






## SHEA White Paper

# SHEA NICU white paper series: Practical approaches for the prevention of viral respiratory infections

Nisha Thampi MD, MSc<sup>1</sup> , Judith Guzman-Cottrill DO<sup>2</sup> , Allison H. Bartlett MD, MS<sup>3</sup> , Wendy Berg BSN, RN, CIC<sup>4</sup>, Joseph B. Cantey MD, MPH<sup>5</sup>, Eimear Kitt MD, MSCE<sup>6</sup> , Karen Ravin MD<sup>7</sup>, Kenneth M. Zangwill MD<sup>8</sup>  and Alexis Elward MD, MPH<sup>9</sup>

<sup>1</sup>Children's Hospital of Eastern Ontario, Ottawa, Ontario, Canada, <sup>2</sup>Oregon Health & Science University, Portland, Oregon, USA, <sup>3</sup>University of Chicago and Comer Children's Hospital, Chicago, Illinois, USA, <sup>4</sup>Children's Minnesota, St. Paul, Minnesota, USA, <sup>5</sup>The University of Texas Health Science Center, San Antonio, Texas, USA, <sup>6</sup>Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, USA, <sup>7</sup>Nemours Children's Health, Wilmington, Delaware, USA, <sup>8</sup>Harbor-UCLA Medical Center, Torrance, California, USA and <sup>9</sup>Washington University School of Medicine, St. Louis, Missouri, USA

### Abstract

This white paper provides clinicians and hospital leaders with practical guidance on the prevention and control of viral respiratory infections in the neonatal intensive care unit (NICU). This document serves as a companion to Centers for Disease Control and Prevention Healthcare Infection Control Practices Advisory Committee (HICPAC)'s "Prophylaxis and Screening for Prevention of Viral Respiratory Infections in Neonatal Intensive Care Unit Patients: A Systematic Review." It provides practical, expert opinion and/or evidence-based answers to frequently asked questions about viral respiratory detection and prevention in the NICU. It was developed by a writing panel of pediatric and pathogen-specific experts who collaborated with members of the HICPAC systematic review writing panel and the SHEA Pediatric Leadership Council to identify questions that should be addressed. The document has been endorsed by SHEA, the American Hospital Association (AHA), The Joint Commission, the Pediatric Infectious Diseases Society (PIDS), the Association for Professionals in Infection Control and Epidemiology (APIC), the Infectious Diseases Society of America (IDSA), and the National Association of Neonatal Nurses (NANN).

(Received 18 May 2023; accepted 23 May 2023; electronically published 25 October 2023)

Viral respiratory infections (VRIs) are an important cause of morbidity and mortality among critically ill infants in the neonatal intensive care unit (NICU) (see Table 1 for abbreviations). The incidence of VRI varies across NICU settings, ranging from 1% to 8% in retrospective analyses of symptomatic patients.<sup>1,2</sup> This figure is likely underestimated; most NICUs do not routinely test for respiratory viruses among infants presenting with compatible symptoms. Prospective surveillance has revealed unrecognized VRI in >50% of infants at some point during their course of birth hospitalization, with evidence of seasonality.<sup>3</sup>

Infants may be infected with viral respiratory pathogens in the NICU setting from infected staff or visitors through the air or via contact with contaminated hands or shared patient equipment.<sup>4</sup> Transmission of respiratory pathogens in the NICU is influenced by several factors, including the structural design of the unit and human behaviors. It is important for healthcare personnel (HCP) to consider healthcare-associated VRI (HA-VRI) for infants who develop signs of infection during their hospitalization and to investigate for a source and/or lapse in infection prevention practices.

Clinical manifestations of VRI can range from asymptomatic or mild upper-respiratory-tract illness to viral pneumonia,

bronchiolitis, respiratory failure requiring mechanical ventilation, sepsis-like syndrome, and rarely, meningitis or encephalitis, with varying morbidity and mortality related to the infant's gestational age and underlying medical fragility.<sup>5,6</sup> Infants are relatively immunocompromised compared to older children and adults and are ineligible for vaccines against respiratory viruses. Thus, we must invest in infection prevention measures that offset transmission in the NICU setting.

This White Paper provides clinicians and hospital leaders with practical guidance on the prevention and control of VRI in the NICU. The term "infants" is used throughout instead of "neonates" because patients in the NICU may be beyond 28 days of age. The breadth of measures includes elimination strategies such as visitor restrictions and screening staff and caregivers for the presence of signs or symptoms; engineering controls including ventilation, masking for source control, distancing between patients, and controlled workflows to reduce foot traffic in the unit; administrative controls including policies and procedures for screening, sick leave, and isolation management; and availability of personal protective equipment (PPE) to care for patients under routine practices and additional precautions. Although many of the recommendations reflect standard principles of HA-VRI prevention, they are also relevant for infants with VRI admitted to an NICU from the community.

Although the COVID-19 pandemic has significantly affected infection prevention and control practices in the NICU, pandemic-related measures are outside the scope of this document, which

**Corresponding author:** Nisha Thampi; Email: [nthampi@cheo.on.ca](mailto:nthampi@cheo.on.ca)

**Cite this article:** Thampi N, Guzman-Cottrill J, Bartlett AH, *et al.* SHEA NICU white paper series: Practical approaches for the prevention of viral respiratory infections. *Infect Control Hosp Epidemiol* 2024. 45: 267–276, doi: [10.1017/ice.2023.120](https://doi.org/10.1017/ice.2023.120)

**Table 1.** Abbreviations

AAP	American Academy of Pediatrics
AHA	American Hospital Association
APIC	Association for Professionals in Infection Control and Epidemiology
CDC	Centers for Disease Control and Prevention
HAI	Healthcare-associated infection
HA-VRI	Healthcare-associated viral respiratory infection
HCP	Healthcare personnel
HICPAC	Healthcare Infection Control Practices Advisory Committee (CDC)
IDSA	Infectious Diseases Society of America
IFU	Instructions for use
NANN	National Association of Neonatal Nurses
NICU	Neonatal intensive care unit
PIDS	Pediatric Infectious Diseases Society
PPE	Personal protective equipment
RSV	Respiratory syncytial virus
SHEA	Society for Healthcare Epidemiology of America
VRI	Viral respiratory infection

does not discuss prevention of infections due to SARS-CoV-2. In addition, this White Paper does not address topics already covered sufficiently in other references, such as infection-specific prevention and control guidance for neonatal populations available in the American Academy of Pediatrics *Red Book: 2021 Report of the Committee on Infectious Diseases*.<sup>7</sup>

### Intended use

The Society for Healthcare Epidemiology of America (SHEA) intends for this document to serve as a companion to the Centers for Disease Control and Prevention Healthcare Infection Control Practices Advisory Committee (HICPAC) “Prophylaxis and Screening for Prevention of Viral Respiratory Infections in Neonatal Intensive Care Unit Patients: A Systematic Review”<sup>8</sup> and to provide practical, expert opinion and/or evidence-based answers to frequently asked questions about viral respiratory detection and prevention in the NICU. The published literature does not contain sufficient high-quality studies to meet Grading of Recommendations Assessment, Development and Evaluation standards; therefore, they were not included in the HICPAC guideline.<sup>9</sup>

No guideline, expert guidance, or policy paper can anticipate all situations. This document is meant to serve as an adjunct to individual judgment by qualified professionals. In general, these recommendations apply to nonoutbreak settings. HCP may implement additional measures during an outbreak or other special clinical scenarios. Further details and references are included in the HICPAC “Prophylaxis and Screening for Prevention of Viral Respiratory Infections in Neonatal Intensive Care Unit Patients: A Systematic Review.”<sup>8</sup>

### Methods

This document was developed by a writing panel of pediatric and pathogen-specific experts who collaborated with members of the HICPAC systematic review writing panel and the SHEA Pediatric

Leadership Council to identify questions that should be addressed. Unlike the SHEA expert guidance format, this document is not based on a systematic literature search. Instead, for the selected topic, the authors provide practical approaches in question-and-answer format based on expert opinion and consensus within the context of the HICPAC systematic review.

