High-Reliability Organizing (HRO) for Disasters: Lessons Learned

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Abstract:

This abstract summarizes critical insights from the manuscript, focusing on lessons learned in neonatal disaster response. The manuscript emphasizes the multifaceted challenges in such scenarios, including environmental issues, clinical care considerations, staffing concerns, communication difficulties, simulation needs, government agency collaboration, and comprehensive planning. Adopting a broader perspective and collaborating with experts from various fields to enhance neonatal disaster preparedness is highlighted. The structured process of lessons learned is emphasized, especially the analysis of observed data, the formulation of corrective actions and recommendations, and the integrating of diverse perspectives and expertise. Ultimately, the goal is to reduce potential failures and improve the survivability of neonates during disasters.

Introduction:

We have reviewed published accounts of disasters that led to Neonatologists evacuating neonates from the NICU or sheltering in place (1-3). The disasters formed three groups: an abrupt change, a rapid approach, and a sustained presence. The reactions of NICU staff were to rapidly protect and move the neonates, consider the dynamically changing safety between evacuation and sheltering, and continual improvisation to preserve life.

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The Lessons Learned that the respective authors and our review identified were shared across all experiences. The authors expressed the more typical lessons learned as suggestions from their experience rather than an investigation expanding their experience into other scientific domains or using outside Subject Matter Experts.

They missed lessons embedded in their vibrant descriptions of their intense experiences. They accepted improvisation as the expected response rather than close adherence to rules or reliance on distant authorities. This was the material we teased out of their experience and presented it with little interpretation of the experience and more interpretation as examples of the natural feel of High-Reliability Organizing (HRO).

It is a testament to the care and evacuation of over 235 infants with prolonged care lasting hours to days that only two infants died. Neonatology would be well-served to exploit the ingenuity and dedication demonstrated by this Neonatology community for answers about preparing to shelter and evacuate.

Lessons Learned programs are continually at risk for "conceptual arrest" – the Lesson Learned that is a concept, an abstraction, something that has not, and cannot, be contextualized. A disaster creates abrupt gaps between what we thought we could do and what we must do, with the urgent need to engage the situation. Lessons Learned convert these experiences into more effective organizational performance and improved personnel capabilities. In these volatile and uncertain environments, failure *is* an option.

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A disaster is an *environmental* disruption of medical care, a *victim generator* that disrupts the *ability to treat* multiple patients. The government's response is to bring in an infrastructure for managing the disaster to increase survivability and return the community to routine operations. The medical response most often relies on the pre-disaster healthcare infrastructure, continuation of medical care, and the goal of *reducing mortality* by treating factors that cause death (4).

The Lesson Learned provides realistic, actionable recommendations that cause an organization to improve from the knowledge acquired after an adverse experience. It reduces or eliminates potential failures and mishaps or reinforces a positive result. Analytical processes discover what happened and why it happened. By identifying the root causes and remedial or corrective actions, experiences are transformed into best practices and lessons. Expert consultation from subject matter experts (SME) helps the organization understand the collected data to create informed recommendations (5).

The US military has a history of active learning from successes and failures from at least WWII. They have structured this learning as "Lessons Learned," a formal approach to collect lessons for organizational improvement: an issue is identified as a potential problem, observation and experience of the conditions, then propose recommendations (5). How civilian organizations carry out a Lessons Learned program will differ from the military Lessons Learned system.

The military operates under a single chain of command with appropriate commands that can take ownership of particular issues.

Though the lessons collected are mainly at the tactical level, the internal structure of the military facilitates absorbing observations from the field. The US Army does not consider a lesson to be "learned" until it is implemented and the problem is solved (6).

Healthcare organizations work with other organizations, regulatory agencies, various funding sources, and diverse professional organizations, resulting in multiple chains of command. Civilian organizations do not have the internal structure to absorb Lessons Learned. No single group or agency has the authority to address problems and solutions identified through Lessons Learned (6). Nevertheless, we can use the structure of military Lessons Learned to develop effective healthcare programs.

A Lessons Learned program does not evaluate, inspect, or review incidents. Lessons Learned derive from thoroughly discussing the observations and experiences, highlighting lessons, and then making recommendations within participants' expertise. Avoid opinions and do not write truisms that are known to be true at all times. "Be generic when it comes to sources but specific when it comes to issues." (5).

The Lesson Learned must connect to measurable change in behavior. The organization must take deliberate corrective actions from the lessons learned to enhance performance (5). Lessons Learned can prepare the organization for the next disaster or improve routine operations in a manner that supports operations during the next disaster.

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A lesson is knowledge gained by observation or experience, often an adverse experience, that changes behaviors in individuals or organizations. Experiences can be positive (a best practice) or negative (a mishap or failure). For negative experiences, the lessons can be how to avoid the incident, but possibly more useful are lessons for correction and recovery. If an incident happened once, it can happen again; if it happens again, it can happen worse. Teaching correction and recovery are seminal to High-Reliability *Organizing* as the verb (compared to the noun form of HRO, High-Reliability *Organization*).

