Special FOCUS

Mass Critical Care: Pediatric Considerations in Extending and Rationing Care in Public Health Emergencies

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ABSTRACT

This article applies developing concepts of mass critical care (MCC) to children. In public health emergencies (PHEs), MCC would improve population outcomes by providing lifesaving interventions while delaying less urgent care. If needs exceed resources despite MCC, then rationing would allocate interventions to those most likely to survive with care. Gaps between estimated needs and actual hospital resources are worse for children than adults. Clear identification of pediatric hospitals would facilitate distribution of children according to PHE needs, but all hospitals must prepare to treat some children. Keeping children with a family member and identifying unaccompanied children complicate PHE regional triage. Pediatric critical care experts would teach and supervise supplemental providers. Adapting nearly equivalent equipment compensates for shortages, but there is no substitute for age-appropriate resuscitation masks, IV/suction catheters, endotracheal/gastric/chest tubes. Limitations will be encountered using adult ventilators for infants. Temporary manual bag valve ventilation and development of shared ventilators may prolong survival until the arrival of ventilator stockpiles. To ration MCC to children most likely to survive, the Pediatric Index of Mortality 2 score meets the criteria for validated pediatric mortality predictions. Policymakers must define population outcome goals in regard to lives saved versus life-years saved. (*Disaster Med Public Health Preparedness.* 2009;3(Suppl 2):S166–S171)

Concepts for mass critical care (MCC) in public health emergencies (PHEs) were recently developed and enumerated in reports from the Task Force for Mass Critical Care[1] and the Task Force on Life and the Law of the New York State Department of Health.[2] Neither of these reports focus on children.

The general concepts of MCC apply across all ages. When a patient surge exceeds the usual intensive care capacity, MCC extends essential lifesaving interventions to larger numbers by delaying or forgoing less urgent treatment. It is recommended that if fully developed, the concept of MCC should triple each hospital's intensive care unit (ICU) capacity for up to 10 days.[1] When resources are inadequate over a wide geographical area despite MCC approaches, rationing is necessary. Rationing provides palliative care to those likely to die regardless of therapy, and allocates MCC to patients with a high probability of surviving as a result of these interventions. This article extends the work of the recent task forces on MCC as it applies to the care of children.

PEDIATRIC NEEDS AND RESOURCES IN PHEs

Pediatric Critical Care Needs

Historically, as many as 30% of hospitalized victims of PHEs have required intensive care.[3–5] Some Department of Homeland Security National Planning Scenarios anticipate critical care needs that far exceed the entire national critical care capacity.[1]

Children account for 6.8%, 6.6%, 6.9%, and 7.2% of the population in the categories, birth to 4 years, 5 to 9 years, 10 to 14 years, and 15 to 19 years, respectively.[6] If a public health emergency affects all ages equally, then children would account for 20% or 28% of the disaster victims, classified as 14 years and younger, or 19 years and younger, respectively. The clinical needs of vulnerable pediatric populations can be expected to be overrepresented in PHEs, however, as a result of immature immune defenses, susceptibility to traumatic injury, and inability to protect themselves in dangerous environments. In addition, children may be disproportionately involved in an accident involving a school, as a result of a natural pathogen mainly affecting infants or children, or in a terrorism-related event intentionally targeting children.[7,8] Irrespective of underlying cause, the younger the patient, the more age specific are the needs for care.

PEDIATRIC CRITICAL CARE RESOURCES

Planners should be aware of local definitions of "pediatric" capability and capacity. *Capability* refers to the actual availability of services to meet specific types of patient needs (eg, pediatric trauma and critical care). The capability to provide age-specific services may be identified according to self-report, by accreditation (an impartial agency certifies that specified services are available at a hospital), or by designation (a government authority identifies specified hospitals that should be used for specified types of patients).[9] *Capacity* refers to the maximum number of patients that can be served, dependent on staffing, equipment, supplies, and space. Empirical and functional definitions of peak capacity are more meaningful than administrative bed counts.

