Pediatric Procedural Adaptations for Low-Resource Settings

A Case-Based Guide

Tina M. Slusher
Ashley R. Bjorklund
Stephanie M. Lauden
Editors

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To the Stop Kernicterus In Northern Nigeria Collaboration; to Professors Angela Okolo, William Ogala, and Joshua Owa, and all the pediatricians and healthcare team members who have taught me to care for children around the world; to the Global Pediatrics Program at the University of Minnesota; to my colleagues at Hennepin Healthcare as well as my friends and family who have made it possible for me to travel; and, finally, to all the children God has blessed me to care for over these past 34 plus years.

Tina M. Slusher

Foreword

Manufactured equipment for pediatric procedures and medical devices are typically very costly, often prohibitively so, in low- and middle-income countries (LMICs). For over three decades, Professor Tina M. Slusher, senior editor of this book, has spent her career dedicated to advancing the care of children across the globe. Through inter- national multi-disciplinary team collaboration, she has studied common pediatric procedures and device designs, in order to modify, teach, and implement adaptations for common pediatric procedures in LMICs.

Prof. Slusher has practiced in settings across the spectrum of resources, learning from her LMIC partners, and working together with them collaboratively, to build strong equitable partnerships in pediatric and neonatal care. Always seeking to practice the best medicine possible in each locale, she has gathered ideas about innovations and adaptions from anyone willing to spend time thinking about how to make more out of less.

Most of these effective "innovations" are resourceful modifications and adaptations that simplify the device design toward the blueprint and the basic concepts behind the design. A few of these adaptations are original with Prof. Slusher, though they would not have come to fruition without the countless collaborators from around the world being willing to share their secrets and brainstorm about the challenges of doing a procedure without a commercial kit or high-cost supplies and equipment.

As a skillful teacher, Prof. Slusher has helped to share the adaptations she has learned from global colleagues and then co-taught with these colleagues in limited resource settings. She has dedicated her career to sharing knowledge of these procedures, teaching countless residents, students, nurses, and other healthcare providers, at the bedside, in conferences and hands-on workshops, and digitally (including free online material), and the content of her teachings have been well received – both in the United States and around the world.

This unique book is the first to package this content in a user-friendly, highly adaptable, pocket size format that is likely to find wide usage around the globe. It uniquely supports different learner preferences, with opportunities to learn via cases, reading, videos, and visual diagrams. This is very welcome given the variable

needs and situations of learners, from limited access to Internet in some places, to visual learners, and those who need an on-the-go resource. Furthermore, having the content in this easily usable format will enable practitioners especially in LMICs to care for children in a cost-effective, evidence-based, and safe way – despite resource limitations.

I congratulate Prof. Tina M. Slusher and her team of co-editors and authors for compiling this very resourceful book, and highly recommend it to practitioners especially in low resource settings, and those (including students) preparing to practice in those settings.

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Editors and Contributors

About the Editors

Tina M. Slusher, MD, FAAP completed her undergraduate studies at Eastern Kentucky University and then medical school at the University of Kentucky. She completed her pediatric residency at Oklahoma University in Oklahoma City, OK. She practiced medicine in Pikeville, KY, for 7 years during which time she made her first trip to Nigeria. This trip led her to leave private practice and do a fellowship in pediatric critical care at the University of Texas Southwestern, Dallas, TX. She did her research year of her fellowship split between Nigeria and Kenya where she worked clinically covering busy neonatal and pediatric services. During that time, she has spent part of each year working on pediatric global health and often in Nigeria and other countries in sub-Saharan Africa with short stints in Asia, Europe, and Central America. She has had several funded pediatric global health research projects (NIH, Thrasher, USAID, etc.) most focused on severe neonatal hyperbilirubinemia/jaundice but on other subjects as well including breast milk use in low birth weight and sick neonates and respiratory support beyond the neonate. She is currently a pediatric intensivist at Hennepin Healthcare and Professor of Pediatrics at the University of Minnesota in the Division of Critical Care, and is the research director for the Global Pediatrics Program. She is active in the leadership of the Global Pediatric Program and continues to network striving for equitable partnerships with colleagues around the globe in research, teaching, and clinical care.