The SHEA Guidelines Committee, the SHEA Publications Committee, the SHEA Board of Trustees, and the NICU Advisory Panel (see Authors section) reviewed this document. The document has been endorsed by the SHEA, the American Hospital Association (AHA), The Joint Commission, the Pediatric Infectious Diseases Society (PIDS), the Association for Professionals in Infection Control and Epidemiology (APIC), the Infectious Diseases Society of America (IDSA), and the National Association of Neonatal Nurses (NANN).

### Authors

The authors are current and past members of the SHEA Guidelines Committee and the SHEA Pediatric Leadership Council, who serve as volunteers. Ms. Berg served as the representative from APIC. All authors have experience in the development of policies pertaining to pediatric infection prevention and either serve presently or served in the past at their respective institutions to develop policies.

The NICU Advisory Panel, which provided oversight and review of the document, is composed of representatives from SHEA, the American Academy of Pediatrics (AAP), AHA, APIC, IDSA, NANN, PIDS, The Joint Commission, and the Vermont Oxford Network.

### Practical approaches: Questions and answers

(See Table 2 for a summary of questions and recommendations.)

#### Question 1: How is a HA-VRI defined in the NICU?

**Recommendation:** A VRI may be designated as healthcare-associated when a patient has clinically significant signs (eg, apnea, rhinorrhea, pneumonia, sepsis-like syndrome, increased respiratory support), a positive viral respiratory test, and has been hospitalized for longer than the known incubation period for that organism.

**Rationale:** A practical definition of a HA-VRI takes into consideration the incubation period (the time from exposure to symptom onset) of the specific respiratory virus. Organizations should create a standardized approach for surveillance to track VRIs that may have been acquired in the healthcare setting. Among infants who have been hospitalized since birth, all VRIs should be considered healthcare acquired. In these cases, it may be useful to consider the incubation period of the specific virus to understand where the patient was most likely exposed, particularly if the infant has been transferred between facilities or units (Table 3).

For example, the incubation period for RSV is 2–8 days. If a patient develops RSV on day 10 of hospitalization, the infection should be considered healthcare acquired because the patient was exposed to RSV (through healthcare personnel, caregivers, or contaminated shared patient equipment) during that hospitalization. But if a patient develops RSV on day 5 of hospitalization, exposure may have occurred prior to or during admission and should be considered indeterminant. For patients not admitted since birth, RSV infection that develops on day 1 or 2 of admission

**Table 2.** Questions and Recommendations

Question	Recommendation
1. How is a healthcare-associated viral respiratory infection (HA-VRI) defined in the NICU?	A VRI may be designated as healthcare-associated when a patient has clinically significant signs (such as apnea, rhinorrhea, pneumonia, sepsis-like syndrome, increased respiratory support), a positive viral respiratory test, and has been hospitalized for longer than the known incubation period for that organism.
2. When should HCP test for VRIs?	<p><i>Individual patients based on clinical signs, index of suspicion</i></p> <ul style="list-style-type: none"> <li>• Test for VRI in infants who present with signs that could be consistent with infection, including apnea, bradycardia, fever, and poor feeding,<sup>12</sup> and respiratory findings, including congestion, cough, tachypnea, and respiratory failure.<sup>13</sup></li> </ul> <p><i>After exposure to caregiver or visitor</i></p> <ul style="list-style-type: none"> <li>• Isolating or testing asymptomatic infants exposed to respiratory viruses from caregivers or visitors is not routinely recommended, but oseltamivir prophylaxis for the infant could be considered after known influenza exposure.<sup>14</sup></li> </ul> <p><i>Outbreak setting or possible in-hospital transmission (patient or HCP)</i></p> <ul style="list-style-type: none"> <li>• Active screening of asymptomatic infants may be considered to understand the extent of an outbreak and to monitor the impact of infection control interventions.</li> </ul> <p><i>To document resolution of infection</i></p> <ul style="list-style-type: none"> <li>• In general, HCP should continue precautions for patients for at least the duration of illness. In patients without respiratory concerns and in the context of ongoing exposure concerns, HCP may consider a strategy of repeated molecular testing and continued isolation until testing is negative.</li> </ul>
3. How can HA-VRIs in the NICU be prevented?	<p>A bundled approach, including hand hygiene, visitor screening, staff illness and vaccination policies, proper isolation precautions and PPE, and environmental cleanliness, is recommended to prevent HA-VRIs in the NICU.</p> <p><i>Hand hygiene</i></p> <ul style="list-style-type: none"> <li>• The NICU actively should incorporate pre-existing hand hygiene programs. In addition to performing observations with in-the-moment feedback provided to staff, metrics on hand hygiene compliance should be available to the unit and hospital. Engagement and education of caregivers and families are important components of HAI prevention.</li> </ul> <p><i>Caregiver and visitor screening practices</i></p> <ul style="list-style-type: none"> <li>• Hospitals should implement caregiver and visitor screening practices that are sustainable for the resources available to their specific institution (see question 7). When a caregiver is sick, unit leadership should clearly communicate the hospital's infection prevention and control guidelines for when the caregiver can return to the unit.</li> </ul> <p><i>Staff illness procedures</i></p> <ul style="list-style-type: none"> <li>• Robust and nonpunitive sick leave policies for staff are helpful in discouraging presenteeism (working despite personal illness). Refreshers on illness procedures should be considered annually and when increased transmission is noted in the unit and/or the community.</li> </ul> <p><i>Vaccination and postexposure chemoprophylaxis</i></p> <ul style="list-style-type: none"> <li>• Vaccination of HCP and caregivers against influenza and compliance with the facility's seasonal vaccine policies are strongly recommended to prevent healthcare transmission of viral respiratory pathogens to infants, who are ineligible under age 6 months for the influenza vaccine and other vaccines to prevent VRI.</li> <li>• In the context of outbreak control, antiviral chemoprophylaxis against influenza with oseltamivir may be recommended for all asymptomatic patients on the unit and to immune-susceptible HCP following a risk assessment.</li> <li>• Palivizumab should not be used as part of RSV outbreak management to prevent further transmission within the unit.<sup>29</sup></li> </ul> <p><i>Isolation precautions and personal protective equipment (PPE)</i></p> <ul style="list-style-type: none"> <li>• Patients should be placed on appropriate isolation precautions when first symptomatic, regardless of whether testing is sent.</li> <li>• Appropriate PPE should be worn for all patients on isolation precautions, donned and doffed in appropriate order.</li> <li>• There should be clear documentation of appropriate transmission-based precautions immediately placed in the patient's chart, and clear signage should be placed at entry to the patient's room or bed space.</li> <li>• If resources allow, units may consider audits on donning and doffing of PPE and appropriate isolation procedures with in-the-moment feedback and unit metrics on appropriate isolation precautions available for comparison.</li> </ul> <p><i>Environmental cleanliness</i></p> <ul style="list-style-type: none"> <li>• All shared patient equipment should be cleaned after use and stored in designated clean utility areas.</li> <li>• At least once daily cleaning of high-touch surfaces using an appropriate surface disinfectant approved by the country's regulatory authority (eg, in the United States, the EPA) and consistent with hospital policy.</li> <li>• Inpatient rooms should be kept clutter-free with support and education provided to families on the importance of their role in HAI prevention.</li> <li>• Ideally, families should keep bedside tables and windowsills clear. They should aim to keep personal items to a minimum, with no more than a 1-week supply of belongings, and place personal items in drawers where available.</li> <li>• Some NICUs have a set day-cleaning process (eg, every 14 days) to ensure ongoing decluttering and deep cleaning.</li> </ul>
4. What is the optimal distance between patients for isolation when not in a private room?	<p>Infants in the NICU who require respiratory isolation should be allocated as much space as is feasible, taking into consideration the physical layout of the NICU, patient census, and staffing level.</p> <ul style="list-style-type: none"> <li>• One meter (3 feet) between infants should be an absolute minimum.</li> <li>• The approach to distancing is not affected by the type of bed (crib, warmer, or isolette).</li> </ul>

