo furono segnalati negli anni Cinquanta e il virus identificato nel 1969. L'infezione avviene attraverso il contatto con roditori infetti o con i loro escreti; la trasmissione secondaria tra esseri umani è legata all'esposizione a fluidi corporei infetti o superfici contaminate (Goeijenbier *et al.*, 2013; Redding *et al.*, 2021). Le donne in gravidanza costituiscono uno dei gruppi più vulnerabili, con tassi di mortalità fino al 30% nel

terzo trimestre e perdita fetale superiori all'80% (Price *et al.*, 1988; Finnegan *et al.*, 2004; Shehu *et al.*, 2018; Chaudhary *et al.*, 2025).

La trasmissione nosocomiale ha avuto un ruolo centrale nelle epidemie di LF, dai primi casi in Nigeria, Liberia e Togo (Balogun, Akande e Hamer, 2020). Nelle aree endemiche, gran parte dei focolai si è sviluppata all'interno di strutture sanitarie, evidenziando le conseguenze di sistemi di Prevenzione e Controllo delle Infezioni (PCI) inadeguati o non funzionanti (Fisher-Hoch, 2005; Kernéis *et al.*, 2009). La prevenzione richiede l'applicazione rigorosa dei protocolli PCI per limitare la trasmissione tra pazienti, operatori sanitari (OS) e assistenti familiari. La Nigeria sostiene il maggiore carico di LF, con oltre 5.000 casi confermati dal 2020 e il ripetersi di epidemie dal 2018. Tra gennaio 2018 e dicembre 2024, il 75% dei casi confermati è stato registrato negli stati di Ondo (33%), Edo (31%) e Bauchi (11%); nello stesso periodo 212 OS sono stati contagiati, pari al 4% del totale dei casi, con una concentrazione prevalente negli stessi stati (NCDC, 2022).

In continuità con precedenti analisi sui CT per Ebola e Marburg (ETC, MTC) (Fontana *et al.*, 2024), questo studio si concentra su strutture permanenti per LF in Nigeria, paese in cui la malattia è endemica, ed esplora come soluzioni spaziali più efficaci possano rispondere ai bisogni di salute materna e neonatale. Nonostante i progressi nella gestione clinica della LF (Alli *et al.*, 2021; Doohan *et al.*, 2024), la progettazione dei CT rima-

## Lassa fever: A review of three treatment centres in Nigeria

**Abstract.** During Lassa fever outbreaks, Treatment Centres (TCs) are critical for patient care and transmission control, yet their design remains underexplored. The study analyses three TC in Nigeria, using a reverse-engineering approach. Findings reveal major differences in capacity, zoning, and service integration, with implications for infection control, staff safety, and inclusivity. Recurring layout trends and critical gaps are identified; a set of spatial indicators is proposed and cross-case results are translated into design principles for LF centres. The work offers a framework for developing design standards to strengthen outbreak management, and highlights the need for adaptable facilities and future research to define indicators linking design with health outcomes and patient experience.

**Keywords:** Lassa fever; Treatment centres; Design; Maternal and neonatal health; Reverse engineering.

## Introduction

Lassa fever (LF) is a viral haemorrhagic disease endemic to West Africa, with an estimated annual incidence of 100,000 to 300,000 cases, and a Case Fatality Rate (CRF) of approximately 15% in hospitalised patients (Naeem *et al.*, 2023).

First reported in the 1950s and identified in 1969, LF spreads via contact with infected rodents and their excreta and, secondarily, through body fluids of infected persons and contaminated surfaces (Goeijenbier *et al.*, 2013; Redding *et al.*, 2021). Pregnancy carries high risk, maternal mortality up to 30% in the third trimester, and more than 80% foetal loss, with obstetric complications increasing healthcare worker (HCW) exposure (Price *et al.*, 1988; Finnegan *et al.*, 2004; Shehu *et al.*, 2018; Chaudhary *et al.*, 2025).

Nosocomial transmission is central in LF outbreaks since the earliest cases were documented in healthcare settings in Nigeria, Liberia, and Togo (Balogun, Akande and Hamer, 2020). In endemic regions, most recorded outbreaks have occurred in health facilities, underscoring the consequences of inadequate Infection Prevention and Control (IPC) systems (Fisher-Hoch, 2005; Kernéis *et al.*, 2009). Prevention requires strict adherence to IPC protocols to avoid cross-transmission between patients, HCWs and caregivers.

Nigeria bears the highest LF burden, with more than 5,000 confirmed cases reported since 2020, and repeated large outbreaks since 2018. From January 2018 to December 2024, 75% of confirmed cases originated from Ondo (33%), Edo (31%), and Bauchi (11%) states. During the same period,

ne ancora poco indagata, particolarmente per quanto riguarda l'organizzazione spaziale e l'integrazione dei servizi destinati ai pazienti più vulnerabili, come donne in gravidanza e neonati.

**Obiettivo della ricerca** Lo studio analizza la progettazione e la costruzione dei CT per LF in Nigeria, con particolare attenzione a flussi, zonizzazione e integrazione delle funzioni di supporto. L'obiettivo è comprendere in che modo le configurazioni spaziali influenzino PCI, la gestione dei pazienti e la sicurezza degli OS durante le epidemie.

Oltre all'analisi delle strutture esistenti, lo studio intende individuare principi e indicazioni progettuali utili allo sviluppo di modelli di CT adattabili, sicuri e inclusivi.

**Metodologia e metodi** Per raccogliere dati sulla progettazione e funzionalità dei CT, è stata condotta una ricerca sistematica della letteratura su MEDLINE, Embase e Google Scholar, combinando termini liberi e vocabolari controllati (MeSH). Titoli e abstract sono stati selezionati da due revisori secondo criteri predefiniti; i testi completi sono stati valutati per la rilevanza. Eventuali discrepanze sono state risolte tramite confronto o con il supporto di un terzo revisore. Le liste di riferimenti degli articoli inclusi sono state esaminate manualmente per individuare ulteriori contributi.

Due organizzazioni umanitarie internazionali, che collaborano con il Ministero della Salute nigeriano, hanno fornito le planimetrie di tre CT; i direttori delle strutture hanno condiviso documentazione fotografica e rapporti descrittivi.

212 HCWs were infected, accounting for 4% of total cases, with the majority concentrated in these three states (NCDC, 2022).

Building on previous analyses of Ebola and Marburg Treatment Centres (Fontana *et al.*, 2024), this study focuses on permanent LF facilities that were chosen because the disease is endemic in Nigeria, and explores how more durable and inclusive spatial solutions can address maternal and neonatal health needs.

Although clinical care for LF has advanced and is relatively well documented (Alli *et al.*, 2021; Doohan *et al.*, 2024), the design of TC remains underexplored in either the scientific literature or in professional practice. Little evidence exists regarding optimal spatial organisation and the integration of services for vulnerable

patients such as pregnant women and neonates.

#### Objective of the research

The study examines the design and construction of LF TCs in Nigeria, focusing on flows, zoning, and support functions. The research aims to investigate how architectural layouts influence IPC, patient management, and HCW safety during outbreaks.

Beyond analysing existing facilities, the study aims to derive architectural design principles and lessons to support the development of adaptable, safe, and inclusive treatment centre models.

#### Methodology and methods

To obtain comprehensive data on the design and functionality of LF TCs, a systematic literature search was conducted in MEDLINE, Embase, and

Gli spazi disponibili (Tab. 1) sono stati analizzati con una metodologia precedentemente descritta (Fontana *et al.*, 2024): le planimetrie sono state ricostruite a partire dagli elaborati tecnici originali al fine di ottenere misure omogenee e visualizzare i flussi (Fig. 1).

Le planimetrie sono state analizzate mediante una tabella comparativa, per il confronto tra i CT e l'estrazione di principi progettuali (Tab. 2).

Gli indicatori (Figg. 2, 5) e le relative soglie di riferimento si basano su standard architettonici consolidati in ambito umanitario (CDC, 2014; World Health Organization, 2014; Médecins Sans Frontières, 2015).

Interviste semi-strutturate con i responsabili dei CT hanno fornito un contesto operativo ed esperti esterni hanno revisionato le planimetrie ricostruite e le analisi spaziali. Le strutture sono state anonimizzate e le osservazioni integrate iterativamente, al fine di garantire coerenza tra evidenze tecniche e condizioni operative reali.

Le differenze emerse tra i CT selezionati hanno permesso di individuare criticità trasversali, soluzioni progettuali ricorrenti e margini di miglioramento.

Sono stati analizzati tre CT utilizzati come principali strutture di riferimento durante i focolai in Nigeria: N01 (21 posti letto), N02 (53 posti letto) e N03 (132 posti letto). Sebbene concepiti come strutture permanenti di riferimento, i CT presentavano variazioni significative negli assetti spaziali, nelle capacità funzionali e nella dotazione di spazi di supporto. Tali differenze evidenziano il rapporto tra scala della struttura, diversità funzionale e capacità di sostenere le pratiche di PCI durante i focolai.