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As an example, the 11 most comprehensive pediatric hospitals across New York State provide most of the state's pediatric ICU (PICU) beds and care for 29% of pediatric hospitalizations.[10] The majority of hospitalized children receive routine care at less comprehensive pediatric hospitals and nonpediatric hospitals.[11]

Vacant hospital beds to accommodate PHE surges, defined on the basis of historical peaks and daily occupancy, are more limited for children than for adults. For example, New York State provides an average of 268 vacant functioning pediatric beds (ICU plus non-ICU) per million age-specific population (0–14 years). Vacancies decline to 193/million during periods of high baseline occupancy on winter weekdays, and increase to 328/million during periods of low baseline occupancy on summer weekends.[12] These data indicate that PHEs involving 50 pediatric hospitalizations per million age-specific population usually could be accommodated, but events exceeding 200/million often could not, unless MCC strategies are used.[13] Comparable New York statewide available hospital vacancies for adults are 555/million age-specific population (seasonal range 328–733/million).[12]

National surveillance indicates a total peak capacity of 54 PICU beds (regionally varying from 36–66) per million age-specific population, 0 to 17 years (equivalent to 65 PICU beds per million age-specific population, 0–14 years).[14] With average occupancy of PICU beds exceeding 50%, typically fewer than 30 vacant PICU beds per million children would be available in a region. Thus, regional PICU resources to provide usual levels of critical care would be quickly overwhelmed by moderate-sized PHEs. Capacity for burn treatment is even more limited than for other aspects of intensive care.[15] Given that pediatric resources and personnel are limited, any aspect of a PHE that reduces the capabilities at the few pediatric facilities may severely degrade pediatric critical care services throughout an entire region.

MCC: PEDIATRIC IMPLICATIONS

Regional Triage

In ordinary circumstances, care of critically ill or injured children tends to be better at a pediatric critical care center[16,17] or a trauma center with pediatric capabilities[18,19] than at a nonpediatric hospital. Quantitative models estimate a favorable impact on population outcomes if patient surges are distributed to take advantage of pediatric hospitals throughout a region, without overloading facilities near the scene of an emergency.[20] Unfortunately, controlled distribution of all high-risk pediatric patients to pediatric hospitals is unlikely in a large-scale emergency. Patient destination is determined by travel time, incapacitated transportation systems, severity of illness and injury, and emergency departments' abilities to accommodate additional patients. Incident commanders cannot control transportation by families.[21] Thus, all hospitals must plan for the care of some children.[22,23]

In the hours following a sudden impact PHE, gaps between regional patient needs and resources must be evaluated periodically. At some point, it may become apparent that redistribution of patients and resources would improve care. If a large excess number of children requiring critical care are located at 1 hospital, then some may be transported to pediatric critical care centers located nearby or in adjacent regions. Critical care transports are labor and equipment intensive, generally requiring 1 ambulance and an advanced life support team for each patient. This may be an inefficient use of scarce resources. Instead, it may be preferable to bring in a team of pediatric critical care providers, equipment, and supplies, or a smaller group of pediatric critical care consultants who would assist local staff previously trained in the principles of pediatric critical care support,[24] to extend mass critical care without moving large numbers of critically ill children.

Alternatively, large numbers of ambulatory, non-ICU pediatric patients could be transferred to other hospitals or temporary nonhospital alternative care facilities in buses or vans with 1 provider caring for many patients.[22,23] After mass evacuation of non-ICU patients, resources at an overloaded hospital may be reallocated to sicker patients who are more difficult to move. Computer-based decision support tools[25] may assist in optimizing patient redistribution, but pediatric-specific considerations are not yet incorporated in these models.

Keeping families together and planning for family reunification are priorities. Care of children is generally more effective and efficient when they are accompanied by an adult family member. Safety and identification of unaccompanied children are promoted by standard methods.[22,23]

General Measures

General measures would extend critical care services for children and adults in a PHE. Strategies include substituting equivalent (or nearly equivalent) staff, equipment, and supplies for unavailable resources, conserving resources by restrictive criteria for interventions, and reusing some disposable items.[1,26] Some equipment and supplies suitable for adults cannot be adapted for use in infants and small children, however; for example, resuscitation masks, intravenous and suction catheters, and endotracheal, gastric, and chest tubes must be available in age-appropriate sizes.