(Continued)

**Table 2.** (Continued)

Question	Recommendation
5. How long should NICU patients with VRIs be isolated?	<p>If respiratory signs were present at the time of VRI diagnosis, precautions should be continued for at least the duration of illness.</p> <ul style="list-style-type: none"> <li>• In the context of an ongoing exposure concern and in the absence of respiratory signs, HCP may consider repeat molecular testing and additional precautions until repeat testing is negative.</li> <li>• Precautions may be discontinued if clinical signs are attributable to a noninfectious etiology and respiratory viral testing is negative.</li> <li>• The duration of isolation following asymptomatic detection of respiratory viral pathogens is unclear; testing of asymptomatic infants should be discouraged outside of the outbreak setting (see question 2).</li> </ul>
6. In NICUs with “open bay” or “pod” layouts, what factors should be considered when determining a possible exposure to a patient with a VRI?	<ul style="list-style-type: none"> <li>• From the infection prevention perspective, private rooms may create greater physical space between patients, visitors, and HCP, potentially decreasing pathogen exposure risk, and may also decrease the use of multipatient equipment, further reducing risk.</li> <li>• In units with open bay or pod layouts, it is particularly important to review the standard operating procedures and policies (or instructions for use, IFUs) related to cleaning and disinfection of shared patient equipment. All units with concerns of intrafacility spread should, at a minimum, focus on systematically assessing and improving infection prevention practices among all staff.</li> </ul>
7. What are the best methods to screen for caregivers and visitors with respiratory illness, and are there reasonable age restrictions?	<ul style="list-style-type: none"> <li>• A combination of procedures should be considered to minimize patients’ exposure to community-acquired pathogens.</li> <li>• At a minimum, these procedures should include symptom-based screening.</li> <li>• Additional measures, such as age-related visitor restriction, education of visitors on local prevention practices, and/or limitation of movement within the NICU may be indicated during periods of high community transmission as defined by public health authorities and as part of outbreak management.</li> </ul>

can be considered community acquired because the exposure likely occurred prior to the patient’s admission.

Ill caregivers and visitors in the healthcare setting may be the source of infection in the infant. Recommendations to reduce transmission risk from caregivers and visitors are described in question 7.

### Question 2: When should HCP test for VRIs?

In theory, early detection of HA-VRI would allow for prompt patient isolation and decrease risk of transmission in the NICU; however, weekly active surveillance with molecular testing for respiratory viruses does not appear to identify infants with HA-VRI sooner than testing either when signs develop<sup>5,10</sup> or as a standard component of sepsis work-ups.<sup>2,11</sup>

### Individual patients based on clinical signs, index of suspicion

**Recommendation:** Test for VRI in infants who present with signs that could be consistent with infection, including apnea, bradycardia, fever, and poor feeding,<sup>12</sup> and respiratory findings, including congestion, cough, tachypnea, and respiratory failure.<sup>13</sup>

**Rationale:** Rates of HA-VRI positivity in infants undergoing evaluation for suspected late-onset sepsis are up to 8%.<sup>2,11</sup> Although there is no direct treatment for HA-VRIs other than influenza, identification of a viral cause of the clinical presentation may decrease unnecessary antibiotic treatment for the patient and protect other patients in the NICU by prompt isolation of the index case.

### After exposure to caregiver or visitor

**Recommendation:** Isolating or testing asymptomatic infants exposed to respiratory viruses from caregivers or visitors is not routinely recommended, but oseltamivir prophylaxis for the infant could be considered after known influenza exposure.<sup>14</sup>

### Outbreak setting or possible in-hospital transmission (patient or HCP)

**Recommendation:** Active screening of asymptomatic infants may be considered to understand the extent of an outbreak and to monitor the impact of infection control interventions.

### To document resolution of infection

**Recommendation:** In general, HCP should continue precautions for patients for at least the duration of illness. In patients without respiratory concerns and in the context of ongoing exposure concerns, HCP may consider a strategy of repeated molecular testing and continued isolation until testing is negative.

**Rationale:** Viral respiratory shedding in infants can be prolonged, and molecular tests can remain positive for weeks despite the absence of infectious virus.<sup>15–17</sup>

### Question 3: How can HA-VRIs in the NICU be prevented?

**Recommendation:** A bundled approach, including hand hygiene, visitor screening, staff illness and vaccination policies, proper isolation precautions and PPE, and environmental cleanliness, is recommended to prevent HA-VRIs in the NICU.

**Rationale:** As defined by the Institute for Healthcare Improvement, a bundle is a group of best practices that individually may improve care but, when applied together, clearly result in substantially greater improvement.<sup>18</sup> HCP should receive education on the rationale behind each individual bundle element, with consideration of an open display of bundle element compliance and healthcare-associated infection (HAI) rates available for review by unit. For the prevention of HA-VRIs in the NICU, implementation of the following bundle elements can be considered.<sup>19</sup>

### Hand hygiene

**Recommendation:** The NICU actively should incorporate pre-existing hand hygiene programs. In addition to performing

**Table 3.** Incubation Periods and Minimum Duration for Viral Respiratory Infections

Respiratory Virus	Incubation Period, Days <sup>a</sup>	Type of Precautions in Addition to Standard Precautions
Adenovirus	2–14	Droplet and contact
Non-SARS-CoV-2 human coronaviruses	2–5	Droplet and contact
Enterovirus	3–6	Droplet and contact
Human metapneumovirus	3–7	Contact
Influenza	1–4	Droplet
Parainfluenza	2–6	Contact
Respiratory syncytial virus	2–8	Contact
Rhinovirus	2–3	Droplet and contact

<sup>a</sup>Adapted from *Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings*<sup>31</sup> and *AAP 2021 Red Book*.<sup>7,31</sup> NICUs may also implement additional precautions as per local protocols. Types of precautions for these infections are being reconsidered by various professional organizations at the time of writing. For all the respiratory viruses noted above, the minimum duration of isolation is the duration of illness. Young infants may shed viruses longer than older children and adults, and a more prolonged duration of isolation precautions may be indicated.

observations with in-the-moment feedback provided to staff, metrics on hand hygiene compliance should be available to the unit and hospital. Engagement and education of caregivers and families are important components of HAI prevention.