Google Scholar. Search strategies combined free-text terms with controlled vocabulary (MeSH) where available. Titles and abstracts were independently screened by two researchers against predefined eligibility criteria with full texts assessed for relevance. Discrepancies were resolved by discussion or consultation with a third reviewer. Reference lists of included articles were hand-searched to identify additional material.

In addition, two international humanitarian organisations collaborating with Nigeria's Ministry of Health were contacted, and provided the layouts of three TCs. Furthermore, the directors of these TCs were invited to provide photographic documentation and reports describing their facilities.

The spaces available (Tab. 1) in the collected layouts were analysed with a methodology previously described

(Fontana *et al.*, 2024). Layouts were reconstructed from technical drawings to both obtain consistent spatial measurements, and visualise circulation patterns (Fig. 1).

Beyond descriptive redrawing, the layouts were analysed using the following table 2 to compare the different TCs and to extract the design principles.

Indicator (figures 02 to 05) selection and thresholds were informed by established humanitarian architectural standards (CDC, 2014; World Health Organization, 2014; Médecins Sans Frontières, 2015).

Semi-structured interviews with facility managers added context beyond drawings. External experts reviewed reconstructed layouts and interpretations of the spatial analyses. Facilities were anonymised, and revisions incorporated iteratively to ensure consistency with operational realities.

Tab. 01 | Funzioni e definizioni degli spazi analizzati  
Functions and definitions of physical spaces assessed

| Physical Spaces Assessed    | Functions and Definitions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ambulance bay               | Area reserved for the arrival of the ambulance and the transfer of patients.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Waiting area                | The place where patients with symptoms wait to be taken care of by health personnel.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Screening and triage        | Screening is the process in which an individual is evaluated to see whether that person meets a standardized case definition. Triage is the process of sorting patients into categories based on the need for time-sensitive treatment using validated tools. Triage identifies those who require immediate medical intervention, and those who can safely wait. Triage may occur at a health post, primary health center, clinic, or emergency unit. It typically requires close physical contact (within 1 m) with the patient during the assessment. Within VHF treatment centers, often screening and triage take place in the same physical space; therefore, for the sake of this study, these areas were assessed and labeled as screening/triage areas. |
| Morgue                      | Morgue is the designated area within the treatment center for the temporary storage of deceased patients' bodies pending final disposition. This space may also feature a designated observation area that allows family members to safely view the deceased.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Offices                     | Dedicated spaces within the treatment center designated for administrative and operational staff to perform non-clinical duties essential to the facility's functioning. These areas are structured to support tasks such as data management, coordination of services, and communication without direct exposure to the pathogens.                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Waste area                  | Waste area is a specifically allocated space within the treatment center dedicated to storage and management of medical and non-medical waste generated by the facility's operations.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Suspect patients' area      | This is a designated section within the treatment center specifically allocated for the isolation and clinical management of individuals who meet the case definition for a suspected case.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Confirmed patients' area    | This is a designated section within the treatment center specifically allocated for the isolation and clinical management of individuals who meet the case definition for confirmed case.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Intensive care unit (ICU)   | In the context of this study, an "Intensive Care Unit" (ICU) can be defined as a specialized section dedicated to providing advanced medical care and continuous monitoring for patients suffering from severe and life-threatening manifestations of Ebola or Marburg virus diseases.                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Obstetric and delivery room | In the context of this study, an "Obstetric and Delivery Room" refers to a specially designated area where pregnant women diagnosed with Lassa Fever diseases receive focused care during labor and delivery.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Laboratory service          | In the context of this study, "Laboratory Service" refers to a dedicated facility designed to perform a wide range of medical diagnostics, including the detection of Lassa Fever using Polymerase Chain Reaction (PCR) testing, as well as various biochemistry analyses and other diagnostic procedures.                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Children and family spaces  | In the context of this study, "Children and Family Spaces" are specialized areas designed to support the unique needs of children and families of patients undergoing treatment for these severe viral infections.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Outdoor area                | In the context of this study, this is a designated outdoor space for suspect and confirmed patients.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Visitor area                | In the context of this study, this is a designated space within or outside the treatment center designed to accommodate visitors, allowing for controlled interaction with patients.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Low-risk area               | In the context of this study, the low-risk area is a designated section within the treatment center allocated for activities and functions that involve no direct exposure to the pathogens. This area, also referred to as the staff area, is where the presence of the virus is not expected.                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| High-risk area              | In the context of this study, the high-risk area is a designated section within the treatment center allocated for activities and functions that involve direct exposure to the pathogens. This area, also referred to as the patients' area, is where the presence of the virus is expected.                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Donning area                | A specifically designated space within the treatment center where healthcare workers and other staff members put on personal protective equipment (PPE).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Doffing area                | A specifically designated space within the treatment center where healthcare workers and other staff members take off PPE.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

| Tab. 01

The diversity among the selected TCs allows the identification of recurrent design strategies, critical gaps and opportunities for improvement. Three TCs were analysed as main referral facilities used during outbreaks in Nigeria, precisely N01 (21 beds), N02 (53 beds), and N03 (132 beds). Although all three were conceived as permanent referral facilities, their spatial layouts, functional capacities, and allocation of support spaces varied substantially. These differences highlight trade-offs between facility scale, functional diversity, and the capacity to sustain IPC practices during outbreaks.

**Results and discussion**

The three sites reflect geographic variation and operational diversity, enabling comparison of different architectural and clinical approaches.

*Centre profiles*

Three referral TCs were analysed, namely N01, with 21 beds; N02, with 53 beds; N03, with 132 beds. All conceived as permanent facilities, they differed markedly in spatial layouts, functional capacities, and support-space allocation. All three centres serve as referral facilities for confirmed LF patients, which explains the consistent absence of screening spaces in their layouts (Fig. 1).

N01 is the smallest facility and has a compact design. It features a single ambulance bay of 36.9 m<sup>2</sup> located inside the high-risk zone. Despite its limited size, it includes ICU and dialysis capacity. However, it does not provide maternity, obstetric, or paediatric services. Interviews revealed that obstetric emergencies frequently required outsourced solutions, often leading to external referrals, with the risk of de-

lays and higher cross-contamination. Lack of training areas and unclear circulation limit preparedness and IPC consistency. The facility has a high/low-risk ratio of 1.7 with 19.7 m<sup>2</sup> per bed in the high-risk area. While N01 is functional at small scale, its constraints in space and service scope could limit its ability to manage complex or vulnerable cases.

N02 is integrated into a teaching hospital and is a medium-capacity facility. The facility does not have an ambulance bay but it offers the most comprehensive range of clinical services, including maternity wards, a delivery suite, ICU capacity, dialysis, a surgery room, and staff training areas. This diversity enables management of both severe cases and vulnerable patient groups. The facility has a high/low-risk ratio of 1.5 with 24.1 m<sup>2</sup> per bed in the high-risk area. N02 stands out

as the only facility equipped to combine advanced care for severe LF with services for obstetric and paediatric patients.

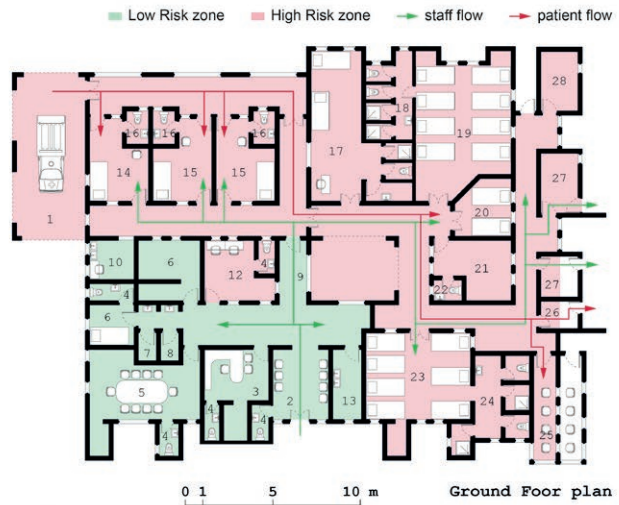
N03, the largest facility, was conceived as a specialised infectious disease hospital. It included two ambulance bays totalling 142 m<sup>2</sup>, both located in the high-risk zone. ICU space is available, but the absence of maternity and paediatric services forces transfers. Notes on the facility highlighted inadequacies in donning and doffing areas, and incomplete separation between disinfection and changing spaces.