Facilities outside ICUs for expanding pediatric critical care include intermediate care areas, postanesthetic recovery units, and non-ICU hospital rooms. Adolescents may receive critical care in adult ICUs. Neonatal ICUs would provide critical care for a surge of postneonatal infants. Likewise, PICUs could care for critically sick neonates that exceeded the capacity of neonatal ICUs. Sample guidelines have been suggested for triage of pediatric patient surges to appropriate areas within nonpediatric hospitals.[22,23]

Supplemental providers who do not usually work in a pediatric critical care setting, but who have certain kinds of experience, could play a role in pediatric mass critical care.

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These may include physicians, physician's assistants, nurse practitioners, nurses, respiratory therapists, and emergency medical technicians. Those with experience in emergency departments, anesthesia, otolaryngology, trauma services, neonatology, and adult ICUs, or non-ICU hospital pediatrics would have valuable skills. Identifying supplemental providers is especially important in hospitals that do not usually care for infants and children.[22,23] In a 2-tiered arrangement, pediatric critical care experts would supervise larger teams of supplemental providers.[1] Prior training of supplemental providers[24] reinforced by just-in-time training by pediatric critical care experts would be useful.

Critical Care Interventions

MCC strategies emphasize the following interventions[1]: mechanical ventilation, intravenous fluid resuscitation, vasopressors, antidotes, antibiotics, sedation, and analgesics. These interventions are similar to those recommended by a panel of pediatric acute care clinicians.[27]

Mechanical Ventilation

Requirements for mechanical ventilation in PHEs have been reviewed.[1,28] Conservation of oxygen and electrical power and simplicity of ventilators, training, and monitoring all are essential. Pediatric ventilator support is ordered according to patients' pathophysiology and severity, as outlined in standard references.[28,29]

The following difficulties will be encountered in attempting to use adult ventilators to support an infant. The inspiratory flow or pressure sensor may not be sufficiently sensitive for an infant to initiate inspiration (for synchronized intermittent mandatory ventilation, assist control, pressure support, or demand flow for spontaneous breaths between ventilator assisted breaths). Likewise, ventilator algorithms may have difficulty terminating inspiration for pressure support, especially in the presence of air leaks. Ventilator monitors for low exhaled volume or low pressure may alarm constantly if air leaks around an uncuffed endotracheal tube.

In a volume-controlled mode, adult ventilators may be unable to provide low tidal volumes and inspiratory flow appropriate for an infant. In addition, breath-to-breath variation in delivered tidal volume will be substantial if peak inspiratory pressure varies with patient effort or changing respiratory mechanics. Large compressible spaces of adult ventilator circuits exaggerate the problem of pressure-dependent losses of tidal volume. Use of a time-cycled, pressure-limited mode of ventilation may allow the support of some infants with adult ventilators, compensating for compression losses as well as leaks around endotracheal tubes.

Manual Ventilation

Multidisciplinary task forces[1,2] have advised against manual ventilation with a resuscitation bag as a substitute for mechanical ventilators. Manual ventilation diverts staff from providing other interventions, is tiring to operators, and may expose operators to unacceptable infection risk. Historically, manual ventilation via tracheostomy tubes was used successfully for days at a time in a polio epidemic in the 1950s[30] and more recently via endotracheal tubes for hours at a time in a power failure[31] and weather emergencies.[32–34] Although controlled trials of performance with manual ventilation in PHEs are not available, manual ventilation has been shown to provide similar short-term gas exchange compared with ventilators in the patient transport setting.[35–37] For nonpandemic conditions, infectious risks to the operator are negligible. Because respiratory work is a function of delivered tidal volume and airway pressure, infants' much smaller tidal volumes require substantially less work and are less tiring to the operator than manual ventilation of an adult. Self-inflatable bags may be used with ambient air or oxygen at low flow rates titrated to adequate oxygen saturations determined by pulse oximeter. Oxygen conservation would compare favorably with mechanical ventilation.