**Rationale:** Improvement in appropriate hand hygiene practices of visitors can significantly decrease HA-VRIs in the NICU. In one study, an increase in hand hygiene compliance from 27% to 85% resulted in a subsequent reduction in overall viral HAIs from 0.67 to 0.23 per 1,000 patient days.<sup>20</sup> Such education can be considered on admission in addition to periods of vulnerability including unit clusters, outbreaks, and/or increased transmission of viral respiratory pathogens within the community. Practices that are essential for preventing HAIs in infants through hand hygiene have been reviewed elsewhere.<sup>21</sup>

### Caregiver and visitor screening practices

**Recommendation:** Hospitals should implement caregiver and visitor screening practices that are sustainable for the resources available to their specific institution (see question 7). When a caregiver is sick, NICU leadership should clearly communicate the hospital's infection prevention and control guidelines for when the caregiver can return to the unit.

**Rationale:** Given the previously described risk of transmission,<sup>22</sup> sick and/or symptomatic visitors should be restricted from the NICU, and a process should exist for both requesting them to leave and ensuring reunification when safe to do so (as outlined in question 7). We recommend additional caregiver and visitor limitations during times of increased transmission risk in the unit, including but not limited to viral respiratory season or times of high viral respiratory activity within the community, and unit clusters and/or outbreaks.

### Staff illness procedures

**Recommendation:** Robust and nonpunitive sick leave policies for staff are helpful in discouraging presenteeism (working despite

personal illness). Refreshers on illness procedures should be considered annually and when increased transmission is noted in the unit and/or the community.

**Rationale:** NICU leadership should communicate to unit staff the hospital's occupational health guidelines for when an ill HCP may return to work. Presenteeism (working despite personal illness) is a known contributor to respiratory viral transmission in healthcare settings, yet it is well described among HCP.<sup>23–27</sup> Presenteeism is caused by a combination of systems-based and complex sociocultural factors, including financial and/or job security, job discipline, social status within an organization, staffing levels, and access to or availability of sick-leave procedures.<sup>23,24</sup> Given well-described risks posed by presenteeism and its reduction noted by paid sick leave, such policies should be universally accessible to staff.

### Vaccination and postexposure chemoprophylaxis

#### Recommendations:

- Vaccination of HCP and caregivers against influenza and compliance with the facility's seasonal vaccine policies are strongly recommended to prevent healthcare transmission of viral respiratory pathogens to infants, who are ineligible under age 6 months for the influenza vaccine and other vaccines to prevent VRI.<sup>28</sup>
- In the context of outbreak control, antiviral chemoprophylaxis against influenza with oseltamivir may be recommended for all asymptomatic patients on the unit and to immune-susceptible HCP following a risk assessment.
- Palivizumab should not be used as part of RSV outbreak management to prevent further transmission within the unit.<sup>29</sup>

**Rationale:** Individuals infected with influenza may shed the virus 1–2 days before symptom onset. HCP may therefore come into work with unrecognized infection and expose patients, caregivers, and colleagues who may be at higher risk for complications of influenza. Staff and caregiver vaccination against influenza can reduce introduction of influenza into the unit and further spread to susceptible HCP and patients in open bays or neighboring pods. Infants exposed to a known case of influenza in the unit (from caregiver, visitor, or HCP) can be offered oseltamivir as postexposure chemoprophylaxis according to clinical practice guidelines.<sup>7</sup> However, no data are available regarding appropriate dosing for infants under 14 days of life.<sup>7</sup> Moreover, no data are available regarding the effectiveness of preexposure chemoprophylaxis for HCP working on an outbreak unit.<sup>14</sup> In the context of an RSV outbreak in the NICU, we agree with the existing recommendation from the AAP Report of the Committee on Infectious Diseases that palivizumab not be used as part of RSV outbreak management to prevent further transmission within the unit, due to a paucity of data.<sup>29</sup>

### Isolation precautions and personal protective equipment (PPE)

#### Recommendation:

- Patients should be placed on appropriate isolation precautions when first symptomatic, regardless of whether testing is sent.
- Appropriate PPE should be worn for all patients on isolation precautions, donned and doffed in appropriate order.
- There should be clear documentation of appropriate transmission-based precautions immediately placed in the patient's

chart, and clear signage should be placed at the entry to the patient's room or bed space.

- If resources allow, units may consider audits on donning and doffing of PPE and appropriate isolation procedures, with in-the-moment feedback and unit metrics on appropriate isolation precautions available for comparison.

**Rationale:** Patient isolation and appropriate use of PPE are foundational infection prevention practices, both for standard and for transmission-based precautions, and have been shown to be effective in preventing transmission in the healthcare setting. By isolating the patient at the source, and by donning PPE targeting the predominant mode of transmission, the risk of healthcare-associated infection is reduced.<sup>30,31</sup> Guidelines on pathogen-specific recommendations for patient placement in negative pressure rooms have been published elsewhere.<sup>31</sup>

### Environmental cleanliness

#### Recommendations:

- All shared equipment should be appropriately cleaned and disinfected after use and stored in designated clean utility areas.<sup>32</sup>
- At least once daily cleaning and disinfection of high-touch surfaces should be performed using an appropriate surface disinfectant registered by the country's regulatory authority (eg, in the United States, the EPA) and consistent with hospital policy.<sup>33,34</sup>
- Inpatient rooms should be kept clutter-free with support and education provided to families on the importance of their role in HAI prevention.
- Ideally, families should keep bedside tables and windowsills clear. They should aim to keep personal items to a minimum, with no more than a 1-week supply of belongings, and place personal items in drawers where available.
- Some NICUs have a set day-cleaning process (eg, every 14 days) to ensure ongoing decluttering and thorough disinfection.

**Rationale:** Optimal cleaning and disinfection of the patient environment should be a shared goal of unit staff, environmental services, and families. Although specific data may be limited, one modeling study showed significant success with this element of prevention, particularly when combined with additional high-yield bundle elements, predicting a decreased VRI risk by 21%–48%, with a 15% increase in hand hygiene and 2 surface cleanings.<sup>35</sup> Evidence surrounding the efficacy of UV-C light-based disinfection is evolving. If readily available, these may be considered adjunctive means of cleaning high-touch devices or equipment in patient-care areas such as phones, in addition to hand hygiene.<sup>36–38</sup>

### Question 4. What is the optimal distance between patients for isolation when not in a private room?

**Recommendation:** Infants in the NICU who require respiratory isolation should be allocated as much space as is feasible, taking into consideration the physical layout of the NICU, patient census, and staffing level.

