Prévention et contrôle des infections dans les unités néonatales et pédiatriques en Tunisie

Infection Control and Prevention in Tunisian Neonatal and Pediatric Care

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ABSTRACT

Healthcare-associated infections (HAIs) pose a major threat in Tunisian neonatal and pediatric units, where vulnerable patients are exposed to high-risk procedures amid resource limitations. This review outlines the epidemiology, risk factors, and microbiological patterns of HAIs in these populations, and examines current prevention practices in Tunisia. Although national guidelines align with WHO and CDC standards, their implementation is uneven due to staffing shortages, infrastructure deficits, and weak performance of Hospital Hygiene Committees. Core preventive measures—hand hygiene, environmental cleaning, isolation practices, and device management—remain insufficiently applied and require stronger training, monitoring, and accountability. Emerging approaches such as family-centered care, safe feeding practices, water safety, and digital auditing offer promising support. Additional priorities include universal masking, and staff vaccination against respiratory virus. Strengthening surveillance, expanding workforce education, and adopting context appropriate innovations are essential to reduce HAIs. A coordinated multisectoral strategy is crucial to protect neonates and children and to align Tunisian healthcare with global standards.

Key words: Neonatal, Infants, Hospital Acquired Infections, Infection Control and Prevention, Tunisia

RESUME

Les infections associées aux soins (IAS) constituent une menace majeure dans les unités néonatales et pédiatriques tunisiennes, où des patients vulnérables sont exposés à des procédures à haut risque dans un contexte de ressources limitées. Cette revue décrit l'épidémiologie, les facteurs de risque et les profils microbiologiques des IAS dans ces populations, et examine les pratiques actuelles de prévention en Tunisie. Bien que les directives nationales soient alignées sur les normes de l'OMS et des CDC, leur mise en œuvre demeure inégale en raison du manque de personnel, des déficits d'infrastructure et de la faible performance des Comités d'Hygiène Hospitalière. Les mesures préventives essentielles — hygiène des mains et de l'environnement, pratiques d'isolement des malades, et gestion des dispositifs — restent insuffisamment appliquées et nécessitent un renforcement de la formation, du suivi et de la responsabilisation. Des approches émergentes, telles que les soins centrés sur la famille, la manipulation sécurisée de l'alimentation, la sécurité de l'eau et l'audit numérique, offrent un soutien prometteur. Les priorités supplémentaires incluent le port universel du masque et la vaccination du personnel, surtout contre les virus respiratoires. Le renforcement de la surveillance, l'élargissement de la formation du personnel et l'adoption d'innovations adaptées au contexte sont essentiels pour réduire les IAS. Une stratégie multisectorielle coordonnée est indispensable pour protéger les nouveau-nés et les enfants et pour aligner le système de santé tunisien sur les normes internationales et promouvoir l'équité dans les soins pédiatriques.

Mots clés : Nouveau-né, Nourrisson, Infections associées aux soins, Contrôle de l'infection, Tunisie

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INTRODUCTION

Healthcare-associated infections (HAIs), also known as nosocomial infections, are infections acquired during the course of receiving medical care that were neither present nor incubating at the time of admission. In pediatric and neonatal settings, these infections pose a particularly serious threat due to the physiological vulnerability of infants and children, the frequent use of invasive procedures, and the immaturity of neonatal immune systems [1]. In Tunisia, as in many low- and middle-income countries, HAIs remain a persistent challenge in hospital environments, especially in intensive care and neonatal units. The burden of HAIs in Tunisian pediatric and neonatal care is multifaceted. Epidemiological studies have reported incidence rates ranging from 5% to over 10% in neonatal intensive care units, with bloodstream infections and pneumonia being the most common, these HAIs were principal causes of mortality and morbidity among pediatricians and neonates complicating treatment and increasing the risk of mortality [2, 3, 4]. The devastating impact of HAIs was brought into sharp public focus in March 2019, when the deaths of eleven newborns at the Rabta Hospital in Tunis shocked the nation [media report]. Investigations revealed that the infants had succumbed to septic shock caused by contaminated parenteral nutrition, highlighting critical lapses in infection control practices. This tragedy underscored the urgent need for robust surveillance systems, strict adherence to hygiene protocols, and comprehensive infection prevention strategies in neonatal and pediatric units.