Therefore, the authors believe that decision makers must evaluate the feasibility, risks, and benefits of temporary manual ventilation for a given emergency situation. If large numbers of infants survive as a result of limited periods of manually assisted ventilation while awaiting the arrival of mechanical ventilators from regional stockpiles, then such support should be considered as an option. This recommendation is consistent with that of another MCC workgroup.[38]

If manual ventilation is indeed an option, then sufficient numbers of manual resuscitation bags and endotracheal tubes must be immediately available. Just-in-time training in manual ventilation may optimize performance of supplemental providers with respect to gas exchange and the avoidance of barotrauma.

Shared Ventilators

Multidisciplinary task forces[1,2] also advise that to control individual patients' inhaled oxygen concentration, tidal volume, and peak and end expiratory pressure, and to provide infection control between patients, a single ventilator is necessary for each patient. A prototype ventilator that provides all of these capabilities while providing shared support to multiple patients is in development.[39]

Bedside Care of Infants on Ventilators

Bedside care of the infant or child receiving mechanical ventilation involves a set of skills that are challenging for non-PICU staff. For example, a small displacement of an infant's endotracheal tube may result in dislodgement. Distinguishing common and easily corrected problems such as airway plugs and equipment disconnections from life-threatening pneumothorax and tube dislodgement are constant concerns in a PICU setting. The clinician must avoid subglottic mucosal ischemia from excessively inflated endotracheal tube cuffs, while ventilation may be inadequate with an excessive leak around an uncuffed tube. Cold stress should be avoided.

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Respiratory Equipment and Supplies

How many different pediatric sizes of endotracheal tubes should be immediately available for PHEs? One approach may be to provide large numbers of cuffed endotracheal tubes in some but not all sizes. For example, if a 3.0-mm tube leaves an excessive air leak in an older infant, then the leak can be controlled with partial or full inflation of the cuff. If a tight seal is not needed, then the cuff is left deflated. Virtually all young infants could be ventilated via 3.0-mm cuffed endotracheal tubes.

Recommendations for immediately available equipment and supply items are suggested in task force recommendations[1] according to target patient numbers. Ideal target numbers of mechanically ventilated patients must be planned. If the mass critical care target at each institution is 3 times the usual number of ICU patients,[1] then patient numbers would always exceed immediately available ventilators. As discussed above, only by use of temporary manual ventilation or possible future development of shared ventilator technology to support multiple patients is it possible to consider tripling ICU capacity in a sudden impact event.

On the one hand, manual resuscitation bags intended for adults can be used for manual ventilation of the smallest infants, if necessary. On the other hand, bags intended for ventilation of infants do not provide an adequate tidal volume for a child or adult. Self-inflatable manual resuscitation bags are necessary because a source of high flow compressed gas may not be available. Resuscitation masks, IV and suction catheters, endotracheal, gastric, and chest tubes must be available in age-appropriate sizes.

Renal Replacement Therapy

Renal replacement therapy (RRT) in the first day of a PHE may exceed available resources of staff, supplies, and equipment. Although seldom lifesaving or feasible in the first hours, RRT may be essential to population outcomes in emergencies involving many crush injuries. Mass evacuation of patients in the days after a PHE may be necessary to facilitate pediatric RRT.

Medications

Guidance for medications and appropriate pediatric doses in PHEs is provided in standard references.[22,23,40] Length-based dosing and equipment guidelines may be more practical than weight-based guidelines for the MCC situation.[41]

RATIONING WHEN POPULATIONS INCLUDE CHILDREN

Protocols to Reallocate Resources

When a PHE involves a wide geographical area and overwhelms MCC despite national efforts to augment care, rationing is necessary.[1,2] Exclusion criteria may specify high-severity chronic conditions, high severity of acute illness (eg, predicted mortality probability ≥80% despite receiving critical care), or failure to improve during repeated evaluations despite ongoing critical care. The intent is to optimize population outcomes by using scarce resources to provide MCC for the eligible patients most likely to benefit from brief critical care interventions.