- One meter (3 feet) between infants should be an absolute minimum.
- The approach to distancing is not affected by the type of bed (crib, warmer, or isolette).

**Rationale:** The amount of physical space required by an infant in respiratory (droplet or airborne) precautions is usually measured either in linear distance from the next patient or in square footage dedicated to the care of the infant. At an absolute minimum, HICPAC recommends 1–2 m (3–6 feet) of linear distance for droplet isolation.<sup>31</sup> Ideally, however, infants should have as much space as possible to minimize the risk of horizontal transmission of their proven or suspected respiratory infection to another patient. Obviously, this can be quite challenging, as local circumstances will affect the space available.

The most immediate limitation, and the one that is the most challenging to change, is the physical layout of the NICU. Single-patient rooms (ie, private rooms) are preferred, as they maximize floor space while ensuring at least 1 physical wall between patients.<sup>31,39</sup> However, many NICUs utilize multibed rooms (bays or a large single room), where there is higher patient density in the space available for patient care. In addition, high patient census and low staffing levels can increase patient density, and HCP time demands have been associated with increased rates of horizontal infections in the NICU.<sup>40,41</sup> Finally, local practices such as cohorting (eg, moving an infant into a room or bay with other infants who share the same colonization or infection pattern) or parent requests to keep siblings close together despite different infection-related exposures can affect transmission risk.

Traditionally, infection prevention organizations used estimates of respiratory particle size as a guide for practice recommendations. Larger particles were assumed to fall to surfaces relatively quickly, and smaller particles were assumed to remain suspended in air for longer periods. Physical proximity of <1 meter (<3 feet) has been clearly associated with increased risk for respiratory transmission of infections such as *Neisseria meningitidis* and *Streptococcus pyogenes*.<sup>42,43</sup> Although respiratory particles historically were described as a dichotomy (large droplets versus small aerosols), the size of the particles is on a spectrum.<sup>44</sup> Coughing, sneezing, and other aerosol-generating maneuvers can generate a variety of different-sized particles.<sup>45</sup>

Dispersion of respiratory secretions is also increased when babies require noninvasive ventilation support, such as high-flow nasal cannula or continuous positive airway pressure.<sup>46</sup> Finally, the potential for transmission also depends on the size of the room and available ventilation. Although isolettes may provide a physical barrier to viral respiratory pathogen exposure through air, the risks of transmission through direct and indirect contact are similar between bed types, so no recommendation is made on the minimum distance between specific bed types.

For neonatal care, the answer to the question, “How much space does this infant need?” is usually “How much space can you make?” A single-patient room is the optimal approach to preventing transmission in the unit. Barring that, physically moving the infant to a bed space where they have as much distance between themselves and other infants—particularly infants who are critically ill—is ideal. If possible, surrounding the isolated infant with a buffer of empty bed spaces is preferred. If NICU census or staffing levels do not allow creation of at least 1 meter (3 feet) of space, then it is important to collaborate promptly with administrative officials to open additional areas (eg, unused space that can be converted into NICU beds) or make additional staff available. These strategies have been used successfully in outbreak management, and failure to provide adequate separation may lead to ongoing transmission within the unit and declaration of an outbreak.

### Question 5. How long should NICU patients with VRIs be isolated?

**Recommendation:** If respiratory signs were present at the time of VRI diagnosis, precautions should be continued for at least the duration of illness.

- In the context of an ongoing exposure concern and in the absence of respiratory signs, HCP may consider repeat molecular testing and additional precautions until repeated testing is negative.
- Precautions may be discontinued if clinical signs are attributable to a noninfectious etiology and respiratory viral testing is negative.
- The duration of isolation following asymptomatic detection of respiratory viral pathogens is unclear. Testing of asymptomatic infants should be discouraged outside the outbreak setting (see question 2).

**Rationale:** Estimated rates of VRI are lower in the NICU than in other pediatric intensive care settings; however, the potential impacts on patient outcomes are significant.<sup>47</sup> VRIs in premature infants can result in the need for increased respiratory support, development of long-term morbidities such as bronchopulmonary dysplasia, longer duration of hospital stays, severe illness, and death.<sup>3,48,49</sup> VRIs may present with nonspecific signs in infants, making detection of transmission chains and timely institution of isolation precautions challenging. The true scope and magnitude of these infections is not well understood.<sup>50</sup>

Although there are established guidelines for the duration of isolation precautions in pediatric and adult settings, NICU-specific guidance is not standardized. As a result, individual healthcare institutions may have varying practices. At the time of the writing of this document, the most recent HICPAC *Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings* from 2007 recommends the use of transmission-based precautions for suspected and confirmed VRIs.<sup>31</sup> For most respiratory viruses, including non-SARS-CoV-2 human coronaviruses, human metapneumovirus, parainfluenza, respiratory syncytial virus (RSV) and rhinovirus/enterovirus, continuation of isolation precautions for the duration of illness is recommended (Table 3).<sup>7,31</sup> For influenza, isolation precautions are recommended for 7 days after illness onset or until 24 hours after the resolution of fever and respiratory symptoms, whichever is longer.<sup>28</sup> Premature infants may not present with typical respiratory signs and may have variable levels of immune compromise. As such, duration of isolation may be difficult to determine using current guidelines.<sup>50</sup> In addition, infants may have prolonged illness and shed respiratory viruses longer than older children and adults, thus a more prolonged duration of isolation precautions may be indicated.<sup>16,51,52</sup>

### Question 6. In NICUs with “open bay” or “pod” layouts, what factors should be considered when determining a possible exposure to a patient with a VRI?

**Recommendation:**

- From the infection prevention perspective, private rooms may create greater physical space between patients, visitors, and HCP, potentially decreasing pathogen exposure risk, and may decrease the use of multipatient equipment, further reducing risk.
- In units with open bay or pod layouts, it is particularly important to review the standard operating procedures and policies (or

instructions for use, IFUs) related to cleaning and disinfection of shared patient equipment. All units with concerns of intrafacility spread should, at a minimum, focus on systematically assessing and improving infection prevention practices among all staff.

**Rationale:** Identification and control of an infection source is foundational to prevent its spread to other patients and staff. This effort requires consideration of many factors, each of which will vary when applied to NICUs of differing size, design, and acuity level.

#### Neonatal unit design

The overall design of a neonatal unit can directly impact an infant’s exposure risk to respiratory pathogens. As the pediatric family-centered care model is followed in more NICU settings, many modern units are now designed with single-patient private rooms. In NICUs with open bays or pods, infants share ventilation airspace and often are near each other. In a study of 2 children’s hospitals, units with <50% single rooms had 1.33 (95% CI, 1.29–1.37) times higher HA-VRI rates than units with ≥50% single rooms; NICUs were not analyzed specifically.<sup>47</sup> This configuration may increase the risk of exposure to respiratory viruses that can also remain viable on shared patient equipment and other fomites for several hours to days.<sup>53</sup> Although there is substantial contamination of “high touch” bedside privacy screens and curtains,<sup>54</sup> data suggesting a link to transmission are limited or inapplicable to the NICU setting.

