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children in disasters; disaster preparedness; hazard vulnerability analysis

Abbreviations:
ASPR, Assistant Secretary for Preparedness and Response; ASPR TRACIE, Assistant Secretary for Preparedness and Response Technical Resources, Assistance Center, and Information Exchange; EMS, Emergency Medical Services; HHS, Department of Health and Human Services; HVA, Hazard Vulnerability Analysis; PHRAT, Pennsylvania Public Health Risk Assessment Tool; RISC, Risk Identification and Site Criticality; THAM, Threat/Hazard Assessment Module; TRACIE, Technical Resources, Assistance Center, and Information Exchange

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Pediatric-Specific Hazard Vulnerability Analysis: The Missing Component of Regional and Hospital-Based Preparedness

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Abstract

Though children comprise a large percentage of the population and are uniquely vulnerable to disasters, pediatric considerations are often omitted from regional and hospital-based emergency preparedness. Children's absence is particularly notable in hazard vulnerability analyses (HVAs), a commonly used tool that allows emergency managers to identify a hazard's impact, probability of occurrence, and previous mitigation efforts. This paper introduces a new pediatric-specific HVA that provides emergency managers with a quantifiable means to determine how a hazard might affect children within a given region, taking into account existing preparedness most relevant to children's safety. Impact and preparedness categories within the pediatric-specific HVA incorporate age-based equipment and care needs, long-term developmental and mental health consequences, and the hospital and community functions most necessary for supporting children during disasters. The HVA allows emergency managers to create a more comprehensive assessment of their pediatric populations and preparatory requirements.

Children under 18 years old comprise approximately one-quarter of the United States population and are one of the country's most vulnerable groups.[1] The unique anatomic, physiologic, and developmental features of children cause them to be disproportionately affected by disasters.[2] Children are at an increased risk for chemical and biological exposures due to their high skin permeability, large body surface to mass ratio, and propensity for spending time outdoors and touching dirty surfaces.[3,4] Children have an inherently higher respiratory rate and inhale greater quantities of toxins near ground level, where chemicals tend to collect.[5] Children are also more vulnerable to disasters characterized by blasts and forceful impacts, as they have large heads and fragile organs, less fluid and blood reserves, and less protective fat and subcutaneous tissue.[2,4] Developmentally, young children lack the mobility to escape from emergencies and often cannot comprehend and appropriately respond to threats.[3,4] Even when children are not physically harmed in disasters, they must often contend with short- and long-term psychological trauma.[1] As a result of these vulnerabilities, studies of recent crises have shown that children compose up to half of all disaster victims,[6,7] whether due to a lack of mobility preventing escape during tsunamis and earthquakes, increased inhalation and exposure during chemical attacks, or mass shootings deliberately targeting schools and day care centers.[1,3,8]

To prepare for and mitigate against disasters, emergency managers and hospitals routinely conduct hazard vulnerability analyses (HVAs). HVAs identify various hazards, their probability of occurrence, each hazard's potential impact, and how prepared a given community or hospital is for a disaster.[9,10] Ideally, they should account for population-specific characteristics (ie, ages, medical needs, health conditions) and population-specific vulnerability to different disasters.[11] HVAs vary based on an institution's location, population served, and community vulnerabilities; for example, California HVAs would likely include wildfires and earthquakes, while Florida HVAs would include hurricanes.

HVAs have become standard practice across the United States due to their ability to inform disaster planning efforts. However, despite the fact that children constitute a large proportion of the total population and are a uniquely at-risk group, they are often omitted from regional, adult hospital, and community hospital HVAs.[12] Nationally, only 47% of all hospitals (and 67% of high-volume hospitals) have disaster plans that include pediatric needs, with the majority of hospital disaster reports not considering pediatric-specific equipment, family reunification procedures, or pediatric standards during crises.[12–14] Less than 50% of hospitals routinely conduct disaster drills with pediatric patients, while only 32% of hospitals have plans incorporating pediatric surge capacity.[15]

Current State of Hazard Vulnerability Analysis (HVA) Frameworks

In the United States, the Assistant Secretary for Preparedness and Response (ASPR), through the Department of Health and Human Services (HHS), provides hospitals and regional managers with an array of HVA frameworks, resources, and examples through its Technical Resources, Assistance Center, and Information Exchange (TRACIE) website.[16] ASPR TRACIE offers many HVA templates[17] that provide methodological approaches to classifying hazards and hazard impacts, as well as a way for organizations (or localities) to gauge preparedness and vulnerability to individual disasters. Some of the most commonly used HVA tools are the Kaiser Permanente framework,[18] the Pennsylvania Public Health Risk Assessment Tool (PHRAT),[19] and the Threat/Hazard Assessment Module (THAM).[20] These frameworks, especially the Kaiser Permanente HVA, are now widely used across the United States and internationally for regional and hospital disaster preparedness.[21–24]