In Tunisia, strengthening infection control programs, investing in staff training, and fostering a culture of safety are essential steps toward reducing the incidence of HAIs and protecting the most fragile patients—newborns and children. The objectives of this review are:

- To describe the epidemiology, risk factors, and clinical impact of healthcare associated infections (HAIs) in Tunisian pediatric and neonatal care, using national data and sentinel events to highlight their burden and population-specific vulnerabilities
- To identify and recommend evidence based infection prevention and control strategies, informed by local and international literature, to guide national policy and enhance patient safety in pediatric and neonatal units.

EPIDEMIOLOGY OF HAIS IN PEDIATRIC AND NEONATAL UNITS IN TUNISIA

HAIs represent a major public health concern in Tunisia, particularly in pediatric and neonatal care settings. Their frequency, impact on infant morbidity and mortality, and the challenges surrounding their prevention have been documented in several local studies, revealing both alarming trends and opportunities for improvement.

-Frequency and Infection Sites

In Tunisia, the 2005 NOSOTUN05 survey reported a 9.03% prevalence of healthcare associated infections (HAIs), reaching 9.8% in pediatric wards and 8.3% in neonatal units [4]. A case control study from CHU Ibn El Jazzar showed a higher neonatal infection rate of 15.8%, mainly septicemia (39.1%), clinical sepsis (37.5%), and pneumonia (19.6%) [5]. A 2021 Maghreb-wide meta analysis, including three Tunisian studies, estimated neonatal HAI incidence at 10% and mortality at 49%, underscoring major heterogeneity and weak surveillance [3]. At Charles Nicolle Hospital, HAIs were independently associated with early neonatal death (aOR 2.05) [6]

- Risk Factors

Across Tunisian studies, risk factors for healthcare associated infections cluster into patient related, care related, and system related determinants. Patient related factors include immunosuppression (OR = 3.3), diabetes (OR = 2.0), and prolonged hospitalization (OR = 4.5); among neonates, low birth weight and prior colonization with multidrug resistant Gram negative bacilli—particularly Klebsiella pneumoniae—are major contributors. Care related factors are dominated by invasive procedures, notably the use of peripheral venous catheters (OR = 10.2), central venous catheters (OR = 2.5), mechanical ventilation, and parenteral nutrition. Finally, system related factors, such as high exposure to invasive interventions and limited infection control resources in neonatal and pediatric units, further amplify the risk of HAIs [2-5].

- Microbiological Profile

The most frequently isolated pathogens in pediatric and neonatal healthcare-associated infections (HAIs) in Tunisia are Gram-negative bacilli, accounting for approximately 68–80% of cases. The predominant species include Klebsiella pneumoniae, Enterobacter cloacae, and Pseudomonas aeruginosa. Gram-positive cocci, particularly Staphylococcus aureus, are also present and have been implicated in outbreak episodes, often linked to cross-contamination by healthcare personnel. In the same study conducted by Ben Jaballah et al., 27% of neonates were found to be colonized with Klebsiella pneumoniae, and notably, 85% of these isolates exhibited multidrug resistance [2]. Recent data indicate a growing burden of carbapenem resistant Enterobacterales (CRE)—particularly Klebsiella pneumoniae—in Tunisian neonatal and pediatric settings. A large genomic epidemiology study from Habib Bourguiba Hospital (Sfax) documented a >10 fold rise in carbapenemase producing K. pneumoniae between 2009 and 2022, driven mainly by OXA 48 like and NDM enzymes [7]. Although national pediatric specific data remain limited, these strains are frequently implicated in neonatal sepsis across North Africa, and their rapid diversification—including emerging NDM variants—poses a major threat to neonatal and pediatric care.

REGULATORY AND ORGANIZATIONAL FRAMEWORK

Tunisia's national infection prevention and control (IPC) strategy—led by "Direction des Soins de Santé de Base" (DSSB) through the Politique Nationale de Lutte contre les IAS—provides WHO aligned guidelines for all healthcare levels, including neonatal and pediatric units. These standards cover hand hygiene, aseptic practices, environmental cleaning, antibiotic stewardship, HAIs surveillance, and care bundles for center line associated blood stream infection (CLABSI), ventilated associated pneumonia (VAP), and neonatal sepsis, alongside family centered care initiatives. Although all hospitals are required to maintain Comité d'Hygiène Hospitalière to enforce protocols and conduct training and audits, many facilities lack functional committees or sufficient qualified staff, weakening IPC implementation. Hospitals are expected to report HAIs and AMR data to national surveillance systems. Despite this strong regulatory framework, adherence remains inconsistent, with gaps in reporting, follow up, and protocol compliance—contributing to persistently high HAIs rates in neonatal and pediatric settings and highlighting the need for stronger accountability and operational support.

