Curr Treat Options Peds (2017) 3:272–282
DOI 10.1007/s40746-017-0096-6

Disaster Medicine (M Anderson and M Dingeldein, Section Editors)

Pediatric Disaster Preparation in the Prehospital Setting

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Published online: 25 July 2017

This article is part of the Topical Collection on *Disaster Medicine*

Keywords Disaster · Pediatric · Prehospital · EMS · Preparedness

Opinion statement

Recent disaster incidents have shown that pediatric disaster preparedness is more important than ever. Children represent nearly 25% of our population and are one of the most vulnerable groups, making them likely to be victims in disaster incidents. However, in spite of repeated efforts to adequately address the needs of children after disasters, progress for pediatric disaster preparedness has lagged behind efforts to improve general disaster preparedness. Previous disasters have demonstrated that children should be considered as part of the general population when planning occurs. Pediatric expertise and participation in disaster planning and drills would be invaluable in addressing the unique needs of children during these incidents. Furthermore, in order to have a sufficient response to pediatric needs by prehospital providers during a disaster, adequate coordination for pediatric care among emergency medical services systems needs to exist. Recent research has been performed on pediatric disaster triage; pediatric disaster training; pediatric chemical, biological, radiological, nuclear, and explosive (CBRNE) events; pediatric decontamination; and pediatric disaster mental health. This work has advanced the knowledge for this very specialized field. However, further research is necessary to continually improve the quality of care that children receive during and after a disaster incident in the prehospital setting, as the pediatric population will very likely be impacted by disasters to come.

Introduction

Recent disaster incidents, including the terrorist bombing at a concert performance in Manchester, England, which contained a significant number of children, have shown that pediatric disaster preparedness is more important than ever.

In June 2006, the Institute of Medicine (IOM) published three reports on the *Future of Emergency Care in the United States Health System* [1–3]. One of the reports was entitled "Emergency Medical Services for Children: Growing Pains," and it outlined recommendations for the improvement of pediatric care within emergency and trauma care systems [3]. At the time, the IOM clearly stated that emergency and trauma care systems were ill prepared to care for children—"If there is one word to describe the current state of pediatric emergency care in 2006, it is

uneven." One of the most important recommendations the IOM made was for emergency medical services (EMS) agencies and hospitals to "appoint pediatric coordinators to provide pediatric leadership for emergency preparedness planning and to ensure day-to-day reading of hospitals, including emergency departments and EMS systems" [4]. This goal is ideal as children, who represent nearly 25% of our population, are one of the most vulnerable groups and are likely to be victims in mass casualty or disaster incidents. Furthermore, children may even be targeted in a terrorist plan.

Prehospital personnel, along with Disaster Medical Assistance Teams (DMATs) if called upon, will be providing the first line of care for these children. However, "substantial deficiencies in the preparedness plans of EMS agencies and in DMAT resources and planning for the care of children have been demonstrated" [4]. One previous survey of 3748 EMS agencies showed that while 73% reported having a written response plan for a mass casualty incident, only 13% had a pediatric-specific mass casualty plan [5]. More than 60% of the plans did not include some provision for children or adults with special health care needs, only 12% of agencies incorporated pediatric representation in planning, and less than half included pediatric patients in disaster drills [5]. Furthermore, only 19% of the EMS services reported using a pediatric-specific triage protocol for mass casualty events [5]. While EMS and emergency department preparedness efforts for children have improved, "only 25% of EMS agencies and 6% of hospital emergency departments have supplies and equipment to treat children" [6•]. In addition, the Strategic National Stockpile is "woefully understocked with medical countermeasures for children" [6•].

It has been argued that in spite of repeated efforts to acknowledge the importance of the needs of children after disasters and to address these needs adequately, "the progress in meeting the needs of children has lagged far behind those to improve preparedness in general" [6•]. The 2010 report by the National Commission on Children and Disasters did provide direction in improving the care of children after disasters. However, barriers to achieving this goal do exist. Programs and practices for managing disasters have been "fragmented and unaccountable to the needs of children; instead, they have been designed primarily to help able-bodied adults" [6•]. An unintended consequence of categorizing children as at-risk, special needs, or as a vulnerable population may be that they receive less attention in disaster planning and management, inadvertently creating their neglect. These designations often lead to their exclusion in planning for disaster preparedness since they may be considered a special population instead of part of the general population like they should be. By separating them from the overall plan and classifying them as a special population, their needs are then "considered only as time and resources permit, rather than being incorporated as an integral part of all communities" [6•].