Ashley R. Bjorklund, MD, FAAP completed undergraduate at North Park University, and then medical school at Rush Medical College at Rush University in Chicago, IL. She went on to complete internal medicine and pediatric residency as well as pediatric critical care fellowship at the University of Minnesota. In residency, she completed both the internal medicine and pediatric global heath program tracks and gained experience training in international partner sites. In fellowship, she was awarded a Thrasher Early Career Award to be the lead investigator with a

team of researchers in the USA and Uganda developing and studying a modification to a low cost bubble continuous positive airway pressure (BCPAP) device for use in children with respiratory distress in limited resource settings. She served as a pediatrician in the United States Navy Medical Corps. In 2019, she joined the Department of Pediatrics at Hennepin Healthcare in Minneapolis, MN, where she is currently the Medical Director of the Pediatric Intensive Care Unit and as an Assistant Professor at the University of Minnesota; she is the Program Director for the Pediatric Critical Care fellowship. As faculty of the University of Minnesota Global Pediatrics Program, she volunteers as co-director of the Global Research Program and she continues to work in partnership with an array of researchers and clinicians on development of low cost respiratory support device modifications and pediatric critical care training for limited resource settings.

Stephanie M. Lauden, MD, CTropMed®, FAAP completed dual-undergraduate degrees at the University of Rochester, and then medical school at the Boonshoft School of Medicine at Wright State University in Dayton, Ohio. She went on to complete pediatric residency at the University of Minnesota. In Minnesota, she served as a Pediatric Global Health Chief Resident, which allowed her to teach and conduct research in the USA, Cameroon, and Thailand, and earn a certificate in tropical medicine through the American Society of Tropical Medicine and Hygiene. Dr. Lauden joined Nationwide Children's Hospital in September 2017, initially in the division of Pediatric Emergency Medicine, and then transitioned to Pediatric Hospital Medicine in 2018. Dr. Lauden joined Nationwide Children's Hospital in 2017. There, she served as co-director for both the ethics and global health residency advanced competencies and Hospital Pediatrics Medical Director at the Behavioral Health Pavilion. In 2022, she was appointed as a Visiting Associate Professor at the University of Colorado and took on a new role as the Program Director for Pediatric and Psychiatric Integrative Services at Children's Hospital Colorado. She continues to be actively engaged in both local and national academic collaboratives with a focus on under-resource populations, communication with patients with limited-English proficiency, and global health education.

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Background

Stephanie M. Lauden, Ashley R. Bjorklund, and Tina M. Slusher

Necessity is the mother of innovation

–Original source unknown

Abbreviations

HIC	High-income country
LMIC	Low- and middle-income country
SDG	Sustainable Development Goal
WHO	World Health Organization

Through robust international collaboration efforts, global partners have seen the under-five mortality rate drop of 61% since 1990, largely due to a decline in infectious diseases. Despite this significant progress, 5.2 million children died in 2019, mostly from preventable and treatable causes [1]. Per the World Health Organization (WHO), two regions accounted for more than 80% of the 5.2 million deaths in 2019—Sub-Saharan Africa and Central Asia. The third Sustainable Development Goal (SDG) [2] includes targets to "end preventable deaths of newborns and children under five years by 2030" and to "reduce newborn mortality to <12 per 1,000

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live births in every country." SDGs also strive to reduce under-five mortality to <25 per 1000 live births in every country. Meeting the SDG 3 target would reduce the number of under-five deaths by 11 million between 2017 and 2030, yet at least 60 countries would require accelerated progress to meet these goals [3, 4]; thus, we have a lot of work to do.

Pediatric and neonatal care continue to advance with the development of new technology and improvements in care delivery methods. However, these advancements are often not affordable, feasible, or available in resource-limited settings. This leads to significant discrepancies in what devices, equipment, monitoring, and therapeutics are available in low- and middle-income countries (LMICs) compared to what becomes standard of care in high-income countries (HICs). Inequalities in resource distribution and availability create significant barriers to providing evidence-based and equitable care for all people [5]. There are increasing calls to "empower frontline innovations" as a way to address these gaps and procure needed medical supplies [5].

Great Need Has Led to Significant Innovation and International Partnerships The first of its kind, we developed this book to compile a series of high yield procedural and device innovations for those working in limited-resource settings. Many of these adaptations are rooted in well-studied evidence, while others are the result of decades of clinical success and experience. It is intended to equip healthcare providers working in low-resource settings with (1) background for how, when, and why an adaptation may be useful, (2) evidence to support use of the adaptation, (3) indications and contraindications for different settings, (4) step-by-step instructions, and (5) advice for troubleshooting and monitoring for possible complications. Importantly, this book is not intended to teach novice providers *how* to perform invasive procedures, as this is beyond the scope of the book. Rather the case studies and topics are written to provide *skilled proceduralists* with alternative, creative, and evidence-based options when faced with patients who require procedural interventions not available in their resource-limited settings.