The Kaiser Permanente tool is primarily targeted at hospitals and health care organizations and provides a method to determine organizational planning priorities and establish the risk of individual hazards.[18] The template classifies hazard impact along *human*, *property*, and *business* dimensions, though it does not allow for additional stratification of at-risk populations or impacts within each dimension. Like the Kaiser Permanente tool, the PHRAT framework[19] helps assess hazard risk and establish planning priorities, yet it is distinct through its further distillation of hazard impact categories and incorporation of an in-depth population impact analysis alongside specific threats. The PHRAT allows an emergency manager to integrate the size of at-risk populations (eg, children age 18 and under, older adults age 65 and older, those with disabilities) as well as to care for these populations during disasters if specific procedures are in place. Finally, the Threat/Hazard Assessment Module (THAM) modality within the HHS risk identification and site criticality (RISC) toolkit[20] contains built-in data to help organizations identify hazard risk based upon geographic location and other inputs. THAM does not allow users to input specific population impacts per hazard.

Regional and hospital-based emergency managers across the world use the Kaiser Permanente, PHRAT, and THAM HVA models, along with several other templates and resources offered through ASPR TRACIE, to inform their own HVAs, with little to no modification of the original templates. However, the fact that the Kaiser Permanente and THAM models do not allow for any specific population inclusions (and even the PHRAT framework does not allow for detailed pediatric inputs) causes these templates to omit many of the pediatric considerations necessary to care for children during disasters. Even if an emergency manager wanted to modify an existing HVA template to include essential pediatric factors, the resources detailing those factors are not readily available. Instead, the majority of commonly disseminated resources available focus on helping caregivers, children, and families prepare and cope with disasters and do not provide a comprehensive framework targeted at regional or hospital emergency managers.[25–29] As a result, without a pediatric-specific hazard vulnerability and preparedness model, regional and hospital-based emergency managers across the country struggle to incorporate pediatric risks and disaster impacts into their work.[14,30,31]

Creating a Pediatric-Specific HVA Template

In order to provide regional and hospital emergency managers with a flexible way to include children in their disaster preparedness efforts, we developed a novel pediatric HVA template to be used on its own or alongside existing frameworks. We based aspects of the template's structure on a combination of HVA guides available from ASPR TRACIE[16] (eg, Kaiser Permanente, PHRAT, THAM), using our pooled expertise in pediatric disaster preparedness to produce a template that offered ease of use and best reflected the unique needs of children during crises. The sub-categories within the template, which detail a given hazard's impact and apply specifically to children, were derived from frequently studied gaps in the pediatric disaster management literature.[1,14] Before finalizing the HVA template, we checked it for overall utility as well as compatibility with other major tools used for hospital and community vulnerability assessments.

The workbook-based template informs regional and hospital managers about their institution's pediatric risk and resiliency as well as how prepared their regions and/or hospitals are for the pediatric consequences of those disasters (Supplemental Content, Pediatric HVA Template Workbook). It is not meant to be a thorough checklist of preparation (eg, the details, coordination, and policies of sheltering children during a displacement event) and instead spurs the inclusion of general pediatric considerations into HVAs. The template equips regional managers to think about children in disasters across multiple dimensions (eg, acute and long-term health impacts, shelter/food) and can be applied to all types of hazards. As listed hazards are intended to represent an impact to the entire region, as opposed to an individual hospital (eg, a tornado that affects a community, as opposed to damaging 1 hospital), it does not replace existing hospital-specific HVAs with intra-facility hazards (eg, water damage or power loss to a single hospital facility).

The pediatric HVA template allows managers to determine a hazard's impact on children (*impact score*) and the probability of that hazard occurring, thereby establishing overall pediatric vulnerability to a given hazard (*vulnerability score*) (Figure 1). Managers can then input currently existing disaster preparedness efforts in order to ascertain their region's and/or hospital's risk to the hazard (*overall risk score*). The template's construction provides managers with both the pediatric-specific impact across various categories (as in the PHRAT template) and the simplicity of a final risk score (as in the Kaiser Permanente template). Hazards included in the template were carefully chosen and based on those found in the Kaiser Permanente, PHRAT, and THAM templates.

Hazard Impact and Severity Measures and Scores

To characterize a disaster's effect on children, the HVA template breaks a given hazard into novel *impact and severity measures*, one of the first instances of an HVA employing pediatric-specific categories to determine a hazard's impact (Figure 2). These measures mirror several of the PHRAT's classifications and are broken into "human impact," "health care system impact," and "community safety infrastructure." Each of these sections is then further distilled into sub-categories that uniquely apply to children. For example, the "community safety infrastructure" category within the pediatric template is further subdivided into sections that prompt managers to consider how displaced children will be brought back to their families ("family reunification" sub-category), how school and day care closures will affect children's safety and a hospital's workforce ("school/childcare" sub-category), as well as how a disaster threatens the shelter and food needs of children in the community ("shelter/food" sub-category).