#### Patient bed type

NICUs utilize a variety of infant beds, including open cribs, open radiant warmers, and isolettes. An open crib is similar to a warmer with regard to potential exposure to pathogens. Infant isolettes, in contrast, provide a physical barrier to most viral respiratory pathogen exposure through air, unless the source is someone who provides direct hands-on care to the patient (eg, the patient’s nurse or parent).

#### Patient equipment

In the NICU setting, contaminated equipment has been identified as a point source leading to indirect contact transmission of pathogens.<sup>53</sup> For example, bacteria have been implicated in outbreaks related to rectal thermometers, breastmilk pump equipment,<sup>55</sup> oxygen saturation probe covers, and even contaminated stethoscopes<sup>56,57</sup>; many of these involve noncritical surfaces. Appropriate disinfection in between each use may not occur for such devices in all NICUs.<sup>58</sup> Viral respiratory outbreaks in the NICU are not uncommon, but those linked directly to equipment are infrequently reported. Contaminated ophthalmologic equipment has been implicated in adenovirus NICU outbreaks during routine eye exams for retinopathy of prematurity.<sup>59,60</sup>

#### HCP, caregivers, and visitors

In addition to patient-specific equipment, the point source for a single HAI or a cluster may be a staff member, a visitor, a shared fomite (eg, disposal sink), or other treatment or intervention that may or may not be centrally prepared (medication, tubing, misassigned breast milk, etc). All staff and visitors who may have interacted with an infected infant should be interviewed for the presence of symptoms. Notably, a point source is unlikely to be identified when considering a single infected infant. In up to 50% of outbreaks, no source was identified, which may contribute to

underreporting of these NICU-based events.<sup>61,62</sup> Also, many units do not have the resources to perform robust outbreak investigations. The rigor with which an individual NICU investigates a disease cluster and infection prevention practices among staff should result from input from all relevant stakeholders in the NICU and institution.

Many units assign individual staff to specific babies or create staff–patient cohorts when disease clusters occur. As a practical matter, this may be reasonable despite the inconsistency of the data on this intervention. Data also are inconsistent on the impact of patient-to-staff ratios during an outbreak as potential risks for ongoing disease spread. High ratios have frequently been linked to an increase in incidence, particularly for bacteria and device-related infection, but rarely as an independent risk factor.<sup>63,64</sup> It may also be a proxy for patient census and other workflow adjustments.

### **Question 7. What are the best methods to screen for caregivers and visitors with respiratory illness, and are there reasonable age restrictions?**

#### **Caregiver and visitor screening practices**

##### **Recommendation:**

- A combination of procedures should be considered to minimize patients' exposure to community-acquired pathogens.
- At a minimum, these procedures should include symptom-based screening.
- Additional measures, such as age-related visitor restriction, education of visitors on local prevention practices, and/or limitation of movement within the NICU, may be indicated during periods of high community transmission, as defined by public health authorities and as part of outbreak management.

**Rationale:** Caregivers and visitors are a central part of the patient's care team in the NICU, where family involvement is crucial and where additional visitors serve as necessary respite for families who are experiencing prolonged hospital stays with critically ill infants.<sup>65</sup> Yet, such benefits need to be weighed against the risk of neonatal exposure to sick caregivers, which is a known and potentially modifiable risk factor for pediatric HAIs and particularly HA-VRIs.<sup>22,66,67</sup>

Caregiver and visitor restriction policies and practices exist in most pediatric hospitals; however, approaches vary, including age-based, symptom-based policies and/or outbreak-specific policies existing either seasonally or year-round.<sup>68</sup> Ideally, these would be symptom-based, maintained year-round, performed daily and in-person with accessible language and infographics. Given that this ideal is generally not feasible, units should consider a process that functions regularly within the extent of their available resources and, most importantly, with clear accountability for action.

Symptom-based screening of caregivers that focuses on infectious symptoms can limit the introduction of viral respiratory pathogens into the unit. NICUs should consider screening processes that function regularly within the extent of available resources and have a clear plan in place for who is accountable for sick caregivers or visitors at a unit level. Screening approaches may include face-to-face questioning and/or use of a smart phone or a paper-based method. Infographics depicting concerning symptoms are recommended to make the tool more accessible.

Family education is strongly recommended to enable caregivers to recognize and report potentially infectious symptoms. Moreover, ensuring a culture of safety in the NICU will empower staff to practice a gentle but direct approach if a caregiver is visibly ill. If they screen positive and symptoms are noted during their visit, they should be asked to leave and to identify an alternative caregiver. In situations where restriction of symptomatic caregivers and visitors from the unit is not possible, including times of critical illness or end of life, the NICU should ensure that appropriate mitigation measures are in place, in consultation with unit leadership and the infection prevention and control team.

#### **Additional measures**

During periods of routine visitation, we do not recommend a particular age restriction for visitors to the NICU. Each unit should consider their own specific needs and ability to support young children in an intensive care setting. For example, we consider it reasonable to have no more than 2 individuals be at the bedside at one time, and we recommend that families remain in their room, pod, or bedspace as much as feasibly possible. During periods of high VRI transmission in the community, as defined locally with public health partners, or in the context of a unit outbreak, the NICU may consider temporarily restricting visitation to essential caregivers. During periods of high VRI transmission or in the context of a unit outbreak, reliable masking among caregivers should be strongly considered as an additional source control measure. Access to shared eating spaces and lounges during these times may also be paused.

The NICU should consider engaging visitors and caregivers in the development of visitor/caregiver policies, with input from additional key working partners, where available, including family advisory and partner councils.<sup>20,66,67</sup>

**Acknowledgments.** The authors wish to thank NICU Advisory Panel Chairs, Drs. Kristina Bryant and Deborah Yokoe. The authors thank Valerie Deloney, MBA, and Jennifer Rigatti for their organizational expertise in the development of this manuscript.

**Financial support.** The SHEA funded the development and publication of this document.

**Competing interests.** The following disclosures reflect what has been reported to SHEA. To provide transparency, SHEA requires full disclosure of all relationships, regardless of relevancy to the guideline topic. Evaluation of such relationships as potential conflicts of interest is determined by a review process. The assessment of disclosed relationships for possible conflicts of interest are based on the relative weight of the financial relationship (ie, monetary amount) and the relevance of the relationship (ie, the degree to which an association might reasonably be interpreted by an independent observer as related to the topic or recommendation of consideration). The reader of this guidance should be mindful of this when the list of disclosures is reviewed. N.T. is the primary investigator for a grant from the Canadian Institutes for Health Research on sampling surfaces in the community for SARS-CoV-2. K.Z. has a grant from the AHRQ to study antimicrobial stewardship in NICUs. All other authors report no conflicts of interest relevant to this article.

NICU Advisory Panel: Kenneth M. Zangwill, MD, American Academy of Pediatrics Section on Infectious Diseases (AAP/SOID); Kavita Bhat, MD, MPH, American Hospital Association (AHA); Jessica R. Rindels, MBA, BSN, RN, CIC, Association for Professionals in Infection Control and Epidemiology (APIC); Jill Jones, MS, APRN, NNP-BC, National Association of Neonatal Nurses (NANN); Pablo J. Sánchez, MD, Infectious Diseases Society of America (IDSA); Aaron M. Milstone, MD, Pediatric Infectious Diseases Society (PIDS); Margaret VanAmringe, MHS, The Joint Commission; and Judith Guzman-Cottrill, DO, The Vermont Oxford Network (VON).