This collection of adaptations is the result of countless global collaborators in pediatric care who have generously shared their successes, failures, and ideas about ways to overcome the challenges encountered while providing care with limited resources. Each chapter is written by authors born in or working largely in a LMIC in collaboration with authors from a HIC with significant experience working in resource-limited settings. Where known, we have given credit to the team who originally adapted the procedure. However, the majority of these procedural adaptations are the result of many individuals and teams working together; therefore, who to credit is simply unknown to us.

By sharing these innovations and adaptations, we, the editors and authors, strive to join with all our global partners in reaching children who are the most vulnerable. We aspire to play a small part in decreasing the morbidity and mortality faced by those struggling to meet the SDG 3 goals through safe, efficacious, affordable, and locally available adaptations. We commit to providing high-quality, evidenced-based care, wherever we care for children, with what we have available. Additionally,

we hope this book will inspire others to dream big, develop new and better adaptations, and share those innovations with the global community. Focusing on innovations does not minimize the importance of addressing larger systemic questions of affordability and ethics surrounding inequitable access to the newest technologies. We applaud those engaged in this work. However, focusing on what we can do right now, with what we have, for the patient in front of us, is a critical first step in improving care in low-resource settings.

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Procedural Adaptation and Device Modification Concepts in a Low-Resource Setting

Ashley R. Bjorklund, Stephanie M. Lauden, and Tina M. Slusher

Abbreviations

BCPAP	Bubble continuous positive airway pressure
HIC	High-income countries
LMICs	Low- and middle-income countries

1 Background

A team of experienced practitioners from both high-income countries (HIC) and low-and middle-income countries (LMICs) collaborated to develop a collection of procedural and device modifications which have been used safely and successfully in limited-resource settings by experienced practitioners with advanced understanding of pediatric care. They sought to share lessons learned with individuals practicing in low-resource settings. This book reviews this series of "Procedural Adaptations" and "Device Modifications." The descriptions are intended to help those practicing in limited resource settings when they need to do a procedure (that they have been trained to perform) but do not have the standard supplies and

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equipment typically available in a higher resource setting. Our hope is that this resource will prevent practitioners from having to "reinvent the wheel." Each possible substitutions or adaptation is covered using case-based scenarios. For this textbook, terms such as under-resourced, resource-denied, underserved and resource-limited are used, though we recognize that these terms have limitations and must be considered in terms of a particular context. For a variety of complex reasons outside the scope of this textbook, the reality is that some patients have access to high-quality healthcare, and others do not. Regardless of origin, local resources, socioeconomic status, or demographics, all individuals are worthy of having access to and receiving high-quality, evidence-based, whole-person care.

2 Ethical Framework

For centuries, healthcare providers have been asked to adhere to the core tenant of the Hippocratic Oath – "First do no harm." Providers must consider the unique vulnerabilities faced by both children and individuals living in low-resource settings, and exercise discernment when weighing the risks and benefits of interventions. The recognition of the intrinsic value of all humans is essential.

Healthcare providers bring their own perspectives, biases, and experiences to clinical encounters. For example, some providers may incorrectly justify the delivery of substandard medical care in settings where resources are limited or denied. However, with the recognition of the intrinsic value of all persons, we argue that medicine practiced in any setting should be high in quality. This book uniquely provides practitioners with the tools to both recognize real resource limitations and provide high-quality medical care using available resources.

As providers consider what procedural adaptations and device modifications might be appropriate in a given setting, we must draw a distinction between merely *trying something* and *conducting research*. All the principles which guide ethical research in high-resource settings apply directly to studying adaptations and modifications in low-resource settings. Experimentation should only be done in the context of *research* with appropriate regulatory controls, research review board evaluation, consent, ethics committee approval, etc. Research conducted in low-resource or resource-denied settings must be both supported and desired by the local community. Ideally, the local healthcare providers lead or co-lead any research and are included in any publications.

Evidence-based medicine should be practiced in all settings, to the best of our ability, regardless of resource availability. All of the device modifications and procedural adaptations discussed in this book have been safely utilized in clinical practice by experienced practitioners. Clinical care should continue to be provided in a manner that is with a "best possible option/outcome" mindset in all populations, which sometimes includes "outside of the box" treatments in emergent or urgent situations. There is a growing body of evidence supporting many of the

modifications and adaptations outlined in this book. When available, this evidence will be cited alongside each procedure.