The template asks managers to assign each category an impact score of 1 (low impact) to 3 (high impact). To assist with these score determinations, the template includes an *impact scoring*

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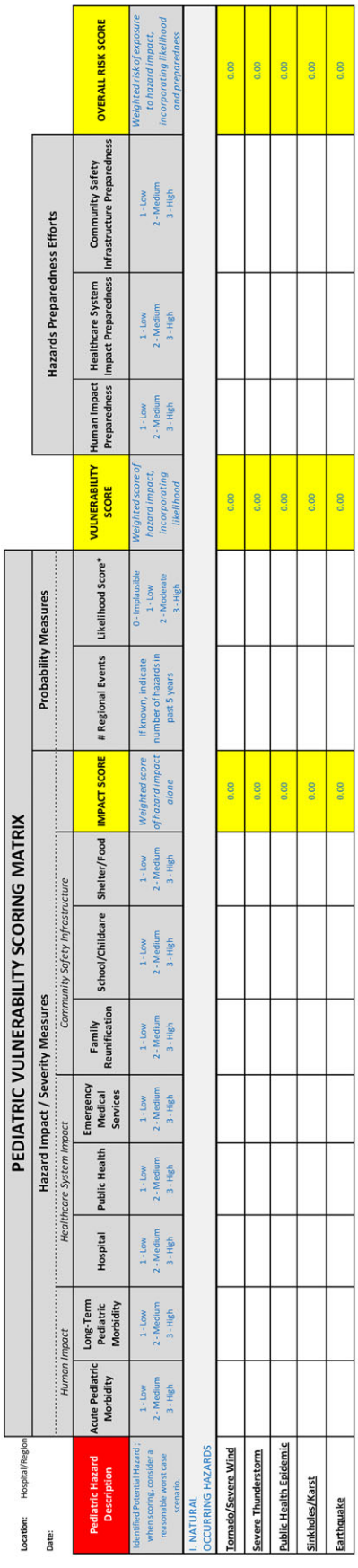

PEDIATRIC VULNERABILITY SCORING MATRIX

Location: Hospital/Region

Date:

Pediatric Hazard Description	Hazard Impact / Severity Measures									Probability Measures		VULNERABILITY SCORE	Hazards Preparedness Efforts			OVERALL RISK SCORE
	Human Impact		Healthcare System Impact			Community Safety Infrastructure			IMPACT SCORE	# Regional Events	Likelihood Score*		Human Impact Preparedness	Healthcare System Impact Preparedness	Community Safety Infrastructure Preparedness	
	Acute Pediatric Morbidity	Long-Term Pediatric Morbidity	Hospital	Public Health	Emergency Medical Services	Family Reunification	School/Childcare	Shelter/Food								
Identified Potential Hazard; when scoring, consider a reasonable worst case scenario.	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	*Weighted score of hazard impact alone*	If known, indicate number of hazards in past 5 years	0 - Implausible 1 - Low 2 - Moderate 3 - High	*Weighted score of hazard impact, incorporating likelihood*	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	*Weighted risk of exposure to hazard impact, incorporating likelihood and preparedness*
I. NATURAL OCCURRING HAZARDS																
Tornado/Severe Wind									0.00			0.00				0.00
Severe Thunderstorm									0.00			0.00				0.00
Public Health Epidemic									0.00			0.00				0.00
Sinkholes/Karst									0.00			0.00				0.00
Earthquake									0.00			0.00				0.00

Figure 1. The pediatric HVA template. The pediatric HVA template allows emergency managers to determine a hazard's impact on children, how vulnerable the region and/or hospital is to the hazard, and the risk of each hazard based on existing preparedness efforts. For each hazard, the template produces 3 unique scores that allow for different insights. The *Hazard Impact Score* is a weighted score of a hazard's impact without incorporating the likelihood of occurrence or preparedness efforts. The *Vulnerability Score* combines a hazard's impact with its likelihood of occurrence. Finally, the *Risk Score* is a weighted score that incorporates existing preparedness efforts into a hazard's projected impact and likelihood of occurrence.

key that assigns each category descriptions and examples across low, medium, and high impacts (Figure 3). Descriptions and examples were derived from commonly outlined pediatric needs during disasters (eg, need for pediatric-specific decontamination units during chemical and biological exposures),[1,2,4,5,12] existing characterizations of hazard impacts,[10,16] as well as descriptions within the PHRAT tool.[19]

Although the scoring key is comprehensive, managers have wide latitude in assigning scores as each sub-category contains multiple components. For example, the "hospital" sub-category under "health care systems impact" asks managers to examine the number of hospitals a hazard affects, hospital capacity, patient flow, and the pediatric-specific equipment a given hazard necessitates. A hazard may affect these components differently, thereby allowing a manager to decide which aspects are most influential in the sub-category's final impact score. For example, within the "hospital" category, a biologic attack on 1 community might be "low impact" in that it affects a small number of hospitals yet "high impact" in that it necessitates more pediatric-specific equipment than the region is able to provide. The manager would need to weigh these contrasting impacts within the same category in order to assign a final numerical score.