## References

- Verboon-Macielek MA, Krediet TG, Gerards LJ, Fleer A, van Loon TM. Clinical and epidemiologic characteristics of viral infections in a neonatal intensive care unit during a 12-year period. *Pediatr Infect Dis J* 2005;24:901–904.
- Ronchi A, Michelow IC, Chapin KC, et al. Viral respiratory tract infections in the neonatal intensive care unit: the VIRIoN-I study. *J Pediatr* 2014;165:690–696.
- Bennett NJ, Tabarani CM, Bartholoma NM, et al. Unrecognized viral respiratory tract infections in premature infants during their birth hospitalization: a prospective surveillance study in two neonatal intensive care units. *J Pediatr* 2012;161:814–818.
- Marr LC, Tang JW. A paradigm shift to align transmission routes with mechanisms. *Clin Infect Dis* 2021;73:1747–1749.
- Poole CL, Camins BC, Prichard MN, Faye-Petersen O, Hutto C. Hospital-acquired viral respiratory infections in neonates hospitalized since birth in a tertiary neonatal intensive care unit. *J Perinatol* 2019;39:683–689.
- Zinna S, Lakshmanan A, Tan S, et al. Outcomes of nosocomial viral respiratory infections in high-risk neonates. *Pediatrics* 2016;138.
- Kimberlin DW, editor. *Red Book: 2021 Report of the Committee on Infectious Diseases*. Itasca, IL: American Academy of Pediatrics; 2021.
- Prophylaxis and screening for prevention of viral respiratory infections in neonatal intensive care unit patients: a systematic review. Centers for Disease Control and Prevention website. <https://www.cdc.gov/hicpac/reviews/prophylaxis-nicu/index.html>. Updated May 2023. Accessed June 2023.
- Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008;336:924–926.
- Kidszun A, Neurohr A, Grondahl B, et al. Low frequency of viral respiratory tract infections during family-centered neonatal intensive care: results of a prospective surveillance study. *Front Pediatr* 2020;8:606262.
- Cerone JB, Santos RP, Tristram D, et al. Incidence of respiratory viral infection in infants with respiratory symptoms evaluated for late-onset sepsis. *J Perinatol* 2017;37:922–926.
- Dizdar EA, Aydemir C, Erdeve O, et al. Respiratory syncytial virus outbreak defined by rapid screening in a neonatal intensive care unit. *J Hosp Infect* 2010;75:292–294.
- Rose EB, Washington EJ, Wang L, et al. Multiple respiratory syncytial virus introductions into a neonatal intensive care unit. *J Pediatric Infect Dis Soc* 2021;10:118–124.
- Uyeki TM, Bernstein HH, Bradley JS, et al. Clinical practice guidelines by the Infectious Diseases Society of America: 2018 update on diagnosis, treatment, chemoprophylaxis, and institutional outbreak management of seasonal influenza. *Clin Infect Dis* 2019;68:e1–e47.
- Reid AB, Anderson TL, Cooley L, Williamson J, McGregor AR. An outbreak of human rhinovirus species C infections in a neonatal intensive care unit. *Pediatr Infect Dis J* 2011;30:1096–1095.
- Hall CB, Douglas RG Jr, Geiman JM. Respiratory syncytial virus infections in infants: quantitation and duration of shedding. *J Pediatr* 1976;89:11–15.
- Hall CB. Nosocomial viral respiratory infections: perennial weeds on pediatric wards. *Am J Med* 1981;70:670–676.
- Evidence-based care bundles. Institute for Healthcare Improvement website. <http://www.ihio.org/Topics/Bundles/Pages/default.aspx>. Accessed July 2022.
- Hei H, Bezpalko O, Smathers SA, Coffin SE, Sammons JS. Development of a novel prevention bundle for pediatric healthcare-associated viral infections. *Infect Control Hosp Epidemiol* 2018;39:1086–1092.
- Linam WM, Marrero EM, Honeycutt MD, Wisdom CM, Gaspar A, Vijayan V. Focusing on families and visitors reduces healthcare associated respiratory viral infections in a neonatal intensive care unit. *Pediatr Qual Saf* 2019;4:e242.
- Glowicz J, Landon E, Sickbert Bennett EE, et al. Compendium of strategies to prevent healthcare-associated infections through hand hygiene: 2022 update. *Infect Control Hosp Epidemiol* 2023;44:355–376.
- Hanley S, Odeniyi F, Feemster K, Coffin SE, Sammons JS. Epidemiology and risk factors for healthcare-associated viral infections in children. *J Pediatric Infect Dis Soc* 2021;10:941–950.
- Szymczak JE, Smathers S, Hoegg C, Klieger S, Coffin SE, Sammons JS. Reasons why physicians and advanced practice clinicians work while sick: a mixed-methods analysis. *JAMA Pediatr* 2015;169:815–821.
- Chow EJ, Mermel LA. More than a cold: hospital-acquired respiratory viral infections, sick leave policy, and a need for culture change. *Infect Control Hosp Epidemiol* 2018;39:861–862.
- Callison K, Pesko MF. The effect of paid sick leave mandates on coverage, work absences, and presenteeism. *J Hum Resour* 2022;57:1178–1208.
- Chiu S, Black CL, Yue X, et al. Working with influenza-like illness: presenteeism among US healthcare personnel during the 2014–2015 influenza season. *Am J Infect Control* 2017;45:1254–1258.
- Widera E, Chang A, Chen HL. Presenteeism: a public health hazard. *J Gen Intern Med* 2010;25:1244–1247.
- Prevention strategies for seasonal influenza in healthcare settings. Centers for Disease Control and Prevention website. <http://www.cdc.gov/flu/professionals/infectioncontrol/healthcaresettings.htm>. Accessed November 2016.
- Respiratory syncytial virus. In: *Red Book: 2021 Report of the Committee on Infectious Diseases*, Kimberlin DW, editor. Itasca, IL: American Academy of Pediatrics; 2021:628–636.
- Picard C, Edlund M, Keddie C, et al. The effects of trained observers (doctors) and audits during a facility-wide COVID-19 outbreak: a mixed-methods quality improvement analysis. *Am J Infect Control* 2021;49:1136–1141.
- Siegel JD, Rhinehart E, Jackson M, Chiarello L. 2007 Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings. Appendix A: Type and duration of precautions recommended for selected infections and conditions (2018 update). *Am J Infect Control* 2007;35:S65–S164.
- Rutala WA, Weber D, HICPAC. Guideline for disinfection and sterilization in healthcare facilities, 2008. Centers for Disease Control and Prevention website. <https://www.cdc.gov/infectioncontrol/pdf/guidelines/disinfection-guidelines-H.pdf>. Updated May 2019. Accessed June 2023.
- Kundrapu S, Sunkesula V, Jury LA, Sitzlar BM, Donskey CJ. Daily disinfection of high-touch surfaces in isolation rooms to reduce contamination of healthcare workers' hands. *Infect Control Hosp Epidemiol* 2012;33:1039–1042.
- Provincial Infectious Diseases Advisory Committee. Best practices for environmental cleaning for prevention and control of infections in all health care settings, third edition. Public Health Ontario website. <https://www.publichealthontario.ca/-/media/documents/b/2018/bp-environmental-cleaning.pdf>. Updated April 2018. Accessed June 2023.
- Wilson AM, Reynolds KA, Canales RA. Estimating the effect of hand hygiene compliance and surface cleaning timing on infection risk reductions with a mathematical modeling approach. *Am J Infect Control* 2019;47:1453–1459.
- Demeersseman N, Saegeman V, Cossey V, Devriese H, Schuermans A. Shedding a light on ultraviolet-C technologies in the hospital environment. *J Hosp Infect* 2023;132:85–92.
- Chiappa F, Frascella B, Vigezzi GP, et al. The efficacy of ultraviolet light-emitting technology against coronaviruses: a systematic review. *J Hosp Infect* 2021;114:63–78.
- Rudhart SA, Gunther F, Dapper L, Stuck BA, Hoch S. UV-C light-based surface disinfection: analysis of its virucidal efficacy using a bacteriophage model. *Int J Environ Res Public Health* 2022;19.
- Kilpatrick, SJ, Papile L, Macones GA, Watterberg, KL, editors. *Guidelines for Perinatal Care, Eighth Edition*. Washington, DC: American College of Obstetricians and Gynecologists; 2017:691.
- Haley RW, Bregman DA. The role of understaffing and overcrowding in recurrent outbreaks of staphylococcal infection in a neonatal special-care unit. *J Infect Dis* 1982;145:875–885.
- Dahl TM, Solevag AL. A cross-sectional study of neonatal intensive care unit overcrowding and understaffing associated with bacterial outbreaks. *Acta Paediatr* 2022;111:2090–2097.
- Feigin RD, Baker CJ, Herwaldt LA, Lampe RM, Mason EO, Whitney SE. Epidemic meningococcal disease in an elementary-school classroom. *N Engl J Med* 1982;307:1255–1257.