Key Concepts in Procedures and Procedural Adaptations There are several key principles which must be understood by readers before attempting procedural adaptations in any setting:

1. *Weighing risks and benefits:* As is true with any procedure, attention should be given to weighing the risks and benefits of any proposed intervention. Complications for the individual patient and their families may carry an even more significant burden in LMIC settings due to resource limitations and fee-for-service models. Risks should be considered carefully prior to proceeding with any invasive procedure, especially if elective. In addition, careful consideration should be given as to which patients are most likely to benefit from aggressive or invasive interventions. In settings with fee-for-service models, the cost of care becomes another key consideration in deciding the extent or level of care pursued in order to avoid additional hardship or financial burdens for families. The ethics surrounding resource distribution and extent of care are outside the context of this textbook, though awareness of these factors is critical to whole-person care. Parents may be choosing between the medical intervention you recommended and funding education for their other three children.
2. *Informed consent:* Providers have an ethical obligation to make sure patients and their guardians understand the indications for the procedure, alternative options, and potential complications. Except in extreme circumstances, consent must be obtained using the patient's native language with consideration for patient's level of literacy. Generally, adaptations that have low to no risk, or have been demonstrated to be safe and efficacious over time, do not require an additional consent process specifically related to the adaptation. An example of this would be using a feeding tube as a safe alternative for an umbilical venous catheter. In contrast, new or unstudied adaptations with beyond minimal risk warrant additional discussion of potential unknowns and complications related specifically to the adaptation. This discussion should occur in addition to the usual procedure discussion and consent. Lack of a policy that specifies need for written consent should not negate families being involved in, at a minimum, a discussion of risks, benefits, and alternatives. Informed consent is guided by ethical and moral principles.
3. *Procedural skills:* Understanding the rationale underlying procedurals steps and specific equipment used in a procedure may allow the proceduralist to understand what can be modified safely. If a modification to an established procedure is to be performed, the proceduralist should rehearse the steps until they feel confident with the proposed adaptation and have all available supplies on-hand. Any provider, including those coming from a HIC, who has not been trained to perform a procedure should not be performing the procedure without the appropriate supervision and guidance. For many of the procedures described in this book, the most experienced providers (i.e., teachers) are the providers living and working in the low-resource setting.

4. *Emergent situations:* Although it would be of ethical and moral concern for a provider without proper training to perform one of the adaptations outlined in this book, there may be extremely rare, life-threatening situations where no other provider is available. In these emergent situations, where it would be impossible to wait for another provider or transfer the patient elsewhere, it may be more harmful to do nothing rather than attempt an emergent procedure. In any setting, when an emergency arises, the most skilled clinician should be identified with the goal of providing every child the highest quality of care available.

Key Concepts in Device Modifications and Innovations

Equipment is often donated to LMICs by well-intentioned HIC partners with the hope of overcoming financial burdens or material resource needs. While some of this equipment can be utilized appropriately, it is not uncommon to have "graveyards" of unused or broken equipment. Even small repair-parts may be unavailable in low-resource settings or too expensive to purchase. Without appropriate training, staff to monitor and implement use, bioengineering support to repair broken equipment, and access to commercialized specialized replacement pieces, donated supplies become unused supplies. It is out of this recognition that device modifications have become an important bridge to the disparities in technology available.

"Blueprint" Model of Device Design Appropriate device modification requires an understanding of the physics of the design and the pathophysiology associated with use of the device. Without this foundational understanding, it is possible to create a device that is dangerous and can do more harm than good. Many helpful "device innovations" are created by reviewing the basic blueprint or original product design that was created prior to commercialization. Examples of this "blueprint" innovation concept are bubble continuous positive airway pressure (BCPAP) and the chest drainage system described in this book – the designs shown/discussed in this text are simply the setup that was created prior to commercialization.

Bioengineers Adding biomedical engineers to any device innovation team should be encouraged. Projects often involve collaboration between engineers from both high- and low-resource sites as they design, troubleshoot, and test device safety. There are many examples of device innovations coming from innovators in LMICs. Input from LMIC engineers, practitioners, and healthcare workers is essential if the innovation is to be sustainable and maximally impactful [1, 2]. Without including engineers from low-resource settings, even the most effective and well-designed innovations will become useless if no one is able to maintain the equipment in its local home.