Lessons come from action, either success or failure, by acting. Action makes the results visible. Karl Weick described failure as not acting, which is not visible and too readily becomes organizational knowledge (7). Social pressure not to act is a hallmark of the ecology of fear, an environment where fear of the threat causes more harm than the threat itself (8). Fear drives failure to act. Hence, fear and "not acting" become a source of organizational knowledge. Error is frequently considered a threat rather than a source of a Lesson Learned (9). Evaluations and investigations of error, the procedure itself is not a Lesson Learned. Error investigations too easily create blame or attribution and an environment that blocks information flow from those who have information to those who need it (5).

In our review of the Neonatology disaster responses (1-3), we find rapid engagement of a problem that abruptly appears. No descriptions or evidence that fear drove inaction. There was also no evidence that fear impaired effective action. These disaster experiences generated material for effective Lessons Learned that can inform disaster plans for NICUs. However, reviewing the Lessons Learned described in the articles reveals observations without analysis. Specific corrections or improvements accompanied no identified actions. Likewise, there were no descriptions of operational methods that should be reproduced.

We identified common problems the operators encountered. The time course of events, as direction and velocity, had material influences on decisions and actions independent of the nature of the disaster. While the disaster environment was influenced by the type of disaster and the season, the common influences were ambient temperature and air quality. Effectively maintaining effective clinical care came from the attitudes and improvisations of bedside staff rather than support from hospital administration or government agencies.

The Lessons Learned

Operational Lessons Learned were from the environment, clinical care, staffing, and evacuation. Logistics Lessons Learned included communication, simulations, government agencies, and planning.

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Environment

Environmental problems are not isolated but are embedded into each other – damaged structures, toxic air, and cold temperatures. Moving the neonate from a hazardous environment often necessitated entering the same environment but with added transport hazards and fewer protections. This is the conundrum of evacuation before the disaster –moving a neonate from a safe environment through a less safe transport environment when there is no surety of evacuation.

Air quality was the focus of wildland fire Lessons Learned (2). If healthcare providers are seriously affected within the hospital, consider the effect of air quality on the babies in the well-baby nursery and NICU. Also, consider that evacuation will expose neonates to smokey conditions, possibly for over an hour. Evacuation plans should include fire hazards, exposure to debris, and poor air quality (10). Despite 'air scrubbers' in place, air quality within the hospitals was poor, with soot and debris (10, 11). Healthcare pro-

viders within the hospital were affected, and some experienced bronchospasm (11).

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Ambient temperatures for neonatal thermoneutral temperatures, around 90° F. (3), would be considered warm for adults, particularly when humid. Neonates can develop hypothermia when directly exposed to such temperatures or from radiant heat loss to a cloudless sky. Neonates did develop hypothermia in humid "warm" weather with temperatures down to 73° F / 23° C (12-16) and when exposed to colder winter temperatures (17). It is a testament to the healthcare providers that only one adverse event, a death due to hypothermia, occurred. (1)

Thermoregulation was the focus of hurricane Lessons Learned (3). Several NICUs placed neonates in the incubator for warmth and better proximity for nursing care (14, 18). Solutions utilized included using polyethylene bags, chemically activated warming or perineum pads, and skin-to-skin contact using kangaroo mother care if possible (14, 16, 18, 19). Also, better charting and education on the thermoregulation of preterm infants during disaster management is needed (14).

Clinical Care

Treat all expectant mothers and infants as neonates. That is, treat the maternity nursery as a NICU. Consider recovery rooms or similar units as a temporary emergency buffer (20).

Staffing

Identify methods to mobilize additional staffing (11). Prepare a script for on-duty staff to explain the crisis, reasons for the recall, and their responsibilities (10, 11). Concerned about their families and homes, staff may need certain information before returning to work (11).

Give staff guidance on when and where to report for duty and clarify their role and responsibility during the disaster (10). Keep everyone informed promptly. A stressful and intense situation with contradictory information from leaders becomes a significant problem and source of confusion. "The realization that knowledge is power against panic" (21).

An internal alarm system for clinical and facility administrators can facilitate the rapid recruitment of sufficient staff (20). A crisis management system can identify who has authority and what instructions can be issued (20). Calmness, open-mindedness, tolerance, and improvisation are valuable traits (22).

Incorporate the NICU social worker into the disaster response rather than a social worker from an unfamiliar unit. The social worker, trusted and familiar to families, assists staff during the crisis (21).

Hospital administrations can assist staff in developing family evacuation plans, alleviating some of their worry (21). To return to, or stay at, work can create untenable tension between their duty to protect patients and their duty to protect their families (11).