KEY PREVENTIVE MEASURES

Effective IPC measures are essential to safeguard pediatric and neonatal patients, who are particularly vulnerable to HAIs, and to improve their clinical outcomes. When properly implemented, these measures can significantly reduce HAIs rates and enhance patient safety across both public and private healthcare settings. In the following sections, we will outline the key IPC interventions that must be prioritized, especially in high-risk areas such as neonatal intensive care units and pediatric wards.

- Hand Hygiene

Hand hygiene is a fundamental component of IPC, particularly in neonatal and pediatric care settings where patients are highly susceptible to HAIs. In Tunisia, enhancing hand hygiene compliance among healthcare workers is essential to reducing pathogen transmission in neonatal intensive care units and pediatric wards. Adherence to the WHO's "My Five Moments for Hand Hygiene" framework, supported by the widespread availability of alcohol-based hand rubs and regular staff training, has been shown to significantly reduce HAIs rates [8]. To ensure sustained improvement, a continuous national campaign promoting the importance of hand hygiene should be implemented across all public and private healthcare institutions. Alcohol-based hand rub dispensers must be strategically placed throughout clinical areas, and daily monitoring of compliance—with timely feedback to healthcare workers—should become a routine responsibility of Hospital Hygiene team. Importantly, changing healthcare workers' behavior and attitudes toward hand hygiene remains one of the most challenging yet critical aspects of successful IPC programs [9]

- Environmental Hygiene

Ensuring rigorous cleaning and disinfection of surfaces, medical equipment, and high-touch areas is essential to interrupt transmission pathways in neonatal intensive care units (NICUs) and pediatric wards [10]. Effective protocols for waste and linen management, coupled with routine microbiological surveillance, are necessary to maintain safety standards. To reduce HAIs rates, healthcare institutions must implement standardized environmental hygiene procedures, ensure adequate staffing and training of cleaning personnel, and conduct regular audits to monitor compliance [11]. Strengthening these practices is vital to protecting vulnerable pediatric populations and improving overall care quality

- Isolation, cohorting, and Spacing requirements

Ensuring the availability of personal protective equipment (PPE) including gowns, gloves, and respiratory masks—combined with comprehensive training on proper donning and doffing techniques, is vital for infection prevention in neonatal and pediatric care settings. Equally important is strict adherence to isolation precautions, including contact, droplet, and airborne protocols, which serve as critical barriers against the transmission of infectious agents to vulnerable infants and children. Together, these measures form the foundation of safe clinical practice and help reduce HAIs in high-risk units such as NICUs and pediatric wards. The Centers for Disease Control and Prevention (CDC) provide detailed guidance on isolation types and durations, underscoring the importance of tailored approaches in pediatric settings [12].

When single-room isolation is not feasible, cohorting patients with similar infection or colonization status offers a practical alternative, especially in resource-constrained environments like many Tunisian hospitals [13]. This strategy also includes assigning dedicated healthcare personnel to specific patient groups to reduce cross-contamination. Maintaining adequate physical spacing between incubators or beds (ideally 1.5 to 2 meters) is another critical measure to limit airborne and contact transmission. International guidelines from WHO emphasize that spatial separation and unit design are foundational to safe neonatal care [14]. In Tunisia, integrating these practices into national IPC protocols is vital, particularly in high-risk units. However, barriers such as overcrowding, infrastructure limitations, and insufficient isolation facilities impede full implementation. Addressing these challenges through targeted investments, workforce training, and alignment with global standards is essential to reducing healthcare-associated infections and improving outcomes for neonates and children.

change airborne by droplet

- Prevention Related to Invasive Devices

Invasive medical devices—such as central venous ca-

theters, urinary catheters, and endotracheal tubes—are indispensable in NICUs and pediatric wards, yet they pose a significant risk for HAIs when not properly managed. International guidelines from the CDC and WHO emphasize the importance of aseptic technique during device insertion, routine assessment of device necessity, and strict adherence to maintenance protocols. For example, CLABSI and catheter-associated urinary tract infections (CAUTIs) can be significantly reduced through care bundles that include hand hygiene, sterile insertion procedures, daily review of device necessity, and prompt removal when no longer indicated [15]. In Tunisian healthcare settings, challenges such as limited staffing, inconsistent training, and resource constraints often hinder full implementation of these protocols. However, targeted interventions—such as standardized insertion checklists, regular audits, and staff education—have shown promise in improving compliance and reducing infection rates [16]