43. Hamburger M Jr, Robertson OH. Expulsion of group A hemolytic streptococci in droplets and droplet nuclei by sneezing, coughing and talking. *Am J Med* 1948;4:690–701.
44. Leung NHL. Transmissibility and transmission of respiratory viruses. *Nat Rev Microbiol* 2021;19:528–545.
45. Javorka K, Tomori Z, Zavorska L. Mechanics of breathing during sneezing and crying in premature newborns. *Eur J Respir Dis* 1982;63:442–448.
46. Sahih M, Schultz A, Wilson A, *et al*. Paediatric headbox as aerosol and droplet barrier. *Arch Dis Childhood* 2022;107:65–67.
47. Quach C, Shah R, Rubin LG. Burden of healthcare-associated viral respiratory infections in children's hospitals. *J Pediatric Infect Dis Soc* 2018;7:18–24.
48. Pichler K, Assadian O, Berger A. Viral respiratory infections in the neonatal intensive care unit—a review. *Front Microbiol* 2018;9:2484.
49. Civardi E, Tziella C, Baldanti F, Strocchio L, Manzoni P, Stronati M. Viral outbreaks in neonatal intensive care units: what we do not know. *Am J Infect Control* 2013;41:854–856.
50. Poole CL, Nyquist AC, eds. Pathogens spread via respiratory route. In: *Handbook of Pediatric Infection Prevention and Control*. New York: Oxford University Press; 2019.
51. Takeyama A, Hashimoto K, Sato M, Kawashima R, Kawasaki Y, Hosoya M. Respiratory syncytial virus shedding by children hospitalized with lower respiratory tract infection. *J Med Virol* 2016;88:938–946.
52. Rubin LG, Kohn N, Nullet S, Hill M. Reduction in rate of nosocomial respiratory virus infections in a children's hospital associated with enhanced isolation precautions. *Infect Control Hosp Epidemiol* 2018;39:152–156.
53. Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. *BMC Infect Dis* 2006;6:130.
54. Cobrado L, Silva-Dias A, Azevedo MM, Rodrigues AG. High-touch surfaces: microbial neighbours at hand. *Eur J Clin Microbiol Infect Dis* 2017;36:2053–2062.
55. Donowitz LG, Marsik FJ, Fisher KA, Wenzel RP. Contaminated breast milk: a source of *Klebsiella* bacteremia in a newborn intensive care unit. *Rev Infect Dis* 1981;3:716–720.
56. Gastmeier P, Groneberg K, Weist K, Ruden H. A cluster of nosocomial *Klebsiella pneumoniae* bloodstream infections in a neonatal intensive care department: identification of transmission and intervention. *Am J Infect Control* 2003;31:424–430.
57. Millan-Lou MI, Lopez C, Bueno J, *et al*. Successful control of *Serratia marcescens* outbreak in a neonatal unit of a tertiary-care hospital in Spain. *Enferm Infecc Microbiol Clin (Engl Ed)* 2022;40:248–254.
58. Kalra S, Amin A, Albert N, *et al*. Stethoscope hygiene: a call to action. Recommendations to update the CDC guidelines. *Infect Control Hosp Epidemiol* 2021;42:740–742.
59. Ersoy Y, Otlu B, Turkcuoglu P, Yetkin F, Aker S, Kuzucu C. Outbreak of adenovirus serotype 8 conjunctivitis in preterm infants in a neonatal intensive care unit. *J Hosp Infect* 2012;80:144–149.
60. Sammons JS, Graf EH, Townsend S, *et al*. Outbreak of adenovirus in a neonatal intensive care unit: critical importance of equipment cleaning during inpatient ophthalmologic examinations. *Ophthalmology* 2019;126:137–143.
61. Gastmeier P, Loui A, Stamm-Balderjahn S, *et al*. Outbreaks in neonatal intensive care units—they are not like others. *Am J Infect Control* 2007;35:172–176.
62. Johnson J, Quach C. Outbreaks in the neonatal ICU: a review of the literature. *Curr Opin Infect Dis* 2017;30:395–403.
63. Hensel KO, van den Bruck R, Klare I, Heldmann M, Ghebremedhin B, Jenke AC. Nursing staff fluctuation and pathogenic burden in the NICU—effective outbreak management and the underestimated relevance of nonresistant strains. *Sci Rep* 2017;7:45014.
64. Rogowski JA, Staiger D, Patrick T, Horbar J, Kenny M, Lake ET. Nurse staffing and NICU infection rates. *JAMA Pediatr* 2013;167:444–450.
65. Murray PD, Swanson JR. Visitation restrictions: is it right and how do we support families in the NICU during COVID-19? *J Perinatol* 2020;40:1576–1581.
66. Johnson J, Akinboyo IC, Schaffzin JK. Infection prevention in the neonatal intensive care unit. *Clin Perinatol* 2021;48:413–429.
67. Paquette M, Shephard A, Bedard P, Thampi N. Viral respiratory infections in hospitalized children with symptomatic caregivers. *Hosp Pediatr* 2022;12:e124–e128.
68. Pong AL, Beekmann SE, Faltamo MM, Polgreen PM, Shane AL. Visitor restriction policies and practices in children's hospitals in North America: results of an Emerging Infections Network Survey. *Infect Control Hosp Epidemiol* 2018;39:968–971.