Some of the categories within the *impact scoring key* encourage managers to review their regional pediatric demographics and surge capabilities before assigning a score (Supplemental Content, Figure 1). While this is not a requirement to completing the HVA, it provides a means for emergency managers to identify broad areas of potential vulnerability, such as if their region lacks pediatric intensive care beds or contains a pediatric population with an uneven distribution (eg, large percentage of 0–2-year-olds). Dividing the pediatric population into separate age ranges prompts managers to appreciate how specific hazards affect pediatric physiology differently, depending on age. It also provides a more holistic assessment of a region's pediatric capabilities, as older children can likely be cared for in adult hospitals during a surge event.

To help illustrate how an emergency manager might use the *impact scoring key*, the HVA template itself includes 2 examples of hazards separated into impact/severity sub-categories (Supplemental Content, Figure 2). Each sub-category is assigned a score based on the components within the *impact scoring key*, with a rationale for why that score was chosen.

Hazard Probability Measures and Scores

For a region or hospital to understand its actual vulnerability to a given hazard, it needs to know both the impact the hazard will have on children as well as the likelihood of the hazard realistically occurring. Building off of decades of risk management theory (where in the simplest form, risk = impact x probability)[32] and mirroring several other HVA templates, managers can assign a *likelihood score* to each hazard from 0 (implausible; no documented historical hazard) to 3 (high likelihood of occurring; hazard occurs every 5 years or more frequently). A weighted calculation then incorporates a hazard's impact and likelihood of occurrence to produce a vulnerability score (ie, how susceptible a region and/or hospital is to a given hazard, without taking into account preparedness efforts).

Hazard Preparedness Measures and Scores

The final step in our pediatric HVA template incorporates hazard impact, hazard likelihood, and existing preparedness efforts in

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Hazard Impact / Severity Measures								
Human Impact		*Healthcare System Impact*			*Community Safety Infrastructure*			
Acute Pediatric Morbidity	Long-Term Pediatric Morbidity	Hospital	Public Health	Emergency Medical Services	Family Reunification	School/Childcare	Shelter/Food	IMPACT SCORE
1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	1 - Low 2 - Medium 3 - High	*Weighted score of hazard impact alone*

Figure 2. Impact/severity measure within the pediatric HVA template. The impact/severity measure allows emergency managers to determine how a given hazard will affect children as well as the magnitude of the impact. It is broken down into "human impact," "health care system impact," and "community safety infrastructure preparedness" categories.

order to produce an overall hazard *risk score*. *Hazard preparedness* mirrors the broad *hazard impact/severity* categories and is separated into "human impact," "health care system impact," and "community safety infrastructure." For a given hazard, emergency managers assign a preparedness score of 1 (low preparedness) to 3 (high preparedness) in each category. To assist with these score designations, the template includes a *preparedness scoring key* (Figure 4) that provides descriptions and examples for each category and numerical score. Similar to the impact scoring key, the *preparedness scoring key* is meant to serve as a guide and emergency managers are ultimately able to assign individual scores based on their own determinations.

In using the preparedness scores to produce a final hazard *risk score*, the HVA template considers both the numerical degree of hazard impact and the score in the corresponding preparedness category. Preparedness in any 1 category (eg, "human impact preparedness") only mitigates the impact in the corresponding hazard impact category (eg, "human impact"). For example, if a hazard is predicted to have a significant health care systems impact (by affecting hospitals, public health, and emergency medical services), and the emergency manager indicates that the region has low health care system preparedness yet high human impact preparedness, the overall risk for that hazard will be much worse than if the region had high health care system preparedness yet low human impact preparedness.

Hazard Impact and Likelihood Weights

Understanding that different regions and institutions across the world face different types and degrees of threats, the pediatric HVA template was meant to be customizable. As a result, though the framework defaults to scoring weights that reflect expert opinion and weighting systems found in other templates,[16] emergency managers are able to assign weights to each hazard impact sub-category (eg, "family reunification") based on which impacts they consider most consequential or relevant. Higher weighted categories have a more significant effect on final score determinations than lower weighted categories. Preparedness scores can also be weighted, so that higher preparedness has an even greater mitigating effect on the final risk score. These weighting features would be useful for emergency managers who want to customize the pediatric HVA based on prior experiences or unique characteristics of their region. For example, in a geographic region where past hurricanes have significantly impacted pediatric morbidity and mortality despite robust preparedness efforts, an emergency manager may choose to increase the *acute pediatric morbidity* impact weight and decrease the preparedness scoring weights, thereby more accurately reflecting hurricanes' severe risk to the region.