- Antibiotic Prophylaxis and Rational Use of Antibiotics

Antibiotic prophylaxis and rational antimicrobial use are essential pillars of IPC to reduce HAIs in neonatal and pediatric populations. Inappropriate or prolonged antibiotic use contributes to antimicrobial resistance (AMR) and disrupts the developing microbiota, increasing the risk of secondary infections. Implementing antimicrobial stewardship programs (ASPs) including prescriber education, regular audits, and resistance surveillance—is vital to promoting judicious antibiotic use [17]. In Tunisia, strengthening ASPs within pediatric and neonatal units can significantly improve clinical outcomes and curb AMR. Beyond institutional protocols, advancing antibiotic stewardship requires specialized expertise. Establishing pediatric infectious diseases as a formal subspecialty within fellowship programs would train clinicians in evidence-based prescribing and IPC leadership, filling a critical gap in pediatric-focused infectious disease management and supporting national policy development.

- Staff Training and Awareness

Comprehensive and continuous training in infection prevention protocols—such as hand hygiene, aseptic techniques, and environmental cleaning—is essential to ensure consistent, evidence-based practices across all levels of hospital care. Embedding infection control principles into the education of all healthcare professionals, including students and new employees, fosters a culture of vigilance, accountability, and safety. In resource-constrained settings like Tunisia, targeted awareness campaigns and structured orientation programs can significantly improve pediatric outcomes and reduce HAIs [18].

- Monitoring, surveillance and feedback

Effective monitoring of infection control key performance indicators (KPIs)—including hand hygiene, device-related infection rates, and environmental cleanliness—is essential for identifying risks and implementing timely corrective actions. Surveillance systems provide the foundation for evidence-based decisions, while regular feedback fosters accountability and continuous improvement. As emphasized by WHO, robust HAIs surveillance is especially critical in resource-limited settings. In Tunisian hospitals, where specialized personnel may be scarce, digital technologies and artificial intelligence can play a transformative role by enhancing data accuracy, streamlining reporting, and supporting proactive infection prevention strategies to protect vulnerable patients and improve care quality [19].

- Family Centered Care (FCC)

In neonatal and pediatric units, FCC emphasizes the active involvement of families in the planning, delivery, and evaluation of care. This approach promotes dignity, respect, information sharing, participation, and collaboration between healthcare providers and families [20]. When families are empowered and educated about infection prevention they become vigilant partners in care. Their presence at the bedside not only supports emotional well-being but also contributes to timely reporting of symptoms and adherence to hygiene protocols [16]. In Tunisia, where neonatal units may face resource constraints and staffing shortages, FCC can help bridge gaps in infection surveillance and prevention. Studies in resource-limited settings show that engaging families in care reduces the incidence of HAIs by improving compliance with infection control measures and encouraging shared responsibility. Moreover, FCC helps mitigate the adverse effects of isolation and enhances communication between caregivers and families, which is crucial for early intervention and improved outcomes.[21]. Implementing FCC in Tunisian hospitals requires structured education for families, clear communication strategies, and policies that support family presence and participation.

- Water supply and use

In healthcare settings, water is not only used for hygiene and sanitation but also for medical procedures, cleaning of equipment, and patient care. Contaminated or poorly managed water systems can harbor opportunistic pathogens such as Pseudomonas aeruginosa, Legionella, and non-tuberculous mycobacteria, which can lead to severe infections in neonates and children with immature immune systems [22]. A 2019 systematic review emphasized that improving water, sanitation, and hygiene (WASH) infrastructure in low- and middle-income countries significantly reduces HAIs, especially when combined with staff training and surveillance [23]

- Handling infant feeds

Proper handling of infant feeds is a critical factor in reducing HAIs among neonates and children. Contaminated feeds—whether expressed breast milk, donor milk, or formula—can serve as vectors for pathogens such as Enterobacter and Salmonella, leading to serious bloodstream and gastrointestinal

infections [24]. Ensuring safe preparation, storage, and administration of feeds is therefore essential to protect these vulnerable populations, implementing standardized protocols for feed handling can significantly reduce infection risks. This includes:
- Dedicated feed preparation areas with proper sanitation and temperature control
- Trained personnel responsible for hygienic preparation and labeling of feeds
- Strict adherence to time and temperature guidelines for storage and warming
- Use of sterile equipment and aseptic techniques during administration
Moreover, educating both healthcare staff and caregivers on safe feeding practices reinforces infection prevention efforts [24]. In Tunisian hospitals, adopting these measures not only improves clinical outcomes but also supports family-centered care by involving parents in safe feeding routines. This collaborative approach enhances trust, reduces contamination risks, and contributes to a safer healing environment for infants.