From a design perspective, compact layouts such as N01 enhance containment and staff control but restrict functional expansion. In contrast, larger facilities like N03, while scalable, risk spatial fragmentation and reduced visibility. N02 represents a more balanced configuration integrating

## 01 | Treatment Centers layouts

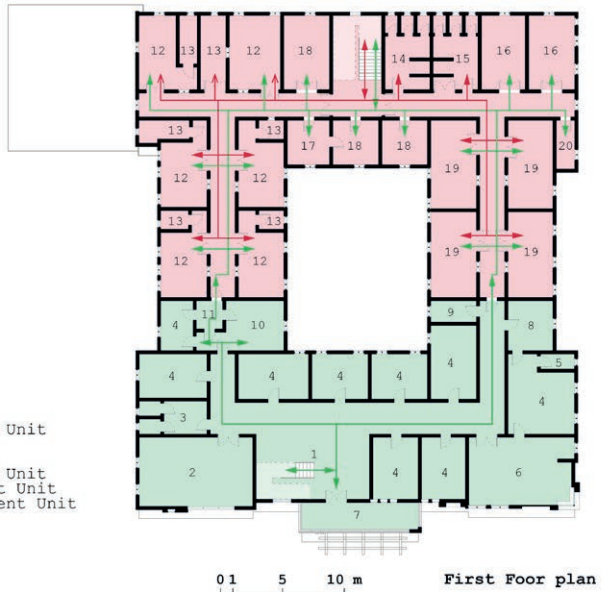
N01

1. Ambulance bay
2. Reception
3. Office
4. Staff toilet
5. Conference room
6. Staff rest room
7. Men locker
8. Women locker
9. Donning
10. Laboratory
12. Nursing station
13. Pharmacy
14. Dialysis room
15. Individual patient room
16. Individual toilet and shower
17. Intensive Care Unit (ICU)
18. Shared toilet and shower (women)
19. Shared room (women)
20. Shared room (children)
21. Delivery room
22. Shared toilet and shower (pregnant women)
23. Shared room (men)
24. Shared toilet and shower (men)
25. Visitor area
26. Discharge station
27. Doffing
28. Storage



N02

1. Lobby
2. Conference room
3. Staff toilet
4. Office
5. Staff toilet
6. Library
7. Balcony
8. Secretariat
9. House keeping
10. Nurse/Doctor station, into Special Isolation Unit
11. Donning
12. Shared room - Special Isolation Unit
13. Shared toilet and shower - Special Isolation Unit
14. Shared toilet and shower (men) - Convalescent Unit
15. Shared toilet and shower (women) - Convalescent Unit
16. Functional space/Clinical trials/Storage
17. Doffing
18. Functional space/Storage
19. Shared room - Convalescent Unit
20. House keeping



N03

1. Staff entrance
2. Doctor's common room
3. Staff Toilet/Shower
4. Nurse's room
5. Cleaners' closet (Donning)
6. Attendant's room
7. Changing room
8. Ambulance/Patient entrance
9. Patient entrance
10. Waiting room
11. Office
12. Pharmacy
13. Store
14. Intensive Care Unit (ICU) and Dialysis
15. Shared toilet and shower (ICU)
16. Monitoring station
17. Equipment room
18. Sterilizing room
19. Storage
20. Shared room
21. Shared toilet and shower
22. Monitoring station
23. Shared room
24. Shared toilet and shower
25. Disinfection/Changing point (Doffing)
26. Staff exit
27. Laundry
28. Staff shower
29. Outdoor staff office



Tab. 02 |

| Risk zoning balance        | Ratio between High-risk floor area (m²) / Low-risk floor area (m²)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Bed ratio                  | Surface in m²/bed in High-Risk zones.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Flow integrity             | <b>1. Staff flow:</b> <ul style="list-style-type: none"><li>– Separate clean/dirty staff access? (Yes/No)</li><li>– Unidirectional flow from low → high → low? (Yes/No/Partial)</li></ul> <b>2. Patient flow:</b> <ul style="list-style-type: none"><li>– Dedicated entrance/exit, no cross-over with staff/waste? (Yes/No)</li></ul> <b>3. Waste flow:</b> <ul style="list-style-type: none"><li>– Dedicated path for waste that does not cross clean flows? (Yes/No)</li></ul> <b>4. Donning/doffing points:</b> <ul style="list-style-type: none"><li>– Donning before entry to high-risk (present/absent);</li><li>– Doffing before re-entry to low-risk (present/absent);</li><li>– Physical separation with clear demarcation (adequate/inadequate).</li></ul> |
| Visibility without entry   | Visibility index = (Visible beds / Total high-risk beds) × 100%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Accessibility              | <ul style="list-style-type: none"><li>– <b>Door clear width</b> (cm) vs ≥110–120 cm</li><li>– <b>Turning radius</b> at junctions (does a bed/stretcher make a 90° turn without multi-point maneuver? Yes/No)</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Support functions          | <b>1. Presence (Y/N)</b> <ul style="list-style-type: none"><li>– Triage area</li><li>– Morgue</li><li>– Visitor area</li><li>– Survivor clinic (or long-term follow-up area)</li></ul> <b>2. Adequacy of size</b> <ul style="list-style-type: none"><li>– Simple ordinal scale per function:<ul style="list-style-type: none"><li>o 0 = absent</li><li>o 1 = present but undersized</li><li>o 2 = present and adequate</li></ul></li></ul> <b>3. Adjacency / zoning quality</b> <ul style="list-style-type: none"><li>– Triage: close to main entrance? (Yes/No)</li><li>– Morgue: accessible without crossing clean flows? (Yes/No)</li><li>– Survivor clinic: accessible from outside high-risk zone, with separation from patient entry. (Yes/No)</li></ul>       |
| Vulnerable-group readiness | <ul style="list-style-type: none"><li>– <b>Dedicated maternity bed/room available?</b> (Yes/No)</li><li>– <b>Dedicated pediatric bed/room available?</b> (Yes/No)</li><li>– <b>Ability to isolate mother + newborn together safely?</b> (Yes/No/Partial)</li><li>– <b>Ability to isolate pediatric patient with caregiver</b> (bed or proper space)? (Yes/No/Partial)</li></ul>                                                                                                                                                                                                                                                                                                                                                                                      |
| Outdoor therapeutic space  | Open-air surface available per bed (m²/bed).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

both infection control and functional diversity (Fig. 1).

*Zoning, donning and doffing areas and flows*

Quantitative analysis highlighted significant contrasts in spatial allocation across the three centres. N01 and N02 demonstrated relatively balanced high/low-risk ratios of 1.70 and 1.46, respectively, whereas N03 was heavily skewed toward high-risk areas at 3.17. High-risk space per bed was most generous in N02 (24.1 m²), followed by N01 (19.7 m²), while N03 offered only 7.6 m². A similar pattern was observed for low-risk space, with N02 allocating 16.5 m² per bed, N01 11.6 m², and N03 just 2.4 m². Inpatient space per bed also varied, being 6.4 m² in N01, 8.7 m² in N02, and 11.4 m² in N03. Although N03 provided the largest per-bed allocation, low-

risk space reduced operational effectiveness. In contrast, N02 achieved a more balanced distribution, while N01 remained the most spatially restricted. Donning areas were provided in all centres but varied in both size and redundancy. N01 included a single 6 m² donning space, limiting throughput during busy periods. N02 incorporated two donning areas with a combined surface of 16 m², offering greater operational flexibility. N03 provided a single, larger donning space of 20 m², but the absence of duplication reduced resilience during peak demand or staff surges. Doffing areas showed an even greater variation. N01 contained one minimal 6 m² space with cross-ventilation. N02 included two doffing areas totalling 16 m², supporting safer exit strategies under pressure. N03 dedicated 76 m² to doffing, the largest provision overall. While larger areas theoretically fa-

**Risultati e discussione**

I tre siti analizzati riflettono differenti contesti geografici e operativi, consentendo il confronto tra approcci architettonici e clinici diversi.

*Profili dei centri*

Sono stati esaminati tre CT: N01, con 21 posti letto; N02, con 53 posti letto; N03, con 132 posti letto. Concepite come strutture permanenti, presentano differenze nelle planimetrie, nelle capacità funzionali e nella dotazione di spazi di supporto. Tutti operano come centri di riferimento per pazienti confermati, condizione che spiega l'assenza di aree di screening (Fig. 1). N01 è la struttura più piccola e presenta un impianto compatto. È dotato di un'unica area per ambulanze di 36,9 m², situata all'interno della zona ad alto rischio. Nonostante la scala contenuta, N01 include spazi di terapia intensiva (ICU) e dialisi, ma non dispone di servizi di maternità, ostetricia o pediatria. Dalle interviste emerge che le emergenze ostetriche richiedono soluzioni esterne, con trasferimenti, ritardi e aumento del rischio di contaminazione. L'assenza di spazi per la formazione e di percorsi definiti indebolisce l'aderenza alle misure di PCI. Con un rapporto tra aree ad alto e basso rischio pari a 1,7 e una superficie di 19,7 m² per posto letto in area ad alto rischio, N01 risulta funzionale su piccola scala, ma i vincoli di spazio e di servizi possono limitare la gestione di casi complessi o di pazienti vulnerabili. N02 è integrato all'interno di un ospedale universitario e rappresenta una struttura di capacità intermedia. Non dispone di un'area per ambulanze, ma offre la gamma più completa di servizi clinici, con reparti di maternità, sala parto, ICU, dialisi,

cilitate safer doffing and accommodate surges, their effectiveness depends on integration with clear unidirectional flows and well-defined zoning. Unidirectional flow was variably maintained. N01 and N03 preserved integrity through staff training, though challenges remained. In N02, the two-storey configuration forced staff to pass through the same areas multiple times, undermining flow consistency. While this limitation was not critical under conditions where only confirmed patients were admitted, the design would require major modifications to safely accommodate suspected cases. Zoning, donning and doffing area differences are illustrated in figure 2.