Discussion

We created an HVA template that can provide emergency managers and public health and hospital leadership with essential insights into how hazards impact their pediatric populations.[33] Hazard vulnerability analyses are a powerful tool for hospital and health coalition engagement and offer a tangible approach to understanding and quantifying what would otherwise be an overwhelming proposition: predicting and mitigating against the outcomes of a devastating event.[9,10] However, as individual disasters have varied and in wide-reaching consequences on different populations, tools that aim to capture hazard impact and preparation on a granular level cannot treat an affected community as a homogeneous group. Children are one of the largest population segments that should be considered separately during disasters given their unique physiologic and developmental vulnerabilities.[2,3] Even within the broader pediatric population, it is necessary to note age-based anatomic variations and equipment needs in order to wholly assess hazard impact. Yet despite the importance of separate pediatric hazard planning, a 2018 study examining the disaster preparations of hospitals across one of the largest US states demonstrated that only 41% of hospitals had guidelines regarding pediatric surge capacity, 44% had reunification procedures for children and families, and a mere 29% of hospitals had protocols to identify and protect displaced children.[34] As our HVA template includes many of these pediatric-specific characteristics, emergency managers can use it to create a more comprehensive assessment of their pediatric populations and preparatory requirements.

Ultimately, being able to accurately and consistently measure hazard risk and impact is an incredibly complex process that no single tool can accomplish on its own. There is a balance between creating a hazard assessment modality that is so broad as to miss meaningful population subtleties and one that is exceedingly specific as to no longer be useful. We designed our pediatric HVA impact categories to have more detailed stratifications than the Kaiser Permanente model,[18] yet not require as many technical or numeric inputs as the PHRAT[19] or THAM[20] models. We also attempted to balance familiar and new features by combining broader impact categories that would be recognizable to emergency managers who have used existing templates ("human impact," "health care system impact," and "community safety infrastructure"), with novel pediatric-specific sub-categories (eg, "acute pediatric morbidity," "family reunification"). For managers

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Impact Scoring Key

		Domain	Impact is Low (1)	Impact is Medium (2)	Impact is High (3)
IMPACT OF IDENTIFIED HAZARD	*Human Impact Preparedness*	Acute Pediatric Morbidity	Small number of children affected; isolated incident	Potential for moderate number of children impacted across multiple locals	Large number of children impacted, potentially state or nationwide
			Minimal types and low number of predicted pediatric acute injuries from hazard	Increasing severity and numbers of pediatric injuries predicted	Very severe types and numbers of pediatric injuries predicted
			Age-based physiology makes children marginally more vulnerable to the hazard	Age-based physiology makes children moderately more vulnerable to the hazard	Age-based physiology makes children significantly more vulnerable to the hazard
			Mild physiologic impact across all pediatric age distributions*	Mild to moderate physiologic impact across all age distributions and/or 1-2 age distributions significantly impacted*	Significant physiologic impact across more than 1 pediatric age distribution and/or 1-2 age distributions lethally impacted*
		Long-Term Pediatric Morbidity	Little to no long-term pediatric injuries predicted from hazard	Increasing severity and types of long-term pediatric injuries predicted	Very severe types and numbers of long-term pediatric injuries predicted
			Long-term effects do not adversely impact youngest age distributions*	Mild to moderate long-term effects adversely impact youngest age distributions*	Lifelong and severe hazard effects adversely impacting youngest age distributions*
			Long-term mental health and/or rehabilition needs met by existing system	Long-term mental health and/or rehabilition needs bring system to capacity; may need to expand beyond current mental health resources	Long-term mental health and/or rehabilition needs exceed current system capacity; state-level support needed due to severe and broad impacts
	Healthcare Systems Impact Preparedness	Hospital	Small number of hospitals impacted	Multiple regional hospitals impacted	Widespread state or nationwide hospital impact
			Patients arrive to ED in 1 low-volume wave or low-volume evenly distributed waves†	Patients arrive in 1 moderate-volume wave or many low-volume waves; ED capacity reached†	Constant mass influx of patients to ED that exceeds ED capacity†
			Patient surge below hospital bed capacity‡	Hospital capacity reached by surge of patients‡	Surge of patients exceeds hospital capacity‡
			Minimal utilization of pediatric-specific equipment; met by hospital resources	Increasing amount of pediatric-specific equipment needed based on age*; often exceeds hospital resources	Significant amount of pediatric-specific equipment needed based on age*; often exceeds state/national resources
			Patient surge does not affect hospital's ability to treat non-hazard patients‡; surge does not cause equipment shortages	Patient surge affects hospital's ability to treat non-hazard patients‡; equipment needs of hospitalized patients stressed due to surge	Patient surge prevents hospital from treating non-hazard patients‡; equipment needs of hospital exceeded due to surge
			Limited hospital operational impact or loss of hospital business	Isolated loss of operational capacity and/or moderate impact on multiple operational units	Significant loss of operational capacity
			Limited impact on total organizational performance	Moderate impact on total organizational performance	Severe impact on total organizational performance
		Public Health	Isolated hazard without public health ramifications	Large or prolonged hazard that requires local/regional public health support	State or nationwide hazard that affects basic community health functions
			Hazard has no impact on at-home children with medical complexity	Hazard impacts ability of children with medical complexity from receiving at-home resources	Hazard prevents children with medical complexity from receiving at-home resources
		Emergency Medical Services	Isolated hazard that only requires local EMS personnel and resources	Large regional hazard that often exceeds local EMS personnel and resources	State or nationwide hazard that exceeds EMS resources and requires governmental response
			Number of children involved minimal; local EMS can treat all affected children	Number of children involved increasing; local EMS struggles to treat all affected children	Large number of children involved; EMS cannot treat all affected children
			EMS able to transport patients without issue	Hazard moderately affects EMS ability to transport patients	Hazard prevents or severely limits EMS ability to transport patients
	Community Safety Infrastructure Preparedness	Family Reunification	Isolated local hazard with minimal displacement	Regional hazard with moderate displacement	State or nationwide hazard with significant displacement
			Reunification can occur at the hospital level	Reunification usually requires regional and outside organizational assistance	Displacement across states, requires nationwide governmental coordination and outside organizational assistance
		School/Childcare	Isolated local hazard with minimal school/child care impact	Prolonged local hazard or region-wide hazards with moderate school/child care impact	Prolonged severe state or nationwide hazard with significant school/child care impact
			Hospital staffing can absorb employees that must remain home with their children	Hospital staffing burdened due to employees that must remain home with their children	Hospital staffing severely affected by employees that must remain home with their children
		Shelter/Food	Isolated hazard that does not affect local food supply	Moderate hazard that requires regional coordination to ensure food supply	Significant or prolonged hazard requiring state or nationwide efforts to ensure food supply
			Local resources can supply shelter for those affected by environmental hazard	Regional resources for supplying shelter from environmental hazard at capacity	Regional resources for supplying shelter from environmental hazard exceeded
			Hazard does not cause pediatric displacement	Region must provide shelter for those children displaced by hazard	State or nationwide efforts needed to provide shelter for those children displaced by hazard