TABLE 1

Tools to Predict Pediatric Mortality Probability

Criteria for Suitable Tool	PRISM III[42]	PIM 2[43]
Validated for infants and children	Yes	Yes
Validated across diagnoses	Yes	Yes
Simple clinical observations	Yes	Yes
Able to score at initial evaluation	No, 24-h score	Yes
Publicly available equations	No	Yes

Pediatric Mortality Risk

To allocate resources to those most likely to benefit, predicted mortality risk for children with acute illness must be estimated using validated tools. Only 2 candidate clinical severity scores predicting mortality risk have been validated for infants and children across critical care diagnoses: the Pediatric Risk of Mortality (PRISM) III score[42] and the Pediatric Index of Mortality (PIM) 2 score.[43] Of these, only the PIM 2 score meets all of the criteria for a suitable tool (Table 1). The validity of any mortality risk model may be impaired when patient populations or conditions of their care differ substantially from those used to derive the model.[44] For example, decisions for a large homogeneous population with burns, a specific infection, or a specific toxic insult may require modified predictive risk models.

Rationing: Children and Other Special Priority Groups

Among eligible patients, it has been recommended that patients be accommodated on a first-come-first-served basis.[1,2] Task forces argue against identifying special priority groups in a rationing strategy. For rationing to be accepted by the public, it is essential that all medically eligible patients be perceived as having equal access to treatment. If priority groups were proposed, then it would be difficult to reach consensus on selecting such groups (eg, children? "important" people? "productive" people? parents of children?). If 1 priority group was excessively large, their care may exclude all other groups from receiving services. Difficulties may be encountered in distinguishing priority patients from others.

It is necessary to clarify population outcome goals pertaining to subgroups. If rationing of MCC is intended to quantitatively maximize population outcomes, what should be maximized: lives saved, life-years saved, or quality-adjusted life-years saved?[45] Data necessary to plan for quality-adjusted life-years saved are almost never available, even in well-controlled clinical trials.[46] Everything being equal, care of previously healthy children would be expected to result in more life-years saved than care of elderly people. These issues have not been addressed by policymakers.

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Public beliefs about care of children in emergencies must be considered to gain public acceptance of a rationing scheme. European and North American maritime tradition is to save women and children first in shipwrecks, even if the practice has been incompletely observed.[47] A commission of the United Nations[48] that considered "putting children first" in disaster relief acknowledged that it may be impossible to accommodate every child. Children may not be viewed as a top priority group in some cultures.[48] If recent actions are a valid indication of current beliefs, then it may be noted that during the accident in which US Airways flight 1549 landed in the Hudson River in 2009, passengers "spoke of a sense of calm and purpose that quickly descended on the passengers and crew as the plane started filling with water and rescue boats swarmed to the scene. *They decided women and children would be evacuated first*" (authors' italics).[49]

NEXT STEPS

Much work remains to be done. Before the concept of MCC can be developed for children or adults, a national public consensus must accept the idea that therapeutic goals change temporarily when needs exceed resources in PHEs. Although this is obvious to public health officials, it may not be apparent to the public. Various terms with overlapping meanings have been used by planners: "mass critical care," "altered standards of care," "standards of care appropriate to the conditions," "stewarding resources," and "rationing." Whatever the terminology, it must be acknowledged without euphemism that in a large PHE, allocation of resources would shift away from optimizing individual outcomes and instead would strive to maximize population outcomes. All patients would receive less care than in ordinary circumstances, and some would receive less care than others.

Next, choices must be made regarding allocation of resources. Should we maximize lives saved or life-years saved? Is there a national preference to treat children as a special group or not? Do we have the collective courage to discuss these disturbing questions publicly? Then, it will be necessary to create the national and state-by-state legal basis, administrative procedures, liability protections,[50] and funding that would allow the implementation of MCC. Based on clear goals, a regulatory framework, and within financial constraints, decision makers at the state, local, and clinical levels can then make operational plans for MCC of target numbers of patients. Operational plans must always include age-specific care of children. Education of the public, decision makers, and clinicians will be essential to promote effective behavioral responses to the distressing necessities of MCC.[51]

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