Local Resource Use Sustainability is critical. As healthcare providers and engineers consider potential modifications to commercialized devices or high-resource procedures, it is critical to consider what local supplies are currently available and how these supplies will continue to be sourced long-term. The use of local supplies for devices must not be so expansive that those supplies become unavailable for other common uses. For example, if all the Foley catheters are used for chest tubes, then a local site may run out of Foleys for urinary retention.

Chest tube placement is relatively rare compared to Foley placement. Similarly, if the nasal cannula supply is diminished as they are utilized for making BCPAP circuits, what happens when a patient needs a simple nasal cannula for low flow oxygen? Relying on supplies shipped from other countries or donated by volunteers creates significant barriers to sustainability and should be avoided if possible. Additionally, ideal devices do not rely on resources that can be unreliable (e.g., electricity or Internet).

Reproducible Device modifications should be easy to build and easy to reproduce. Design simplicity is key. As with any process, the more complicated and numerous the steps required, the more likely that error may be introduced.

Durability In environments with limited bioengineering support, lack of temperature control, and heavy patient loads in crowded conditions, the long-term durability of a device modification must be factored into the design. Examples of these factors include limited air conditioning, lack of reliable electricity, and dust storms (Harmattan in sub-Saharan African). In addition, fragile, temperature-sensitive devices may work well in a high-resource setting, but mechanically fail in a low-resource setting, even with well-trained and dedicated staff. Even the most highly trained staff cannot overcome a brownout, extreme weather, etc.

Cost-Effective "Low cost" is a relative term depending on the reach of the innovation and the efficacy of the device. The impact on resource allocation (nursing, electricity, bed space, families, communities, etc.) should be considered.

Safety It is essential to ensure safety as we design device modifications. As the device is designed, attention should be paid to how each modification might affect the safety. For example, before trialing a device which makes contact with a patient's skin, it is appropriate to question if this device has been tested on the skin previously. Is there a risk of skin irritation, pressure ulcers, etc.? Anyone using a modified device should understand potential complications or what could happen if that device were to malfunction. For example, with the chest tube/pleuro-drainage system, if this malfunctions or is set up inappropriately, it could cause a tension pneumothorax. Safety and risk considerations are balanced with patient acuity and overall harm vs benefit calculation.

Efficacy Finally, it is essential to evaluate device efficacy. Every effort should be made to promote clinical trials of modified devices, especially those that have not been used extensively in the past, prior to widespread adaptation. Several device modifications have successfully been studied and used in multiple low-resource settings without additional known complications. An example of this is using a using a home-made spacer for bronchodilator therapy [3]. This is both effective and without additional risk. Other procedural or device modifications have only been tested in certain populations or specific clinical contexts. For example, BCPAP is well-established as a safe alternative to conventional CPAP in the neonatal population, but additional studies are required to understand safety in efficacy in more acutely ill children [4].

Clinicians designing new low-cost adaptations should be encouraged to incorporate clinical trials into their design. Grant committees should be made aware of the value of funding research focused on evaluating the safety, efficacy, and implementation of these modifications.

3 Using This Book

Understanding the foundational concepts behind procedural adaptations and device modifications is required before utilizing the information contained in each chapter of this book. These chapters have been written in a format that outlines (1) the need for the innovation or adaptation, (2) the evidence behind the innovation or adaptation described, (3) step-by-step instructions, and (4) complications that should be understood prior to proceeding with the procedure or using the modified device. In addition to providing the device modifications and procedural adaptations that are currently available, we hope that understanding these concepts will help guide future innovators to advance pediatric care in limited resource settings with ethically responsible, sustainable, and effective innovations. Should this book lead to further questions, please do not hesitate to contact our corresponding author.