Figure 3. Impact scoring key. The *impact scoring key* provides many different considerations for each impact/severity sub-category. These considerations align across impact levels, thereby allowing managers to easily assign a score. For example, within the "acute pediatric morbidity" sub-category, the physiologic impact across age distributions is classified as mild across all ages (low impact), mild to moderate across all ages and/or severe across 1-2 age distributions (medium impact), or significant across all ages and/or lethal across 1-2 age distributions (high impact).

looking for even more specificity and customization, the impact, preparedness, and likelihood weights can be adjusted within the template to better reflect an individual region or hospital.

Additionally, to better capture hazard impact, an ideal HVA should instruct users on what a hazard's potential impacts could be. The pediatric HVA template was designed for emergency managers with both comprehensive and limited pediatrics experience. The *impact and preparedness scoring keys* provide enough examples to guide managers who have not previously considered children in HVAs yet allow experienced managers to deviate and make their own scoring determinations. Our HVA was also designed to minimize potential bias; an examination of hospital HVA practices found that preparedness results differed based on the HVA facilitator's background (eg, facility engineering, public health), despite facilitators using the same HVA template and working for hospitals within close geographic proximity to one

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Preparedness Scoring Key

		Preparedness is Low (1)	Preparedness is Medium (2)	Preparedness is High (3)
PREPAREDNESS FOR IDENTIFIED HAZARD	*Human Impact Preparedness*	Staffing, beds, and resources ill-equipped to handle unique hazard-specific injuries and/or age-distributions affected by the hazard.	Staffing, beds, and resources can handle some, but not all, of unique hazard-specific injuries. Can treat most of the age distributions affected by the hazard.	Staffing, beds, and resources in place that allows for the treatment of all ages of affected children with various types of hazard-related injuries.
		Coordination among fatality agencies, poison control, and biohazard unitis has not yet been established	Coordination among fatality agencies, poison control, and biohazard unitis is not well-established.	Coordination among fatality agencies, poison control, and biohazard unitis is strong.
		No clear plans or regional coordination among pediatric and adult hospitals to accomodate older children.	Preliminary plans and/or regional coordination among pediatric and adult hospitals to accomodate older children exists, however, it is unclear if it will be successful.	Regional coordination among pediatric and adult hospitals to accomodate older children is well-established and has been stress-tested.
		Current staffing and resources ill-prepared to address long-term impacts of hazard, including mental health and/or rehabilitation.	Current staffing and resources somewhat prepared to address long-term impacts of hazard, including mental health and/or rehabilitation.	Staffing and resources in place to address long-term impacts of hazard, including mental health and/or rehabilitation.
		Hospital and/or regional plans do not exist to address the physiologic impact of hazard across multiple age distributions. No hazard-specific drills or routine trainings have occurred.	Hospital and/or regional plans exist to address the physiologic impact of hazard, yet minimal to no hazard-specific drills or routine trainings have occurred.	Hospital and/or regional plans exist to address the physiologic impact of hazard across multiple age distributions. Periodic hazard drills have been conducted and routine training occurs.
	Healthcare Systems Impact Preparedness	Hospital and/or region is poorly equipped to handle surge of patients due to hazard; EDs will be overwhelmed and hospital beds filled. Limited to no regional and statewide coordination to direct overflow patients and assist with treatments.	Hospital and/or region is somewhat equipped to handle surge of patients due to hazard. EDs can handle most of patient surge, with some patients unable to be treated due to hospital bed capacity. Moderate, yet unproven, regional and statewide coordination exists to direct overflow patients and assist with treatments.	Due to hospital and regional ED/bed surge capacity, as well as regional and statewide coordination, able to successfully treat all children impacted by the hazard.
		Hospital and/or region has limited amounts of equipment to treat uniquely hazard-impacted children of all ages.	Hospital and/or region has most of the equipment needed to treat uniquely hazard-impacted children of all ages.	Hospital and/or region has all necessary equipment to treat uniquely hazard-impacted children of all ages, including PPE, CBRNE prophylaxis, etc.