Previous disasters have demonstrated that children should be considered as part of the general population when planning occurs. Of the more than 400,000 people dispersed to 48 states in the aftermath of Hurricanes Katrina and Rita, more than 5000 children were reported missing and the last of the missing children were not reunited with their parents until 6 months after the hurricane made landfall [4]. In the aftermath of Hurricane Katrina, evacuees were sent to the Astrodome in Houston, TX. A mobile pediatric emergency response team evaluated more than 3500 pediatric patients in 13 days and a large majority of these minor children were unaccompanied by an adult [7]. Of the 2196 patient encounters performed by a DMAT during two hurricanes, 643 (30%) were children under the age of 18 years old, and due to challenges in communication and assessment, pediatric patients were significantly more likely to have undocumented severity of illness than the adult patients [8]. Consequently, pediatric disaster planning needs to be an integral part of overall disaster planning when it occurs. Furthermore, pediatric disaster planning needs to start with prehospital agencies, as they are the first responders to children when a disaster occurs. Accordingly, recent research has addressed this gap in pediatric disaster preparedness in the prehospital setting, and this paper will review some of the most recent developments in this area.

Recent statements and documents

In 2015, the American Academy of Pediatrics (AAP) published a policy statement entitled *Ensuring the Health of Children in Disasters* [9••]. Among the many

recommendations it makes, one is that "community, state, and federal disaster exercises and drills should be performed routinely and should include community pediatricians, pediatric casualties, and pediatric scenarios as part of a 'whole community' effort" [9••]. In addition, the AAP encourages pediatricians to enhance their own disaster education and to consider enrollment in a local medical reserve corps or participation on a federal DMAT or state medical assistance team. Pediatric expertise and participation in these drills and on these teams would be invaluable in addressing the unique needs of children during disasters.

Furthermore, in order to have a sufficient response to pediatric needs by prehospital providers during a disaster, adequate coordination for pediatric care among EMS systems needs to exist as "children account for up to 10% of EMS transports" [10••]. In 1995, Snyder et al. documented pediatric-oriented deficiencies in state EMS systems, with 77% lacking prehospital triage protocols for specialty populations such as pediatrics [11]. Since 2006, the federal EMS for Children program has been developing performance measures to help states evaluate pediatric emergency care. The 2011 National EMS Assessment by the Federal Interagency Committee on Emergency Medical Services showed that "of the 38 responding states, 15 (39%) reported a Pediatric Medical Director" [10••]. The 2014 EMS for Children Performance Measures found that among 6000 EMS agencies, written pediatric protocols were immediately available to 63% of Basic Life Support (BLS) agencies and 90% of Advanced Life Support (ALS) agencies [10••]. In addition, more than 90% of BLS and ALS agencies have access to online pediatric medical direction [10••]. With regards to pediatric equipment, as of 2014, "BLS and ALS agencies carried on average 91 and 96% of the nationally recommended pediatric equipment, respectively," which was only marginally improved over the 2011 assessment [10••]. Nevertheless, in 2014, "over 82% of states and territories require pediatric education for license and certification renewal of prehospital providers, and 88% have formal EMS for Children Advisory Committees" [10••]. Accordingly, while EMS systems have increasingly made pediatric care a priority since prehospital providers infrequently perform procedures on children and since "children arriving to the emergency department by ambulance are more likely to have higher-acuity illnesses than those arriving by other means" [10••], gaps still exist and improving prehospital pediatric care continues to be necessary.