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Basics of Pediatric Intensive Care, Neonatal Intensive Care, and Pediatric Emergency Medicine in a Low-Resource Setting

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Abbreviations

BUN	Blood urea nitrogen
CBC	Complete blood count
CO2	Carbon dioxide
CPAP	Continuous positive airway pressure
CR	Cardiorespiratory
CSF	Cerebral spinal fluid
CT	Computed tomography
CVP	Central venous pressure
ED	Emergency department
EMR	Electronic medical records
ETCO2	End-tidal carbon dioxide
HAAs	High acuity areas
Hct	Hematocrit

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Hgb	Hemoglobin
IV	Intravenous
IVF	Intravenous fluid
LBW	Low birth weight
MD	Medical doctor
MOH	Ministry of Health
MRI	Magnetic resonance imaging
NG	Nasogastric
NICU	Neonatal intensive care unit
NIPVV	Noninvasive positive pressure ventilation
NPO	Nothing per os
NSAID	Nonsteroidal anti-inflammatory drugs
OR	Operating room
PCV	Packed cell volume
PED	Pediatric emergency department
PICU	Pediatric intensive care unit
PO	Per os
POC	Point of care
QI	Quality improvement
RN	Registered nurse
RT	Respiratory therapist
T&C	Type and cross
VLBW	Very low birth weight

1 Background

Many procedures described in this book are performed in high acuity areas such as the pediatric intensive care unit (PICU), neonatal intensive care unit (NICU), and pediatric emergency department (PED). The purpose of this chapter is to provide a basic outline for the development and sustainability of a PICU, NICU, or PED, subsequently referred to as high acuity areas (HAAs), in limited resource settings in order to provide good clinical care, thereby reducing morbidity and mortality. These general guidelines are intended to be adapted for specific local, regional, and countrywide circumstances and cultural considerations.

1.1 Administration

Essential to the successful development and maintenance of an HAA is not only the commitment from the local hospital administration and leadership but also commitment from all involved levels of government including district/regional administrators and the Ministry of Health (MOH). Establishing and maintaining good relationships with referral sources is essential. Bidirectional communication

between and integration with regional healthcare sites (e.g., regional hospital, district hospital, health centers) is needed to assure provision of appropriate levels of care, consultation, referral, and transfer of patients between sites. The MOH and hospital administration, in consultation with the HAA team, should develop guidelines for referrals between HAA facilities and all associated healthcare sites to enable appropriate escalation or de-escalation of care. The care for critically ill neonates and children at each site should be performed according to protocols and treatment guidelines that meet the national standards.

The setting up and maintaining of an HAA in developing countries requires a long-term administrative and financial commitment. Sustaining a functional PED, PICU, or NICU may be more challenging than establishing one. The decision to develop and support an HAA should be congruent with overall hospital goals and objectives, and be independent of individual changes in hospital administrative positions or board membership. Sufficient, ongoing financial and administrative commitment from the hospital, government, and/or MOH is essential to prevent the collapse of the HAA. Annual MOH and hospital budgets need to be sufficient for the support of personnel; for procurement, maintenance, and repair of necessary capital equipment (e.g., ventilators, warmers, suction machines, and IV pumps); for replacement of associated disposables (e.g., IV tubing, ventilator/continuous positive airway pressure (CPAP) circuits, nasal cannula); and for other essential supplies (e.g., gloves, needles, syringes, feeding tubes, alcohol wipes). MOH funding and health insurance reimbursement should be sufficient to cover the level, type, and volume of care provided by the HAA rather than being based only on hospital location or designation. MOH funding and health insurance reimbursements need to be prompt; delays result in difficulty paying suppliers and staff salaries, adversely affecting the quality of patient care.

1.2 Levels of Care

Local experts, regional health leadership, and the MOH should develop standards for all levels of care associated with HAAs. Definitions of **"**levels of care" in the PICU, NICU, and PED may vary depending upon resources available or as determined by individual country standards and guidelines. There is no system that will fit the needs of every region or resource-limited setting. Defining tiered approaches to care should be considered by all administrative levels of healthcare (i.e., country, region, institution). An example of care levels is shown for NICUs in Table 1.

1.3 Personnel

Personnel are essential to the function of any unit. Hospital staffing or personnel is often provided through the cooperation between government and individual institutions. Personnel for an HAA include registered nurses (RN), medical doctors (MD),

Table 1 Examples of tiered levels of neonatal care

Level of care	Description
Basic	Provide emergency bag and mask resuscitation at delivery of a newborn; bulb suction or other suction device, intermittent vital sign monitoring (heart rate, respiratory rate, temperature); routine postnatal care for the healthy, physiologically stable term (≥38 weeks' gestation) and late preterm (35–37 weeks' gestation) newborns; enteral nutritional support, cup feeding, initial fluid resuscitation; administration of antimicrobials
Intermediate (basic plus the following)	Care for moderately preterm (32–34 weeks' gestation) and LBW (<2500–1500 g) newborns; vital sign monitoring (heart rate, respiratory rate, temperature, oxygen saturation); respiratory support including supplemental oxygen and CPAP; nutritional support with NG tube feeding; intravenous fluids and antibiotics; phototherapy, transfusion, surgical and medical subspecialty consults available; basic radiographic and laboratory support
Advanced (intermediate plus the following)	Comprehensive care for VLBW (<1500 g), very preterm (<32 weeks' gestation) neonates and sustained life support for any critically ill newborn; respiratory support including invasive mechanical ventilation; intravenous vasoactive support and parenteral nutrition; emergent surgical and medical specialty consultation; readily available radiographic and ultrasonic imaging; wide range of laboratory support