*Visibility, accessibility, and provision of outdoor areas*

Differences also emerged in patient visibility and accessibility. In N01, the

absence of transparent barriers prevented staff from monitoring patients from low-risk areas, necessitating entry into wards with PPE even for basic surveillance. In contrast, N02 incorporated transparent partitions, enabling direct visual monitoring from the low-risk area to the ICU. However, staff stations in the low-risk zone lacked visual access to high-risk wards. As a result, routine monitoring still required donning PPE and entering patient areas. N03 also utilised transparent partitions, allowing continuous visual monitoring and reducing unnecessary PPE use. Design implications: Transparent partitions enable low-risk visual monitoring, cutting unnecessary entries and PPE use. They could be included as standard IPC and case management features (Fig. 3).

una sala operatoria e aree per la formazione. Questa articolazione funzionale consente la gestione sia di casi gravi sia di pazienti più vulnerabili. Il centro è caratterizzato da un rapporto tra aree ad alto e basso rischio pari a 1,5 e una superficie di 24,1 m<sup>2</sup> per posto letto in area ad alto rischio, configurandosi come l'unica struttura in grado di integrare cure avanzate per LF con l'assistenza ostetrica e pediatrica.

N03, la struttura più grande, è stata concepita come ospedale specializzato per le malattie infettive. Comprende due aree per ambulanze per un totale di 142 m<sup>2</sup>, entrambe situate nella zona ad alto rischio. Sono presenti spazi ICU, ma non servizi di maternità e pediatria, rendendo necessari trasferimenti o cure non ottimali. Sono state rilevate carenze nelle aree di vestizione e svestizione e una separazione incompleta tra spazi di decontaminazione e spogliatoi.

Da un punto di vista progettuale, i layout compatti (N01) favoriscono il controllo delle attività, ma limitano la possibilità di espansione. Al contrario, strutture più grandi (N03), pur scalabili, rischiano frammentazione spaziale e minore visibilità. N02 mostra un equilibrio migliore tra controllo delle infezioni e diversità funzionale (Fig. 1).

#### *Zonizzazione, aree di vestizione/svestizione e flussi*

L'analisi quantitativa ha evidenziato differenze significative nella distribuzione spaziale tra i tre centri. N01 e N02 hanno rapporti tra zona ad alto e basso rischio relativamente equilibrati (1,70 e 1,46), mentre N03 risulta fortemente sbilanciato a favore delle aree ad alto rischio con un rapporto pari a 3,17. La superficie ad alto rischio per posto letto è maggiore in N02 (24,1 m<sup>2</sup>), seguita da N01 (19,7 m<sup>2</sup>), e minore in N03 con 7,6 m<sup>2</sup>. Un

andamento analogo si osserva per le aree a basso rischio: 16,5 m<sup>2</sup> in N02, 11,6 m<sup>2</sup> in N01 e appena 2,4 m<sup>2</sup> in N03.

Anche lo spazio complessivo per posto letto varia tra i CT: 6,4 m<sup>2</sup> in N01, 8,7 m<sup>2</sup> in N02 e 11,4 m<sup>2</sup> in N03. In N03, la prevalenza di aree ad alto rischio e la scarsità di aree a basso rischio ne compromettono l'efficacia operativa; N02 risulta il più bilanciato, N01 il più vincolato.

Le aree di vestizione di Dispositivi di Protezione Individuale (DPI) sono presenti in tutti i centri, ma variano per dimensioni e numero: N01 include un unico spazio di 6 m<sup>2</sup>, che limita la capacità nei periodi di maggiore affluenza; N02 include due aree per un totale di 16 m<sup>2</sup>, offrendo maggiore flessibilità operativa. N03 dispone di un unico spazio più ampio (20 m<sup>2</sup>), ma l'assenza di altre aree riduce la capacità in caso di aumento di pazienti o di personale.

Le aree di svestizione mostrano differenze ancora più marcate. N01 dispone di uno spazio minimo di 6 m<sup>2</sup>, con ventilazione incrociata. N02 dispone di due aree per un totale di 16 m<sup>2</sup>, favorendo modalità di uscita più sicure. N03 dispone di aree di svestizione per un totale di 76 m<sup>2</sup>, la più estesa tra i tre CT. Tuttavia, superfici più ampie non garantiscono maggiore sicurezza senza una zonizzazione chiara e flussi unidirezionali.

La gestione dei flussi nei centri N01 e N03 è garantita grazie alla formazione del personale, nonostante le criticità. In N02 la configurazione su due livelli costringe il personale a passaggi ripetuti nelle stesse aree, compromettendo la coerenza dei flussi. Tale limite richiederebbe modifiche sostanziali qualora il centro dovesse accogliere anche casi sospetti.

Le differenze relative alla zonizzazione e alle aree di vestizione (*Donning*) e svestizione (*Doffing*) sono illustrate in figura 2.

Accessibility standards were inconsistently applied across sites. The ward entrance in N01 measured only 0.85 m, below the international standard of 1.0 m, thereby restricting wheelchair access and complicating stretcher transfers. N02 fully complied with accessibility standards, whereas N03 provided the most generous access, with an entrance width of 1.70 m, facilitating smooth mobility for both wheelchairs and stretchers.

Outdoor space provision further distinguished the centres. Neither N01 nor N03 included outdoor areas, while N02 incorporated an outdoor space equivalent to 1.2 m<sup>2</sup> per bed, supporting patient rehabilitation and psychosocial well-being.

Areas and services related to visibility, accessibility, and outdoor spaces are illustrated in figure 3.

#### *Supportive areas*

The configuration of waiting, triage, morgue and visitor areas varied considerably across the three centres. N03 incorporated a waiting area of 43 m<sup>2</sup> (0.3 m<sup>2</sup> per bed), designed to be accessible for patients with reduced mobility, and included a dedicated triage space.

Visitor policies reflected distinct design philosophies. N01 included a 17 m<sup>2</sup> visitor room (0.8 m<sup>2</sup> per bed) located within ten metres of patient wards. While this facilitated family presence, it also raised IPC concerns. N02 did not include visitor areas within the facility, restricting family interaction to external spaces. N03 provided no visitor space, thereby eliminating family presence from the treatment environment altogether.

Survivor clinics were the only outpatient service consistently integrated in

all three centres. These facilities provided follow-up care for discharged patients, including management of sequelae and psychosocial support. It reflected a shared recognition of the need for continuity of care beyond acute treatment.

Morgues were inconsistently integrated. N01 and N03 lacked mortuary capacity, relying instead on external arrangements. N02, by contrast, included a 44 m<sup>2</sup> morgue (0.8 m<sup>2</sup> per bed) with a viewing area for relatives, reflecting more comprehensive planning for safe and dignified management of the deceased.

Figure 4 highlights the absence of standardised solutions for visitor management and morgue provision. Architectural solutions enabling controlled family contact-through viewing areas or separated visitor zones-could en-

hance psychosocial support without compromising infection control.

The screening-visitor-survivor-morgue chain follows VHF operational guidance for safe and dignified burial management (CDC, 2014).