In 2017, a resource document entitled *Coordination of Pediatric Emergency Care in EMS Systems* was published [10••]. It conducted a systemic review of the literature to identify descriptions of and scientific evidence for pediatric coordination across the emergency care continuum. Out of 149 initial citations, nine ultimately met their inclusion criteria for review. While it acknowledges that the presence of a pediatric emergency care coordinator (PECC) enhances the readiness of emergency departments to treat children, "having a designated individual who coordinate pediatric emergency care may be even more important for EMS systems, where pediatric care is less of an everyday occurrence" [10••]. An advisory committee to the EMS for Children program determined that states and territories be required to report the percentage of EMS agencies that have a PECC. Accordingly, the "Maternal and Child Health Bureau of the Health Resources and Services Administration has set the following goals for obtaining this performance measure: 30% of agencies by 2020, 60% of agencies by 2023, and 90% of agencies by 2026" [10••]. The PECC within an EMS agency or system would work collaboratively with the EMS administrative director and

physician medical director to improve the care of children in the prehospital setting. Complementary to the PECC would be a Pediatric Advisory Committee composed of key stakeholders in pediatric care. One of the main responsibilities for this committee would be to develop a local and regional pediatric disaster plan and organize and assist with pediatric disaster drills. A program in Oregon in which "experts from Oregon's two children's hospitals and Oregon Emergency Medical Services for Children developed interactive workshops for medical providers covering the care of sick children at both individual and mass casualty levels," including pediatric triage, weight-based medication administration in emergencies, and disaster planning, was met with positive feedback [12]. More than 80% of the participants, who consisted of physicians, nurses, advanced practitioners, and prehospital providers, requested that similar offerings be available every 6–12 months. Accordingly, these initiatives would not only elevate the ability of EMS agencies to provide optimal pediatric care on a day-to-day basis but also improve the readiness of prehospital agencies to prepare and care for children when a disaster occurs.

Pediatric disaster triage

One of the critical elements affecting the readiness of EMS agencies to care for children in a disaster is their ability to triage pediatric patients. However, pediatric disaster triage performing by prehospital personnel is not without some obstacles. Koziel et al. performed a qualitative investigation into the barriers to pediatric disaster triage [13]. They found the following barriers self-reported by paramedics: "(1) lack of familiarity with children and their physiology; (2) challenges with triaging children with special health care needs; (3) emotional reactions to triage situations, including a mother holding an injured/dead child…; (4) training limitations, including poor simulation fidelity"; and "(5) disaster-related stressors, including using a pediatric disaster triage strategy, utilizing scarce resources, and deciding whether a disaster or multiple-casualty event is happening" [13]. The authors advocate that several of the barriers may be overcome with continuing education and modifications to existing pediatric triage and disaster management strategies. In addition, just-in-time training may be necessary immediately before EMS providers respond to a disaster in order to re-familiarize them with pediatric disaster triage principles and techniques. Koziel et al. also note that previous authors disagree as to whether a separate algorithm for pediatric disaster victims improved children's outcomes and is justified. Accordingly, they argue for the "urgent need to establish a single, widely acceptable disaster triage strategy for all victims, including children" that would "(1) be easy to learn, remember, and apply; (2) have an evidence base that demonstrated better outcomes for disaster victims when it is used; and (3) be adopted nationally and beyond, so EMS providers and other disaster responders would manage disaster triage with the same strategy and language" [13]. Furthermore, anticipating the mental health needs for prehospital providers during and after a disaster is crucial, as the strong emotions that EMS personnel experience as a result of a disaster, especially one that involves children, should be not be ignored.

Recent research has addressed these challenges to effective pediatric disaster triage. Cicero et al. designed three multiple patient incidents for EMS provider

training simulations and sought "to determine the appropriate interventions and triage level for each victim in each of the simulations and develop evaluation instruments for each simulation" [14]. They created disaster simulations consisting of a school shooting, a school bus crash, and a multiple-victim house fire. Subject matter experts consisting of eight physicians and paramedics performed a modified Delphi iterative critique of the simulations and evaluation tools. Consensus for expected triage level was >85% for 28 of the 30 victims after two rounds of the modified Delphi and for the remaining two victims after three Delphi rounds. This process "eliminated biases toward specific [pediatric disaster triage] strategies in the evaluations" [14].

Donofrio et al. sought to develop a "set of criteria for outcomes and interventions to be used as a validation tool for testing an MCI algorithm's ability to correctly triage patients from a cohort of pediatric trauma patients" [15]. An initial Criteria Outcomes Tool (COT) was formulated using expert opinion and literature review. The tool was used to retrospectively categorize pediatric (≤14 years old) MCI victims based on resource utilization and clinical outcomes using the classic Red to Black MCI triage designations. A summative COT was then created using an anatomic approach and a modified-Delphi approach and reviewed by the AAP Disaster Preparedness Advisory Council. This COT was then "independently applied to a weighted retrospective cohort of 24 pediatric victims from a single level I trauma center by two reviewers to determine reproducibility" [15]. The COT ultimately had 47 outcomes and interventions to validate an MCI algorithm's triage designation. The two reviewers had 100% agreement in each of the four Red to Black triage categories.