		Limited or no plans exist to transport patients between regional hospitals and restore hazard-impacted community health functions. Limited or no drills for these functions have occurred.	Plans exist, yet have not been fully stress-tested, to transport patients between regional hospitals and restore hazard-impacted community health functions. While some drills for these functions have occurred, there is no continued education.	Comprehensive plans exist and drills have been conducted involving the transportation of large amounts of patients between hospitals and the sucessful restoration of community health functions. Continued hazard education occurs.
		EMS is overwhelmed by the number of children impacted and the hazard-specific injuries; EMS cannot transport and treat all children. No pediatric-specific training for local/regional EMS and no regional/statewide EMS coordination.	EMS has the resources and coordination to transport and treat most, but not all, of the children impacted and the hazard-specific injuries. Regional and statewide EMS coordination exists but is unproven. Some pediatric-specific training for local/regional EMS exists, without regular drills.	EMS is able to treat and transport all affected children, both through their own resources as well as through regional and statewide coordination. Pediatric-specific training for EMS is robust with regular drills and mass-casualty incident protocols.
		Limited or no mitigation and preparedness efforts are in place to blunt the loss of operational capacity and impact on organizational performance due to hazard.	Some mitigation and preparedness efforts are in place to blunt the loss of operational capacity and impact on organizational performance due to hazard.	Proven mitigation and preparedness efforts are in place to significantly blunt the loss of operational capacity and impact on organizational performance due to hazard.
	Community Safety Infrastructure Preparedness	Hospital and/or region has limited reunification procedures. Limited to no plans to provide temporary shelter for displaced children. State and nationwide coordination for large-scale hazard displacement has not yet been established.	Hospital and regional reunification procedures are in place to reunite children with their families, though are not well-tested. Able to provide shelter for some (but not all) displaced children. State and nationwideplans for large-scale hazard displacement exist but are not well-established.	Hospital and regional reunification procedures are in place to reunite large amounts of children with their families, as well as potentially provide shelter for displaced children. State and nationwide coordination for large-scale hazard displacement is well-established.
		School and childcare closures have the potential to greatly impact staffing, with existing procedures unable to overcome shortage. Hospital and/or regional alternative childcare options do not exist.	Staffing impacted due to school and childcare closures, yet the effects are overall blunted due to flexible staffing procedures, enough staff, and/or alternative childcare options.	Staffing uninterupted due to school and childcare closures as a result of flexible staffing procedures, enough staff, and/or alternative childcare options.
		Limited to no plans are in place for regional, state, and nationwide coordination that would be able to provide food and shelter, as well as address lingering environmental/CBRNE effects of a hazard.	Plans are in place , but are not stress-tested, for regional, state, and nationwide coordination that would be able to provide food and shelter, as well as address lingering environmental/CBRNE effects of a hazard.	Regional, state, and nationwide coordination exists and is proven among private and public agencies in order to provide food and shelter, as well as address lingering environmental/CBRNE effects of a hazard.
		No establishment of connections with private and/or public outside organizations.	Connections with private and/or public outside organizations have been established.	Connections with private and/or public outside organizations have been established and the hospital/region continuously uses these organizations for new insights.
		Hospital and/or region has not recognized or considered the adverse effects the hazard has on disparate populations and does not equitably address issues of race, gender, education, and socioeconomic status in the setting of hazard outcomes.	Hospital and/or region has recognized the adverse effects the hazard has on disparate populations and considered issues of race, gender, education, and socioeconomic status. However, proven plans are not yet in place to address equity and barriers to treatement.	Hospital and/or region has considered and has plans to mitigate against the adverse effects the hazard has on disparate populations. Plans include providing food, shelter, and healthcare access to communities experiencing low socioeconomic conditions and other barriers to treatement. Equity in terms of race, gender, education, and other factors are considered.