#### *Specialised care*

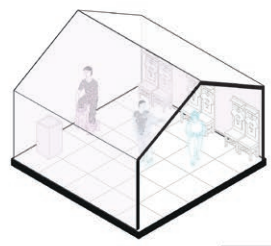
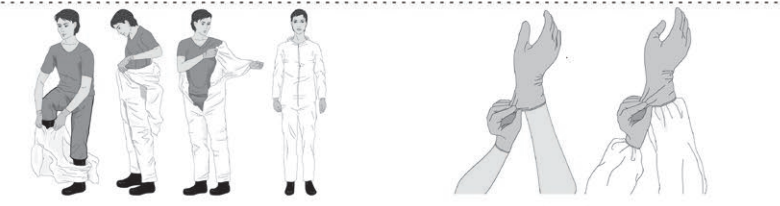
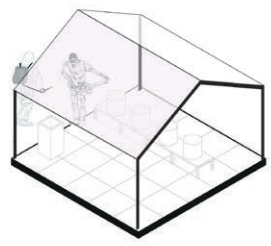
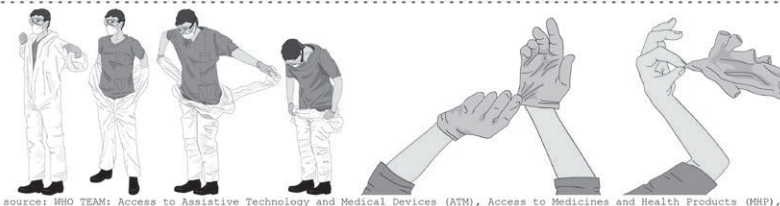
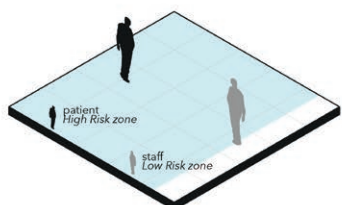
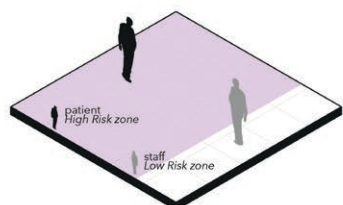
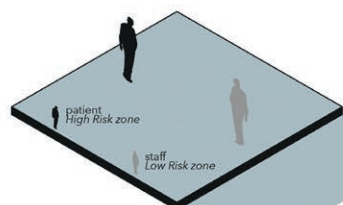
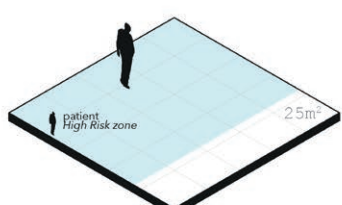
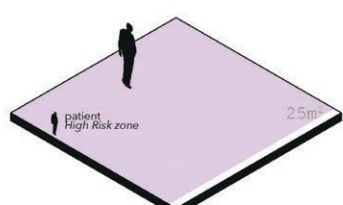
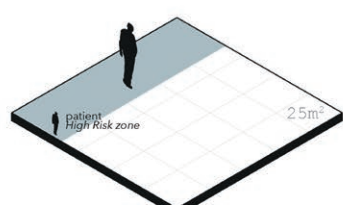
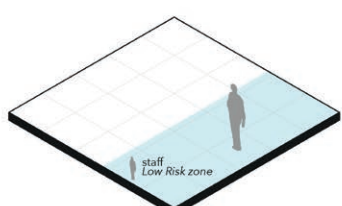
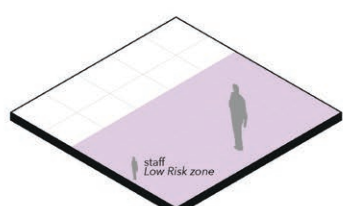
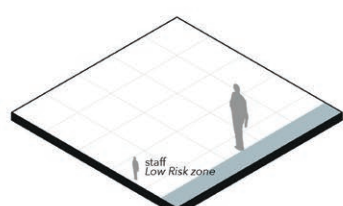
Specialised services also varied substantially. ICUs were present in all three facilities, reflecting a uniform recognition of the importance of advanced monitoring and treatment for severe cases. However, surgical capacity was provided only in N02. This absence in N01 and N03 restricted their ability to manage complications requiring operative intervention, such as obstetric emergencies.

Dialysis services were integrated across all centres but differed in configuration. N01 and N02 offered standalone dialysis units, whereas N03

## Zoning, donning and doffing areas

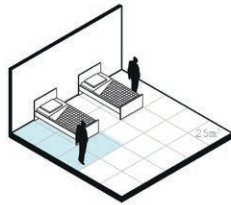
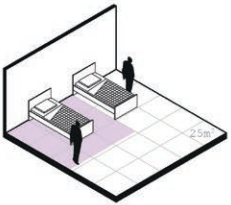
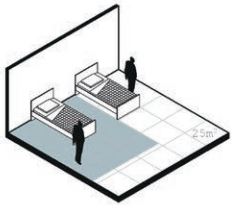
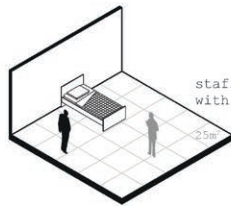
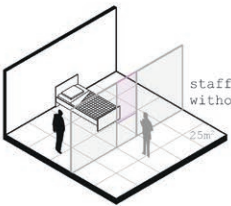
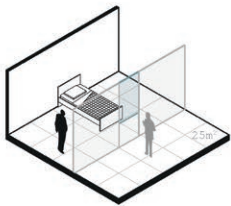
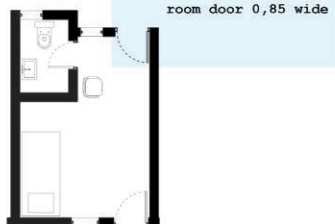
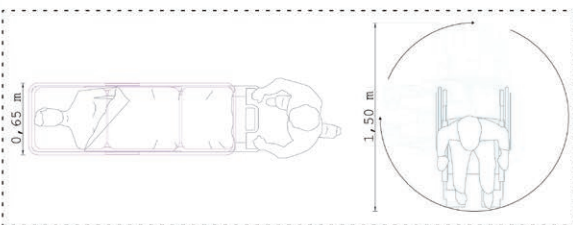
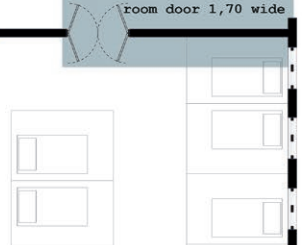
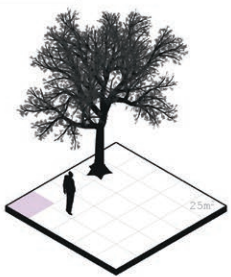
X: Yes  
N/A: Not Applicable

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| N01                                                                                                                                                                                                                        | N02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | N03                                                                                                                                                                                                                           |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Donning area</b></p> <p>1 num. of donning area<br/>6 m<sup>2</sup> total surface</p>  <p>area within High Risk zone: X</p>          | <p><b>Donning area</b></p> <p>2 num. of donning area<br/>16 m<sup>2</sup> total surface</p>  <p>source: WHO TEAM: Emergency Preparedness (NPE) (2017) Steps to put on personal protective equipment (PPE) including coverall</p> <p>area within High Risk zone: X</p>                                                                                                                                                                         | <p><b>Donning area</b></p> <p>1 num. of donning area<br/>20 m<sup>2</sup> total surface</p>  <p>area within High Risk zone: N/A</p>        |
| <p><b>Doffing area</b></p> <p>1 num. of doffing area<br/>6 m<sup>2</sup> total surface</p>  <p>Single sided   Cross ventilation<br/>X</p> | <p><b>Doffing area</b></p> <p>2 num. of doffing area<br/>16 m<sup>2</sup> total surface</p>  <p>source: WHO TEAM: Access to Assistive Technology and Medical Devices (ATM), Access to Medicines and Health Products (MHP), Health Product Policy and Standards (HPS), Medical Devices and Diagnostics (MDD) (2015) Steps to take off personal protective equipment (PPE) including coverall</p> <p>Single sided   Cross ventilation<br/>X</p> | <p><b>Doffing area</b></p> <p>4 num. of doffing area<br/>76 m<sup>2</sup> total surface</p>  <p>Single sided   Cross ventilation<br/>X</p> |
| <p><b>High Risk zone/Low Risk zone ratio</b></p> <p>1,7</p>  <p>patient High Risk zone<br/>staff Low Risk zone</p>                      | <p><b>High Risk zone/Low Risk zone ratio</b></p> <p>1,5</p>  <p>patient High Risk zone<br/>staff Low Risk zone</p>                                                                                                                                                                                                                                                                                                                           | <p><b>High Risk zone/Low Risk zone ratio</b></p> <p>3,2</p>  <p>patient High Risk zone<br/>staff Low Risk zone</p>                       |
| <p><b>High Risk zone/bed ratio</b></p> <p>18,8 m<sup>2</sup></p>  <p>patient High Risk zone<br/>25m<sup>2</sup></p>                     | <p><b>High Risk zone/bed ratio</b></p> <p>24,1 m<sup>2</sup></p>  <p>patient High Risk zone<br/>25m<sup>2</sup></p>                                                                                                                                                                                                                                                                                                                          | <p><b>High Risk zone/bed ratio</b></p> <p>7,6 m<sup>2</sup></p>  <p>patient High Risk zone<br/>25m<sup>2</sup></p>                       |
| <p><b>Low Risk zone/bed ratio</b></p> <p>11,1 m<sup>2</sup></p>  <p>staff Low Risk zone</p>                                             | <p><b>Low Risk zone/bed ratio</b></p> <p>16,5 m<sup>2</sup></p>  <p>staff Low Risk zone</p>                                                                                                                                                                                                                                                                                                                                                  | <p><b>Low Risk zone/bed ratio</b></p> <p>2,4 m<sup>2</sup></p>  <p>staff Low Risk zone</p>                                               |