Another study by Cicero et al. compared the accuracy and triage outcomes of the Smart and JumpSTART pediatric disaster triage strategies and clinical decision-making (CDM) with no algorithm among a sample of emergency medical services providers through a prospective cohort study [16]. Ten-victim, multi-modal disaster simulations were used and a Delphi method determined patients' expected triage levels in the classic Red to Black categories. The authors found greater accuracy with JumpSTART triage than with either Smart ($p < 0.001$) or CDM ($p = 0.02$). For Red patients, JumpSTART outperformed Smart ($p = 0.05$). For Yellow patients, JumpSTART outperformed both Smart ($p < 0.001$) and CDM ($p < 0.001$). JumpSTART also outperformed CDM for Black patients ($p = 0.01$).

A 2017 study by Cicero et al. measured the effect of a multiple-patient, multiple-simulation criteria on the accuracy of pediatric disaster triage among paramedics, paramedic students, and emergency medical technicians (EMTs) [17]. Triage accuracy was measured three times (time 0, time 1 [2 weeks later], and time 2 [6 months later]) during a disaster simulation consisting of high- and low-fidelity manikins and actors portraying 10 victims. Triage category was predetermined for each victim. Between time 0 and time 1, the participants completed an interactive online module. After each simulation, an individual debriefing also occurred. The authors found that triage accuracy improved significantly from time 0 to time 1 with a median 10% overall improvement ($p < 0.001$) with paramedics and paramedic student improved more than EMTs ($p = 0.02$). The greatest improvement in overall triage accuracy was for Yellow patients from 50% accuracy at time 0 to 100% accuracy at time 1. The second greatest improvement in accuracy was for Red patients with 80% accuracy at time 0 to 100% accuracy at time 1. No significant difference in accuracy occurred between time 1 and time 2 ($p = 0.073$).

This research on pediatric disaster triage adds valuable knowledge to an area that is crucial for effective prehospital pediatric disaster preparedness. Additional research on pediatric disaster training has also been recently performed, which will be reviewed in the next section.

Pediatric disaster training

As previously mentioned, gaps in pediatric disaster preparedness do exist. Unfortunately, "despite calls for a national standardized pediatric emergency preparedness training, no universal standard of competency for pediatric disaster training exists" [18]. In 2011, the National Center for Disaster Medicine and Public Health conducted a meeting entitled Pediatric Disaster Preparedness Curriculum Development and had the objective of initiating the development of infrastructure and methodology to create a competency-based pediatric disaster preparedness training program. The meeting identified the roles of health care provides that needed to be trained and the priority of their training and established some preliminary curriculum recommendations.

Behar et al. conducted a study that was consistent with this framework in which the Pediatric Disaster Resource and Training Center (PDRTC) at Children's Hospital Los Angeles (CHLA) developed a competency-based curriculum and provided a 1-day course in pediatric disaster preparedness for health care providers and emergency planners in Southern California [18]. Through didactic lectures and hands-on breakout sessions, their goal was to create and administer a curriculum that defined specific pediatric disaster preparedness competencies. Of the health care workers, 326 were scored on a 30-item pediatric disaster test before and after the educational interventions. The authors found that most attendees, the majority of whom infrequently care for pediatric patients, had significant improvements between the preeducational and posteducational intervention test scores ($p < 0.0001$). Consequently, the competencies could be used in formulating a standardized curriculum, including one for prehospital providers.

Another study examined the utility of a checklist in evaluating pediatric disaster training [19]. In this study, residents for four different academic pediatric residency programs volunteered to participate in a tabletop simulation of a timed, pediatric disaster scenario. Care intervention requests corresponding to each of the three pediatric patients were recorded on a premade checklist. On average, the 36 teams requested 65% of the interventions, were prompted to request 11%, and missed 22% of all checklist interventions. Only 2% of all the items on the checklist were not recorded. The training allowed the participants an opportunity to explore pediatric disaster preparedness in a low-stress environment. This kind of training could easily be adapted to prehospital providers. One specific area of training for pediatric disaster preparedness is that for a chemical, biological, radiological, nuclear, or explosive (CBRNE) attack, and this will be explored in the next section.