- Additional Preventive Measures

Universal masking, staff vaccination, and controlled visitation are essential strategies for reducing HAIs among neonates and children, particularly during respiratory infection seasons. In high-risk areas such as NICUs, PICUs, and pediatric wards, consistent use of surgical masks by healthcare workers significantly lowers the risk of droplet transmission to immuno-compromised patients. Post-pandemic evidence confirms the effectiveness of masking during periods of high viral circulation [25]
Vaccinating healthcare staff against respiratory infections like influenza and COVID-19 adds a critical layer of protection, minimizing cross-transmission and enhancing herd immunity within hospital settings [16]. This is especially important in Tunisia, where pediatric units may face staffing and resource limitations.
Finally, controlling hospital visits—by limiting visitor numbers, screening for symptoms, and enforcing hygiene protocols—further reduces the risk of introducing community-acquired pathogens. Studies in resource-constrained environments show that such measures correlate with lower HAI rates and better patient outcomes [16].

INNOVATIONS AND PERSPECTIVES

Ultraviolet C (UV C) light has emerged as an effective adjunct environmental disinfection strategy to reduce HAIs, particularly in high risk neonatal and pediatric units. By inactivating a broad spectrum of pathogens on surfaces and equipment, UV C enhances standard cleaning practices and helps limit transmission of multidrug resistant organisms. Recent evidence from a tertiary pediatric hospital demonstrated that integrating UV C disinfection into routine infection prevention bundles significantly reduced HAIs rates in the neonatal intensive care unit, including infections caused by ESBL producing bacteria [26]
Environmental sensors and digital audit tools are increasingly integrated into neonatal and pediatric infection prevention strategies, offering real time monitoring and early detection of risks that traditional surveillance may miss. Environmental and physiological sensors enable continuous tracking of temperature, humidity, air quality, and patient physiological parameters, supporting early warning of clinical deterioration and reducing infection rates in NICUs [27]. Digital audit platforms further strengthen infection control programs by standardizing data collection, improving adherence to cleaning and hand hygiene protocols, and enabling rapid feedback loops for clinical teams [28]. Together, these technologies enhance situational awareness, support timely interventions, and contribute to measurable reductions in hospital acquired infections among vulnerable neonatal and pediatric populations.

CONCLUSION

HAIs remain a major challenge in Tunisian neonatal and pediatric wards, particularly in NICUs and PICUs where highly vulnerable patients face elevated risks. Although several preventive measures—such as hand hygiene protocols, basic staff training, and limited surveillance—are already in place, these efforts often lack consistency, standardization, and technological reinforcement. Resource limitations, including shortages of trained infection control personnel and restricted access to advanced disinfection technologies, further hinder progress.
To strengthen infection prevention efforts, recommendations can be grouped into the following key domains:

Technological and Environmental Enhancements

- Integrate digital audit tools to improve monitoring and compliance.

- Adopt UV C disinfection systems and environmental sensors to enhance environmental safety.

- Improve water and feed safety through routine monitoring and standardized protocols.

Workforce Capacity and Education

- Expand and standardize staff training programs in infection prevention and control.

- Increase the number of trained infection control professionals to ensure sustained oversight.

Clinical and Public Health Measures

- Reinforce vaccination programs for healthcare workers, caregivers, and eligible patients.

- Implement universal masking during respiratory virus seasons.

- Establish structured visitor control policies tailored to neonatal and pediatric units.

Governance and Institutional Structure

- Rename the Hospital Hygiene Committee as the Infection Control and Prevention Committee to reflect a broader, more strategic mandate.

- Emphasize that infection prevention extends beyond hygiene to include surveillance, clinical practices, environmental safety, antimicrobial stewardship, and continuous staff education.

By addressing these interconnected domains, Tunisia can build a more resilient and effective infection prevention system capable of reducing HAIs in neonatal and pediatric care settings.

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