## 03 | Visibility, accessibility and outdoor area

X: Yes  
 NA: Not Available

| N01                                                                                                                                                                                            | N02                                                                                                                                                                                     | N03                                                                                                                                                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Bed capacity</b><br>21 beds                                                                                                                                                                 | <b>Bed capacity</b><br>53 beds                                                                                                                                                          | <b>Bed capacity</b><br>121 beds                                                                                                                                                              |
| <b>Patient ward/room</b><br>98 37 m <sup>2</sup> total surface<br>6,4 m <sup>2</sup> /bed surface per bed<br> | <b>Patient ward</b><br>460 m <sup>2</sup> total surface<br>8,7 m <sup>2</sup> /bed surface per bed<br> | <b>Patient ward</b><br>1.510 m <sup>2</sup> total surface<br>11,4 m <sup>2</sup> /bed surface per bed<br> |
| <b>Transparent barrier</b><br>NA<br>no direct visibility of the patient from Low Risk zone<br>               | <b>Transparent barrier</b><br>X<br>direct visibility of the patient from Low Risk zone<br>            | <b>Transparent barrier</b><br>X<br>direct visibility of the patient from Low Risk zone<br>               |
| <b>Accessibility</b><br>patient ward/room not accessible<br>room door 0,85 wide<br>                         | <b>Accessibility</b><br>X<br>patient ward/room accessible<br>                                       | <b>Accessibility</b><br>X<br>patient ward/room accessible<br>room door 1,70 wide<br>                    |
| <b>Outdoor area</b><br>NA<br>                                                                               | <b>Outdoor area</b><br>1.2 m <sup>2</sup> /bed surface per bed<br>                                   | <b>Outdoor area</b><br>NA<br>                                                                           |

**accessible:** whether the access door is at least 1,0 meter wide and is on the level 0, to allow passage for a wheelchair. The space should ensure enough clearance for a wheelchair to turn within a 1,50 meter diameter.

### Visibilità, accessibilità e spazi esterni

Sono emerse differenze in termini di visibilità dei pazienti e accessibilità. In N01, l'assenza di partizioni trasparenti impedisce al personale di monitorare i pazienti dalle aree a basso rischio, rendendo necessario l'ingresso nei reparti con DPI anche per controlli di base. In N02 sono presenti partizioni trasparenti verso l'ICU, ma le postazioni del personale non garantiscono una visibilità adeguata sui reparti ad alto rischio, rendendo comunque necessario l'accesso con DPI. In N03, l'adozione di partizioni trasparenti permette un monitoraggio continuo, riducendo l'uso non necessario di DPI.

Le partizioni trasparenti consentono il monitoraggio dei pazienti dalle aree a basso rischio e potrebbero essere considerati elementi standard a supporto delle strategie di PCI e della gestione clinica dei casi (Fig. 3).

Gli standard di accessibilità sono applicati in modo non uniforme. In N01, l'ingresso del reparto misura solo 0,85 m, al di sotto dello standard internazionale di 1,0 m, limitando l'accesso in sedie a rotelle e i trasferimenti con barella. N02 rispetta pienamente i requisiti di accessibilità, mentre N03 garantisce l'accesso più ampio con una larghezza di 1,70 m, facilitando la mobilità sia delle sedie a rotelle sia delle barelle.

La presenza di spazi esterni rappresenta un'ulteriore differenza tra i CT. Solo N02 include uno spazio esterno pari a 1,2 m<sup>2</sup> per posto letto, a supporto della riabilitazione e del benessere psicosociale dei pazienti.

Aree e servizi relativi a visibilità, accessibilità e spazi esterni sono illustrati in figura 3.

### Aree di supporto

La configurazione delle aree di attesa, triage, obitorio e spazi per i visitatori varia tra i tre CT. N03 include un'area di attesa di 43 m<sup>2</sup> (0,3 m<sup>2</sup> per posto letto), accessibile per pazienti con mobilità ridotta, e un triage dedicato, utile in caso di accesso di pazienti sospetti.

La gestione dei visitatori riflette diversi approcci progettuali. N01 dispone di una sala visitatori di 17 m<sup>2</sup> (0,8 m<sup>2</sup> per posto letto) entro dieci metri dai reparti, facilitando la presenza dei familiari, ma con criticità in termini di PCI. N02 non prevede spazi per i visitatori all'interno della struttura, limitando l'interazione familiare, mentre N03 non include spazi per le visite. Le cliniche per sopravvissuti sono l'unico servizio ambulatoriale comune ai tre CT e garantiscono follow-up clinico e supporto psicosociale dopo la dimissione.

Gli obitori non sono presenti nei centri N01 e N03 e si affidano a soluzioni esterne, mentre N02 dispone di un obitorio di 44 m<sup>2</sup> (0,8 m<sup>2</sup> per posto letto) con un'area di osservazione per i familiari, evidenziando la necessità di una gestione sicura e dignitosa dei defunti.

La figura 4 evidenzia l'assenza di soluzioni standardizzate. Aree di osservazione o spazi per visitatori separati, che consentano un contatto familiare controllato, potrebbero rafforzare il supporto psicosociale senza compromettere il controllo delle infezioni. La sequenza funzionale screening-visitatori-sopravvissuti-obitorio è coerente con la guida operativa VHF per la gestione sicura e dignitosa dei deceduti (CDC, 2014).

co-located dialysis within the ICU, a design that facilitated oversight but limited flexibility when both services were required simultaneously.

Maternity and delivery rooms were included in N01 and N02 but were absent in N03. Given the disproportionate risk LF poses to pregnant women, the omission of obstetric capacity in the largest facility represented a critical shortcoming. Paediatric wards followed a similar pattern, being included in N01 and N02 but excluded in N03. This omission highlighted the limited inclusivity of the largest centre, which, despite its scale, failed to address the needs of vulnerable populations.

Laboratories were the only consistently provided function across all three facilities, underscoring universal recognition of the need for on-site diagnostics to confirm cases and monitor treatment progression.

Figure 5 shows inconsistent integration of obstetric and paediatric services.

### Adherence to national guidance

Nigerian VHF IPC guidance requires entrance screening, unidirectional flows (staff, patients, waste, deceased), barrier nursing and rigorous hygiene/disinfection (Akpede *et al.*, 2018; NCDC, 2020). Among the three referral centres – each admitting confirmed cases – none included screening/triage spaces in the layouts, which is consistent with their referral role but implies reliance on external screening nodes (Fig. 1). Flow integrity varied with N02 showing clearer zoning and redundant donning/doffing, compared with N01 and N03, aligning more closely with IPC expectations (Fig. 2). Visitor mediation and mortuary solutions were standardised only in N02

(Fig. 4). Overall, partial adherence was observed with gaps in visibility features and services for vulnerable groups, especially in N03 (Figs. 3, 5).

### Common challenges

Several recurrent challenges were observed, despite some variations. In all three centres, demarcation of donning and doffing areas could be further clarified to reduce contamination risks. Facilities for staff support and training were limited. Only one of the three centres (N02) included dedicated training areas, which may contribute to fatigue and affect adherence to IPC measures. Circulation patterns did not always achieve a fully unidirectional flow between high-risk and low-risk areas, thus raising potential safety concerns. Provision of maternity and paediatric care was inconsistent, leaving some gaps in services for vulnerable

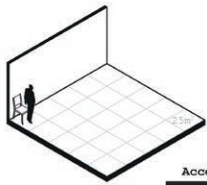
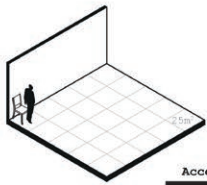
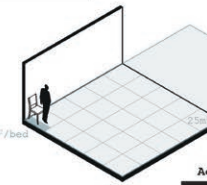
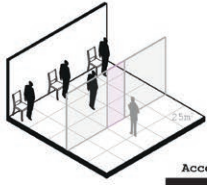
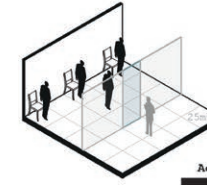
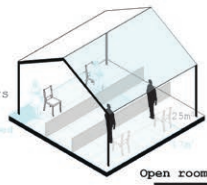
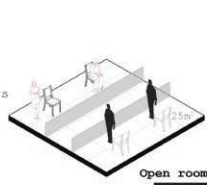
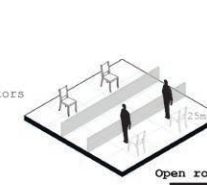
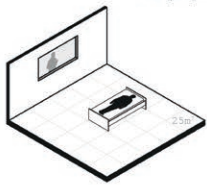
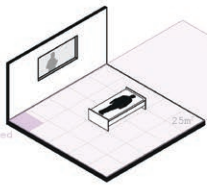
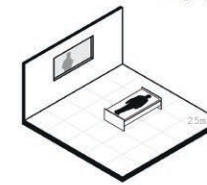
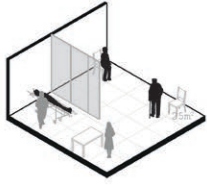
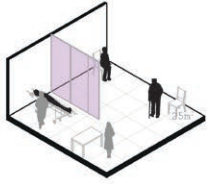
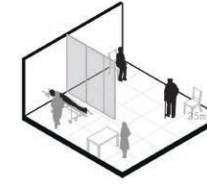
patient groups. Visitor areas were often improvised or not well integrated, making safe family interaction more difficult.