Pediatric CBRNE training and decontamination

As previously mentioned, the NCDMPH convened a pediatric disaster preparedness conference in 2011. A main product of the conference was the initial groundwork for development of a pediatric disaster preparedness curriculum. Since children, due to their unique anatomy and physiology, are particularly

vulnerable to a CBRNE attack, the conference found that the "greatest impact on reducing pediatric morbidity and mortality can be achieved by providing CBRNE training as a first step for prioritized EMS, emergency department (ED)/hospital, and ambulatory clinicians" [20].

The EMS subject matter expert group at the 2011 NCDMPH conference found several key content areas within CBRNE. For explosives, pediatric trauma management concepts of importance included crush injuries, compartment syndrome, and airway management. Chemical weapon topics included toxic syndromes and typical presentations of chemical exposures, including how children might present differently than adults. They also identified which chemical agents would need time-sensitive treatment, specifically organophosphates and cyanide. Regarding biological agents, one of the key issues was infection control, which included isolation and quarantine management. Another key issue was the recognition of which patients may be affected by a biologic agent. For radiation exposure, personal protection and decontamination were perceived to be the most important content areas [20].

There are several high-quality, vetted literature, and web-based CBRNE resources that could be used to develop user-friendly platforms for educational, reference, and just-in-time training. The second generation of the Chemical Hazard Emergency Medical Management (CHEMM) website housed at the National Library of Medicine serves as a comprehensive reference for the diagnosis and treatment of chemical warfare and hazardous material agents for prehospital and hospital care providers. Toxidrome and individual agent-based just-in-time sheets for clinicians are also provided on this website, including the vulnerabilities and treatment of children affected by a chemical attack. The Radiological Emergency Medical Management (REMM) website and app is a comprehensive educational and patient management resource, utilizing highly user-friendly algorithms for succinct initial and follow-up care guidance. The CDC has developed a blast injury application, and its website has blast injury fact sheets for professionals that provide a broad overview of the mechanism, clinical effects, and treatment of blast-related injuries, including pediatric content. Pediatric Anthrax Clinical Guidance was also developed based on the proceedings from a workshop jointly sponsored by the CDC and AAP in November 2012. It provides a comprehensive understanding of the disease as well as clinical guidelines for the prophylaxis and treatment of children exposed to this specific agent. A highly vetted comprehensive document providing an excellent overview of the microbiology, toxin mechanism of action, clinical presentation, diagnosis, and treatment of children and adults for a botulinum toxin mass casualty incident was the result of 2-day conference hosted by the Division of Medical Countermeasures (MCM) Strategy and Requirements within the United States Health and Human Services Office of Policy and Planning (OPP). Training Finder Real-Time Affiliated Integrated Network (TRAIN) is a web-based platform that provides a clearinghouse of on-site training and distance learning programs. The National Disaster Medical Systems utilizes Responder e-learn 2.0, which is an integrated medical, public health, preparedness, and response educational platform [20].

Decontamination of a pediatric patient requires a specialized approach since "infants, children, and adolescents are prone to increased health risk from chemical, biological, and radiological contaminants when compared with the adult population because of their physiological and psychological immaturity"

[21]. Infants are at increased risks of hypothermia, so supplies for warming are critical in the decontamination zone. Warming supplies, such as air warming systems, blankets, overhead heat lamps, radiant warmers, and gowns, should be included on the decontamination supply list when operationally feasible. Children are also prone to greater exposure of an airborne toxin due to their increased respiratory rate. Their shorter stature could lead to greater exposure of contaminants that settle to the ground and airborne toxins that have greater density than air. Their greater surface area-to-body weight ratio and more permeable skin may make them more susceptible to CBRNE agents. Since children have less fluid reserve than adults, toxins causing the loss of bodily fluids through vomiting or diarrhea would have a greater impact on the pediatric population. Furthermore, the toxic effects of contaminants are likely to appear sooner in children due to their faster metabolic rate when compared to that of an adult. Infants and children with immature immune systems may also have a different presentation when exposed to a contaminant compared to the clinical presentation of an adult [21].