Staff as Victims

A person becomes drained after 24-48 hours of uninterrupted professional experience with disruption and loss (21, 23). The disaster experienced personally by staff compounds the fatigue.

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Healthcare providers and hospital workers may have young children, teenagers, or disabled dependents at home. To stay at the hospital could endanger their family members. Staff may also need to remain at home or return home (11). PICU staff at Loma Linda University Children's Hospital, supported by colleagues and hospital administration, returned to their homes and children during the Panorama Fire (CA) on November 24, 1980.

Under even mild stress, we lose our prefrontal cortex abilities (24). Adolescents are the most susceptible. Their loss of PFC function is more significant, yet unrecognized, as they revert to an earlier childhood state. Adults commonly revert to the mental state of middle adolescence.

Staff may be losing their homes or a loved one during the disaster (23). Travel during a disaster can become deadly. One nurse, evacuating with her family during a wildland fire, was caught in the fire. Her daughter died, and another daughter suffered severe burns (11). Returning to duty immediately after the Northridge Earthquake, an LAPD officer died as he drove his motorcycle off a sheared-off freeway (25).

Evacuation

Develop a central authority or system to facilitate mass transfers of neonates (26). Inefficiencies and communication disconnections interfered with the development of evacuation plans and evacuation preparation (10, 21). Identify methods to mobilize additional staffing, develop transportation options, and identify receiving hospitals (11).

The JSNHD disaster communication team facilitated a network with remote NICUs. The online directory and communication tools included internet phone text messages facilitating contact with outlying NICUs (17). Not having a program like this was identified as a significant deficit during an abrupt disaster (20). Such a system would benefit larger hospitals for internal communication, where communication during an internal disaster became problematic (27).

Develop a NICU-specific evacuation policy with procedures, have

a quick triage method, and create easy-to-use checklists and supply lists (21). Improvisation for transport triage is effective. One NICU created its system for evacuation priority, relying on its knowledge of the infants.

Envisage evacuation, emergency routes, and necessary actions you would take if the expected route becomes obstructed or dangerous (20). In an emergent evacuation, specialized ambulance transport teams would be used without accompanying neonatologists or nurses (21). Medicating patients prior to transfer reduces difficulties in equipment (11) and medication administration by EMS personnel.

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Urgent or emergency transportation exposes infants to kinetic activity and vibration, exposing them to the risk of compromised cerebral circulation or loss of a secure endotracheal tube or vascular access (17, 20). For sick infants on long-distance transportation, minimize the threat from transport using helicopters or neonatal ambulances (17).

Impaired patient handoff for the adult hospital resulted when patients were transported with minimal medical information. Nurses counteracted this problem by nurse-initiated RN-to-RN phone reports (10).

For internal evacuation of patients, bring care stock items and medication carts to the same unit (27).

Communication

Improve the communication structure and include physicians in hospital incident command meetings. Inefficiencies and communication disconnections interfered with the development of evacuation plans and evacuation preparation (10, 21). Develop an incident command communication workflow specific to the NICU that connects to the hospital incident command (21, 28).

Simulations

Conduct simulations for evacuation and/or transport. Prepare or think through general scenarios for a framework to operate in a disaster (21)—h*ospital as a haven.* Residents arrived at the hospital with families and pets (10).

Government Agencies

Work with government agencies to correct "covert but serious risks in relying on the adult-based coordination system of transportation" (17). Neonatologists can present to government disaster agencies the unique way the danger of a disaster brings threats to the neonate, such as hypothermia, vibration, and toxic air (17, 20, 27).

Work with public safety to develop a unified or unifiable command structure with public safety. Obtain the capability to communicate on a public safety radio frequency (27).

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Planning

Food supplies in the NICU (22) . From experience, it is recommended that each person should bring necessary food and supplies for three days separate from the hospital supply.

Created an organizational structure for NICU-specific disaster management (26):

- Evacuation and surge plans are incorporated into the preparedness plan.
- Coordinated with the New York City Pediatric Disaster Coalition.
- Explicitly detail our NICU Incident Command Structure, which includes the designation of our staff social worker as liaison to NICU families.
- NICU-specific evacuation equipment must be stocked in an easily accessible location.
- The disaster plan includes strategic placement of transport isolettes (ground floor)
- Evacuation and power outage checklists.
- Simulation center has a plan for neonates and vertical evacuation.

The listed Lessons Learned tended toward generalities with few concrete recommendations. No Lesson Learned went beyond the domain of Neonatology or contained information from Subject Matter Experts (SME). No Lessons Learned connected a problem described in the article with a solution that the Neonatologist can act upon. Our review identified consequential problems that may lead to more robust discussions for disaster education, training, and planning.

Problems Encountered

For healthcare, a disaster is an *environmental disruption* of medical care that disrupts the *ability to treat multiple patients*. This is a functional, ecological definition (29). Environmental problems are not isolated but are embedded into each other – damaged structure, toxic air, cold temperatures, moving from one problem places the neonate into another.