HCW interviews supported these observations. Staff described challenges in facilitating patient-family contact, and in adapting facilities to the changing needs of outbreak response. These qualitative insights reinforced the architectural analysis, suggesting that spatial and functional constraints can translate into operational difficulties during outbreaks.

Concerning pathogen-specific implications, LF's burden in pregnancy makes obstetric/delivery capacity and neonatal isolation core functions. Ebola/Marburg TCs prioritise larger doffing suites, longer suspect holding, and stricter cohorting. LF referral TCs – often for confirmed cases – still benefit from entry screening to redirect

## 04 | Supportive areas

X: Yes  
NA: Not Available  
N/A: Not Applicable

| <p><b>N01</b></p> <p><b>Waiting area</b><br/>NA</p>  <p><b>Accessibility</b><br/>N/A</p>                                                                                                                                                                                   | <p><b>N02</b></p> <p><b>Waiting area</b><br/>NA</p>  <p><b>Accessibility</b><br/>N/A</p>                                                                                                                                                                                                                                                                      | <p><b>N03</b></p> <p><b>Waiting area</b><br/>43 m<sup>2</sup> total surface<br/>0,3 m<sup>2</sup>/bed surface per bed</p>  <p><b>Accessibility</b><br/>X</p>                                                                   |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Screening/Triage</b><br/>N/A* m<sup>2</sup><br/>N/A* m<sup>2</sup>/bed</p>  <p><b>Accessibility</b><br/>N/A</p> <p><i>*Not Applicable: Screening/Triage area is outside the building and not included in the project drawing</i></p>                                 | <p><b>Screening/Triage</b><br/>NA</p>  <p><b>Accessibility</b><br/>N/A</p>                                                                                                                                                                                                                                                                                    | <p><b>Screening/Triage</b><br/>NA</p>  <p><b>Accessibility</b><br/>N/A</p>                                                                                                                                                     |
| <p><b>Visitor area</b><br/>17 m<sup>2</sup> total surface<br/>0,8 m<sup>2</sup>/bed surface per bed</p>  <p><b>Open room   Closed room</b><br/>  X</p> <p><b>area close to patient ward/room:</b> X<br/>[close: the farthest room is at a distance of less than 10m]</p> | <p><b>Visitor area</b><br/>N/A* m<sup>2</sup><br/>N/A* m<sup>2</sup>/bed</p>  <p><b>Open room   Closed room</b><br/>X  </p> <p><b>area close to patient ward/room:</b> N/A<br/>[close: the farthest room is at a distance of less than 10m]</p> <p><i>*Not Applicable: Visitor area is outside the building and not included in the project drawing</i></p> | <p><b>Visitor area</b><br/>NA</p>  <p><b>Open room   Closed room</b><br/>N/A  </p> <p><b>area close to patient ward/room:</b> N/A<br/>[close: the farthest room is at a distance of less than 10m]</p>                       |
| <p><b>Morgue</b><br/>N/A* m<sup>2</sup><br/>N/A* m<sup>2</sup>/bed</p>  <p><b>viewing area, for relatives:</b> NA</p> <p><i>*Not Applicable: Morgue is outside the building and not included in the project drawing</i></p>                                              | <p><b>Morgue</b><br/>44 m<sup>2</sup> total surface<br/>0,8 m<sup>2</sup>/bed surface per bed</p>  <p><b>viewing area, for relatives:</b> X</p>                                                                                                                                                                                                             | <p><b>Morgue</b><br/>N/A* m<sup>2</sup><br/>N/A* m<sup>2</sup>/bed</p>  <p><b>viewing area, for relatives:</b> N/A</p> <p><i>*Not Applicable: Morgue is outside the building and not included in the project drawing</i></p> |
| <p><b>Survivor clinic</b></p>                                                                                                                                                                                                                                            | <p><b>Survivor clinic</b><br/>X</p>                                                                                                                                                                                                                                                                                                                         | <p><b>Survivor clinic</b></p>                                                                                                                                                                                                |

### *Cure specialistiche*

Tutti i CT sono dotati di ICU, confermando l'importanza del monitoraggio avanzato e del trattamento dei casi gravi, ma solo N02 include una sala operatoria dedicata. L'assenza in N01 e N03 limita la gestione di complicanze, incluse le emergenze ostetriche. La dialisi è presente nei tre CT, ma con configurazioni diverse: unità autonome in N01 e N02; integrazione con l'ICU in N03, una scelta progettuale che facilita la supervisione, ma limita la flessibilità quando i due servizi sono richiesti contemporaneamente.

I servizi di maternità, parto e pediatria sono presenti in N01 e N02, ma assenti in N03. Considerato l'elevato rischio associato alla LF in gravidanza, questa mancanza nella struttura più grande rappresenta una importante criticità.

Tutti i centri dispongono di laboratori, sottolineando la necessità di diagnostica in loco per la conferma dei casi e il monitoraggio clinico.

La figura 5 mostra la distribuzione disomogenea dei servizi ostetrici e pediatrici.

### *Aderenza alle linee guida nazionali.*

Le linee guida nigeriane per la PCI nelle VHF prevedono screening, flussi unidirezionali (personale, pazienti, rifiuti, deceduti), barrier nursing e rigorose misure di igiene e disinfezione (Akpede *et al.*, 2018; NCDC, 2020). Nei tre centri non sono presenti aree di screening/triage, in coerenza con il ruolo di CT per pazienti confermati; ciò implica la necessità di spazi di screening esterni (Fig. 1).

N02 presenta una zonizzazione più chiara e più aree di vestizione e svestizione rispetto a N01 e N03, mostrando mag-

giore aderenza alle indicazioni PCI (Fig. 2). Aree destinate alle visite e l'obitorio risultano presenti solo in N02, mentre sono parziali o assenti negli altri centri (Fig. 4). Nel complesso emerge un'aderenza parziale alle linee guida, con carenze su visibilità e servizi per pazienti vulnerabili, in particolare in N03 (Figg. 3, 5).

### *Sfide comuni*

Nonostante le differenze, emergono criticità comuni: delimitazione poco chiara delle aree di vestizione e svestizione, per ridurre i rischi di contaminazione; spazi limitati per la formazione del personale (solo N02 dispone di aree dedicate), che può influire sull'aderenza alle misure di PCI; flussi non sempre unidirezionali, sollevando criticità in termini di sicurezza; carenza nei servizi di maternità e pediatria, con lacune nell'assistenza ai gruppi più vulnerabili; aree per i visitatori, quando presenti, poco integrate, rendendo complessa l'interazione familiare sicura.

Le interviste con gli OS hanno confermato tali osservazioni, evidenziando difficoltà nel garantire un contatto sicuro con i familiari e nell'adattare le strutture a esigenze variabili. Queste evidenze qualitative rafforzano l'analisi, mostrano come vincoli spaziali e funzionali si traducano in difficoltà operative durante i focolai.

L'impatto della LF in gravidanza rende centrali le funzioni ostetriche e neonatali. Al contrario, i CT per Ebola e Marburg privilegiano aree di svestizione più ampie, una degenza più lunga dei sospetti e un isolamento più rigoroso. I CT per LF - spesso per i casi confermati - beneficiano di uno screening all'ingresso per reindirizzare i sospetti, ma dovrebbero privi-

mis-routed suspects, but should shift footprint toward maternity/paediatrics and Low-Risk visibility (transparent partitions) without weakening IPC (Fig. 3). This explains why N02's balanced zoning and maternity/surgery stack fit LF needs better than N03's scale without inclusive services (Figs. 2, 5).

### *From layouts to design principles*

Cross-case synthesis yields five principles for Lassa Fever TCs (Tab. 3). These principles adapt established ETC architectural standards to LF referral contexts (CDC, 2014; World Health Organization, 2014; Médecins Sans Frontières, 2015).

### *Limitations*

The limited number of case studies precludes statistical generalisation. Nevertheless, triangulating layouts,

literature-derived evidence, HCW interviews and external expert review offers robust qualitative insight. The diversity among the selected TCs supports the identification of recurrent design strategies, critical gaps and opportunities for improvement.

### **Conclusions**

The comparative analysis of three LF TCs in Nigeria highlights important variability in spatial configuration, functional scope, and supportive infrastructure, underscoring the need for harmonised, evidence-based design criteria.

The absence of harmonised design standards has contributed to inconsistent provision of functions such as maternity and paediatric care, morgue capacity, and staff support spaces. Clear design criteria are needed to ensure safe, inclusive and resilient facilities.