and mid-level providers such as clinical officers, respiratory therapists (RT), pharmacists, biomedical engineers, and environmental service workers. Commitment to provide sufficient annual funding for HAA personnel is essential. Nurses often provide the majority of patient care in the HAA. It is essential to recruit and retain a sufficient number of experienced, well-trained nursing staff in order to provide quality patient care. There should be a commitment to adequate initial training, ongoing medical education, as well as engagement of nursing at all levels in quality improvement initiatives.

The availability of personnel to fulfill specific roles involved in providing care for critically ill children is important. The training level of the personnel available to fulfill these roles may vary between institutions. In high-resource settings, individual specialists are responsible for performing specific functions such as overseeing respiratory care, medication management to assure proper drug selection and dosing, and equipment maintenance. Where staffing is limited, individual doctors and nurses can assume these specialized roles. On-call or standby staffing allows for some flexibility when patient census changes. Personnel assigned to perform duties other than direct patient care in the HAA may be able to provide patient care when census changes during surges. Having specifically designated staff to regularly clean all equipment and the physical environment is very important to reduce the risk of transmission of potentially deadly pathogenic organisms to the staff and from one patient to another.

Managing critically ill patients requires a team approach to care. The team includes all those providing patient care: physicians, nurses, and ancillary staff. Each team member should be aware of their individual responsibilities on the team. Respect for each other and open communication between team members are critical for a well-functioning team and optimal patient care. For instance, during

resuscitation it is important to have a team leader – most often a physician – who oversees the resuscitation and coordinates care efforts among the team.

Staff burnout, low salaries, and the intensity of the work all threaten the integrity of HAAs. In addition to the initial training, regular education including in vivo simulation in the HAA or simulation mock codes reinforces familiarity with procedures, teaches team-building strategies, and encourages team cohesion. Once trained to provide care in an HAA, staff should be allowed to remain in such areas to maintain high levels of clinical competency. Every effort should be made to retain experienced staff who choose to work in the HAA and who find working there rewarding. Transfer into the HAA and/or retention of staff who are either disinterested or who have difficulty personally tolerating the stressful intensive care environment can be detrimental to patient care.

Initial and recurrent training of personnel, providing levels of staff certification, remuneration for subspecialty or advanced training and competitive salaries to encourage experienced staff to work in the unit, maintaining an adequate annual budget, establishing sources of funding commensurate with the goals of the unit, and a safe and robust system for addressing staff concerns without retribution will all help sustain a successful ED, NICU, and PICU.

2 Physical Resources and Spaces

The establishment and maintenance of an HAA in a resource-limited setting is contingent upon the availability of sufficient space for patient care and the healthcare workers. A reliable supply of electric power (including a backup generator if needed), oxygen (with backup tanks or concentrators as needed), and clean water is critical in any HAA to support the use of lifesaving equipment such as ventilators and infusion pumps and for the prevention of hospital-acquired infection by encouraging effective handwashing and environmental cleanliness.

Adequate physical space in which HAAs are located is essential. Depending on the source of admissions to the PICU, proximity to the emergency department (ED), operating room, or both may be important; the NICU should be located close to the labor and delivery areas and accessible to postpartum mothers; and the ED should be readily accessible to the public or an ambulance arriving to the hospital. The size of the area designated for each patient may be determined by governments or standards of care in a country, but ideally each patient area will have enough space for the patient bed, equipment, and medical personnel and for the presence of family. The area should have adequate lighting and temperature control, a dependable electrical supply, and a clean, potable water supply.

In addition to direct patient care areas, the PED and ICUs will require identified space for nursing and physician staff to perform charting, medication preparation, as well as cleaning equipment. The nurses' station should be located in a position to easily visualize patient care areas with the ability to readily identify changes in patient acuity and the recruit help when needed. Space should be designated for