"Children are also limited in skills of communication, self-care, independence, supervision, and transportation, presenting interlinked challenges" [21]. The planning of a decontamination area should take these factors into account when determining staff and space requirements. Children may not be able to answer triage questions. They also may take longer to disrobe, which is a crucial step of the decontamination process. One method to reduce the length of exposure to contaminants is having a parent present to help the child follow instructions, disrobe, and shower in a timely manner.

Psychological trauma is another important consideration for pediatric victims of a CBRNE attack. Responders may not able to distinguish a pediatric victim's distress being due to the physical exposure of a contaminant or being a psychological response to the situation. Pediatric victims are more likely to suffer anxiety reactions since they are more prone to psychological effects from traumatic incidents. Children may also regress in these situations with clinging, inattentiveness, separation anxiety, or aggression. Any decontamination protocol should anticipate these factors in the planning and implementation phases since they can affect the efficiency and effectiveness of the decontamination process. Consequently, it has been recommended to "maintain the integrity of the family unit when processing children through decontamination areas" [21]. Family-centered decontamination plans are critical, particularly for hospitals that do not typically care for all age groups, such as pediatric hospitals. It is recommended that the minimum staffing for safe decontamination of an infant is two staff members in addition to the parent or guardian. Age-specific materials and signs to guide patients as well as specific provider training regarding the different needs of pediatric patients at different ages should also be provided [21].

In addition to the physical effects of a disaster on children, the mental health consequences that children experience cannot be ignored, and recent research exploring this area of pediatric disaster preparedness will be explored in the next section.

Pediatric disaster mental health

Due to the exposure of children to scenes of devastation and the possibility of being uprooted from their usual living situation, children are more vulnerable

than any other age group. One recent study examined the life process of children who survived the earthquake of Manjil in the northern side of Iran [22]. It is found that the "life process of children earthquake survivors consists of 'unexpected encounter,' transient relief activities,' and 'long-lasting consequences'" [22]. One of the factors affecting the health of these children is providing non-specific and transient services. Accordingly, relief staff need to be trained to "consider the specific needs of… children at the time of the rescue operation" [22]. Some of the most important public health priorities for children affected by disasters include planning and taking action to identify misbehaviors along with raising awareness, especially for parents, on techniques to manage the outcomes of natural disasters. Public mental health services for parents and children are essential to address any potential psychological problems in survivors.

A recent report provides a review of the components included in available child disaster mental health interventions [23]. The nine core trauma-focused cognitive behavioral therapy components used with child trauma survivors, given the acronym "PRACTICE," include (1) psycho-education, (2) parenting skills, (3) relaxation skills, (4) affect modulation skills, (5) cognitive coping and processing, (6) trauma narrative, (7) in vivo mastery of trauma reminders, (8) conjoint child-parent sessions, and (9) enhancing future safety and development through garnering social support and parent involvement. Furthermore, the timing of intervention delivery is critical, whether it is preevent to improve the resiliency of children when a crisis occurs or postevent during the early aftermath or recovery period to provide support for the pediatric victims [24]. The setting of the intervention also plays a role, whether in a school, a clinic, or other community settings. The setting may also be determined partly by the individuals delivering the interventions "since it is not always possible to recruit an adequate number of licensed mental health professionals after a disaster" [24]. Consequently, other child-serving professionals, such as teachers or school staff, may need to be recruited and trained to provide mental health interventions for children after a disaster. Flexibility in setting and provider type may be required when providing pediatric disaster mental health services.

Conclusion

Children are affected by both natural and man-made disaster worldwide. Unfortunately, they are often overlooked, which should not be the case as they are the most dependent on others for survival. Much has been done to improve the ability of prehospital agencies to care for pediatric disaster victims. However, the ability to care for children in the aftermath of a disaster is dependent upon the ability of the prehospital agency and its providers to care for pediatric patients on a daily basis. Proper training, equipment, and coordination are essential to achieve these goals. Recent research on pediatric disaster triage, training, and mental health has advanced the knowledge for this very specialized field. However, further research is necessary to continually improve the quality of care that children receive during and after a disaster incident in the

prehospital setting, as the pediatric population will most certainly not escape the effects of disasters to come.

Compliance with Ethical Standards

Conflict of Interest
Jeffrey H. Luk declares that he no conflict of interest.

Human and Animal Rights and Informed Consent
This article does not contain any studies with human or animal subjects performed by any of the authors.

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