Figure 4. Preparedness scoring key. The *preparedness scoring key* provides examples and descriptions of low, medium, and high levels of preparedness. The preparedness categories ("human impact preparedness," "health care system preparedness," and "community safety infrastructure preparedness") align with the hazard impact/severity categories.

another.[11] Even when asked to assess identical hazards, different groups can produce disparate risk calculations, at least somewhat due to the effects of recent bias and subjective risk perceptions.[11,35] The *scoring key* examples and descriptions of graded severity (ie, low impact to high impact) within our pediatric HVA template frame pediatric issues within an appropriate context to try and reduce the potential of biased scoring by individuals with different backgrounds and those less familiar with pediatric disaster management. For example, within the "public health" sub-category of the template's "health care systems impact preparedness," a low-impact hazard would not be expected to affect the road conditions, power grids, or transportation necessary for children with medical complexity to receive at-home resources, while a high-impact hazard would be expected to prevent these ill children from

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receiving necessary home care. Even when the scoring keys' examples and descriptions do not directly apply to a manager's region or hospital, reading through the keys can provide a frame of general pediatric issues that managers should consider when planning for children in disasters.

Reducing an HVA's many insights into a single final score allows managers to compare the risks of different hazards to one another but also to minimize the HVA's usefulness for those managers who want more stratification. The template provides 3 different scores: an *overall risk* score that lets managers analyze traditional hazard risk (incorporating preparedness), as well as *impact* and *vulnerability* scores that allow managers to compare isolated hazard impacts and pediatric population exposures. These additional scores would be important for managers wanting to isolate impact in order to reapportion existing resources or managers looking to remove probabilities and accepted consensus from their analysis in order to prepare for worst-case scenarios.

Further work is needed to determine the overall usefulness and applicability of the pediatric HVA template, its sub-categories, 3 different scores, as well as the impact and preparedness scoring keys. Next steps involve disseminating the template to regional emergency managers and managers of adult and pediatric hospitals. It will be important to observe whether and how managers integrate the template into their existing systems and how managers with limited pediatric experience handle the template's scoring.

Limitations

There are important limitations to acknowledge regarding the pediatric HVA template. By design, all HVA templates attempt to reduce complex disaster outcomes into discrete numbers. However, there are several qualitative factors and consequences that HVAs cannot capture. Leaving these out can lead to overconfident predictions and deter preparations for rare hazards (either due to a low likelihood of occurrence or high existing preparedness). Furthermore, our HVA template is built around the idea that disasters have such a unique impact on vulnerable populations that each population needs to be analyzed separately. While this template concerns children only, there is no shortage of other important vulnerable populations such as the elderly, disabled, homeless, and impoverished communities. Using a different HVA for each vulnerable population may become too time-consuming and complicated for emergency managers to realistically undertake. The pediatric HVA template, in particular, contains above-average levels of required reading and analysis (eg, the scoring keys) that managers may not want to complete.

Finally, although the template was designed to provide emergency managers with the flexibility to apply hazards to their individual circumstance, some managers may still find it too limiting. Managers may not agree with the template's sub-categories or the fact that in the overall risk score, preparedness only mitigates hazard impact in its corresponding category. Some managers may also find the 1 to 3 scoring criteria to be overly restrictive, instead preferring a wider range of scoring options.

Conclusion

Though children comprise a large proportion of the population and are one of the most vulnerable sub-groups, they are often overlooked within the field of disaster management. We created a pediatric-specific HVA template that includes relevant pediatric categories absent from other templates in order to allow emergency managers to better consider the needs of children during crises. Our HVA incorporates both the impacts of individual hazards on children as well as the preparedness necessary for hazard mitigation. This encourages managers to plan for pediatric-specific outcomes that they may not have previously recognized, while simultaneously strengthening existing preparedness efforts. The template is available for download and can immediately be used either on its own or as a complement to other existing HVA tools.[33] The use of our template could practically lead to improved pediatric equipment management, the creation of previously absent reunification procedures, and the incorporation of children into disaster drills. Managers can apply our template's analysis to establish relationships with nearby hospitals, emergency medical services, and local government agencies to plan for pediatric surge events that overwhelm a single hospital's bed capacity, require patient and resource diversions, and necessitate providing food and shelter to children. We hope that the template's widespread dissemination can create a standardization for comparing pediatric disaster impacts and preparedness across different geographic regions and health care systems. Further work is needed to determine the overall effectiveness and usefulness of the pediatric HVA template.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/dmp.2022.90

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