This study offers an architectural and functional assessment of three main TCs used during recent LF outbreaks in Nigeria. Findings show variations in capacity, zoning, accessibility, and service integration, influencing patient care, staff safety, and IPC effectiveness. Only one facility had a dedicated maternity ward, while others lacked services for pregnant women and children, who are particularly vulnerable to LF. Limited separation of flows, constrained donning and doffing areas, and inflexible layouts sometimes hindered adaptability during emergencies. In certain cases, spatial arrangements reduced staff visibility of patients from low-risk areas, necessitating more frequent entry into high-risk zones. These issues affected operational efficiency, and underline the importance of spatial design in outbreak response.

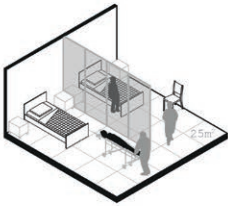
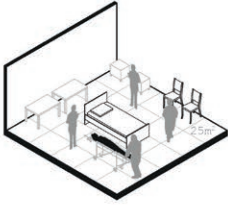
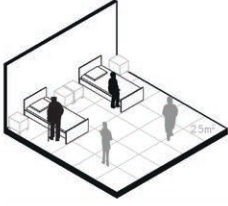
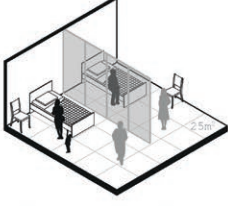
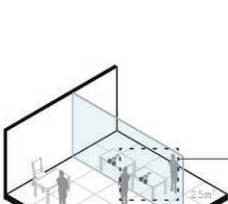
Addressing such gaps will require evidence-based design guidance tailored to epidemic-prone contexts. Priorities include dedicated maternity and paediatric spaces, minimum per-bed space standards, well-demarcated donning and doffing areas for unidirectional flows, and modular layouts for surges.

Although centred on Nigeria, the lessons from this analysis on IPC, patient privacy and staff support can inform TC planning globally, especially in epidemic-prone regions. Facility design can become a core component of global health preparedness.

Future work should seek to establish standardised indicators to assess how design influences clinical outcomes, staff safety, and patient experience. Expanding data collection through both quantitative and qualitative methods will deepen understanding of the im-

05 | Specialised care

X: Yes

|                                                                                     | N01                            | N02                            | N03                                                                                  |
|-------------------------------------------------------------------------------------|--------------------------------|--------------------------------|--------------------------------------------------------------------------------------|
|    | Intensive Care Unit (ICU)<br>X | Intensive Care Unit (ICU)<br>X | Intensive Care Unit (ICU)<br>X                                                       |
|    | Surgery room                   | Surgery room<br>X              | Surgery room                                                                         |
|    | Dialysis area<br>X             | Dialysis area<br>X             | Dialysis area<br>X*<br><br>*Dialysis is located inside the Intensive Care Unit (ICU) |
|  | Delivery room<br>X             | Delivery room<br>X             | Delivery room                                                                        |
|  | Laboratory<br>X                | Laboratory                     | Laboratory                                                                           |

pact of facility design on outbreak response.  
In conclusion, integrating evidence-based architectural principles into LF TC planning can strengthen preparedness, reduce transmission, and sustain efficient, inclusive responses.

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The authors thank Dr. Mahmood Dalhat, Dr. Yusuf Jibrin, Dr. Anaïs Legand, Dr. Sylvanus Okogbenin, and Dr. Joshua Ofoli for facilitating access to tech-

nical documentation. Special thanks are extended to Dr. Mahmood Dalhat, Dr. Yusuf Jibrin, and Dr. Sylvanus Okogbenin for their availability, and for generously sharing their in-depth knowledge during the interviews.

legiare funzioni di maternità/pediatria e visibilità dalle zone a basso rischio, senza compromettere PCI (Fig. 3). Questo spiega perché la zonizzazione equilibrata e i servizi di maternità e chirurgia in N02 rispondono meglio alle esigenze della LF, rispetto alle maggiori dimensioni di N03 privo di servizi inclusivi (Figg. 2, 5).

### Dai layout ai principi di progettazione

La sintesi trasversale restituisce cinque principi per i CT per LF (Tab. 3).

Questi principi rielaborano gli standard architettonici consolidati per ETC, adattandoli ai contesti di riferimento per LF (CDC, 2014; World Health Organization, 2014; Médecins Sans Frontières, 2015).

### Limitazioni

Il numero ridotto di casi studio non consente generalizzazioni statistiche. Tuttavia, la triangolazione tra planimetrie, evidenze in letteratura, interviste con OS e revisione da esperti esterni fornisce un quadro qualitativo solido. La diversità tra i tre CT permette l'identificazione di strategie ricorrenti, criticità e margini di miglioramento.

### Conclusioni

L'analisi comparativa di tre CT per LF in Nigeria evidenzia una marcata variabilità nella configurazione spaziale, funzionale e nelle infrastrutture di supporto, sottolineando la necessità di criteri progettuali coerenti basati su evidenze.

L'assenza di standard condivisi ha contribuito a una dotazione disomogenea di servizi di maternità e pediatria, capacità mortuaria e spazi per il personale, rendendo necessarie linee guida progettuali per strutture sicure, inclusive e resilienti.

Lo studio propone una valutazione architettonica e funzionale di tre CT per LF impiegati durante i recenti focolai in Nigeria, evidenziando differenze in termini di capienza, zonizzazione, accessibilità e integrazione dei servizi. Questi aspetti incidono sull'assistenza ai pazienti, sulla sicurezza del personale e sull'efficacia delle misure di PCI. La carenza di servizi sia per donne in gravidanza sia per bambini (presenti entrambi in un solo CT), la limitata separazione dei flussi, gli spazi ridotti per vestizione e svestizione dei DPI e le planimetrie rigide hanno talvolta ostacolato l'adattabilità nelle emergenze. In alcuni casi, le configurazioni spaziali riducono la visibilità dalle aree a basso rischio, aumentando gli ingressi del personale nelle zone ad alto rischio. Tali criticità incidono sull'efficienza operativa e confermano l'importanza della progettazione dello spazio nella risposta ai focolai.

Colmare queste lacune richiede linee guida progettuali basate su evidenze, adattate ai contesti a rischio epidemico. Tra le pri-

|                                      |                                                                                                                                  |         |
|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|---------|
| <b>Balance risk zoning</b>           | to avoid staff congestion and keep unidirectional flows (Fig. 2).                                                                | Tab. 03 |
| <b>Visibility</b>                    | transparent partitions and clear staff sightlines, to cut avoidable entries into High-Risk zones and reduce PPE burden (Fig. 3). |         |
| <b>Design for vulnerable groups</b>  | by integrating dedicated maternity/delivery and paediatrics, as standard programme elements, not additions (Fig. 5).             |         |
| <b>Complete the supportive chain</b> | entry screening, visitor mediation spaces, survivor clinic, and a morgue with viewing (Fig. 4).                                  |         |
| <b>Dimension for surge</b>           | ensuring layouts remain safe and legible under peak loads.                                                                       |         |

orità emergono spazi per maternità e pediatria, standard minimi di superficie per posto letto, aree di vestizione e svestizione chiaramente delimitate a supporto di flussi unidirezionali e l'adozione di planimetrie modulari capaci di espandersi.

Sebbene focalizzata sulla Nigeria, l'analisi offre indicazioni di più ampia rilevanza. Approcci progettuali orientati al controllo delle infezioni, alla tutela della privacy dei pazienti e al supporto al personale possono aiutare la pianificazione dei CT a livello globale, particolarmente nelle regioni soggette a focolai di malattie infettive. La progettazione delle strutture può assumere un ruolo strategico nella preparazione a emergenze sanitarie.

Il lavoro futuro dovrebbe mirare alla definizione di indicatori standardizzati in grado di valutare l'influenza della progettazione sugli esiti clinici, sulla sicurezza del personale e sull'esperienza dei pazienti. L'ampliamento della raccolta dati, sia quantitativa sia qualitativa, consentirà di approfondire la comprensione del ruolo dell'ambiente costruito nella risposta alle epidemie.

In conclusione, lo studio mostra come l'integrazione di principi architettonici basati su evidenze nella pianificazione dei CT per LF può rafforzare la preparazione, ridurre i rischi di trasmissione e garantire risposte più efficienti e inclusive, in grado di rispondere alle esigenze delle popolazioni vulnerabili.

### ATTRIBUZIONE, RICONOSCIMENTI, DIRITTI D'AUTORE

Gli autori desiderano ringraziare il Dr. Mahmood Dalhat, il Dr. Yusuf Jibrin, la Dr.ssa Anaïs Legand, il Dr. Sylvanus Okogbenin e il Dr. Joshua Ofoli per aver facilitato l'accesso alla documentazione tecnica. Un ringraziamento al Dr. Mahmood Dalhat, al Dr. Yusuf Jibrin e al Dr. Sylvanus Okogbenin per la disponibilità e per aver generosamente condiviso la propria conoscenza del contesto durante le interviste.

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