A disaster creates an adverse, austere environment. Whether remaining in the disaster environment or evacuating to a better location, healthcare providers will improvise. Evacuation has hazards unique to transportation, contributing to whether to transport neonates when the environment is stable or unstable and hazardous. Standards of care also differ. Stable circumstances constrain the choice of transport team and vehicle to a higher level with less

availability. More typical was transport when the environment had become hazardous, changing the standards of care to allow access to more vehicles. However, during the disaster, government agencies control transport resources and restrict the movement of vehicles, whether air or ground. This is the disaster infrastructure that was unfamiliar to hospital-based healthcare professionals.

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Time Course

When the environment abruptly entered the NICU, evacuation became an action rather than a decision (1). Staff responded expeditiously to protect the neonate from cold while moving to a safer location. These are granular actions taken at the local level emerging from local capabilities and resources. In the published experiences, one neonate died from exposure to the environment.

- Staff may benefit from preparatory discussions regarding the movements of multiple neonates and safe zones at various distances from the NICU - Also, articulating what constitutes a safe zone for various circumstances: damaged windows, fire, smoke, etc.

A slower-approaching danger, such as wildland fire, creates a different dilemma between evacuating or sheltering (2) - Visibility from smoke impaired surface transport of neonates and air operations (10, 11, 21). Congestion from evacuating residents, fire burn over, and visibility impaired the use of roads (10, 11, 21). The Neonatologists made simultaneous plans to shelter and transport.

- Staff may benefit from preparatory discussions regarding road conditions and hazards, 'weatherproofing' neonates, and articulating dangers from smoke or flood.

After the disaster event passes, a different time course develops – the return of regular operations or formal evacuation out of the hospital. Evacuation times in this series were 4-12 hours at approximately 2-4 neonates per hour. One hospital had data for evacuation *before* a hurricane – 19 neonates in 18 hours, one neonate per hour. The need for specialized ambulance transport as a standard of care accounted for the longer evacuation time.

- Preparatory discussions about transportation constraints and modes of transportation available or unavailable due to the disaster or disaster management can better support improvised transportation. Neonatologists have used private vehicles, including the personal vehicles of physicians and canoes with a Chief Orthopedic Resident, followed by a fire engine. Neonatologists could become familiar with evacuation times *before* and *after* a disaster.

An additional time course occurred for evacuating several NICUs, with delays in days due to limited resources for evacuation. In one case, disaster managers' lost' the hospital, which was evacuated days after staff called a friend out of state who called the NICU evacuation dispatch center.

- Neonatologists can discuss food reserves and toiletries brought by staff for personal use should evacuation from the NICU be delayed for several days.

Environment

Disasters compromise the environment of the NICU and during transport. Neonates may become exposed to cold air, water and contamination, smoke, soot, and toxic gases—visibility from the smoke impaired staff recall, surface transport of patients, and air operations. Hospital ventilation systems could not maintain clean air (10, 11, 21), with some hospitals creating internal respiratory treatment stations (11).

- Preparatory discussions can focus on methods to maintain neonate body temperature and air filtering for the NICU. Hospital and NICU respiratory treatment stations will support staff and family members present during the disaster.

Communication

Communication is commonly brought up in discussions of disaster and a problem for a hospital operating during a structure fire (27). However, *no* NICU reported communication problems, either internal or external.

"After the disaster event passes, a different time course develops – the return of regular operations or formal evacuation out of the hospital."

Internal command lines of authority and communication did not function well (26, 30). Hospital administration and NICU staff often lacked a clear communication structure. Medical directors and physicians were not included in hospital incident command meetings. In one instance, medical staff leadership decided on evacuation, while nursing leadership decided on shelter. The contradictory conclusions were communicated to their respective staff, creating confusion and exacerbating the tension of an intense situation (21). Furthermore, delegation of responsibilities was problematic. One participant said that if they could have changed one thing, it would be to have a clear command structure in the unit (1, 23).

- Preparatory discussions can bring Neonatologists into medical staff governance and hospital administration to make the neonates' unique and specific needs visible.

Emergency communication was hampered when staff members were unfamiliar with portable radios, and the hospital had no shared frequency with public safety (27). Notification of family by the media sometimes occurs. If an internal disaster occurs, the family may not know about the problem until they see it on the news (27). For an area-wide disaster, the family may not realize the hospital was evacuated (31).

- Preparatory discussions can bring Neonatologists into the hospital communication system to keep families apprised of the status of the NICU during a disaster.

Transport communication for bed availability, acceptance of the referral, and transportation became a problem independent of the technology. One participant had to text an intermediary to communicate (23). Neonates might arrive at the referral NICU without a call from the evacuating NICU asking for permission or providing a warning. Internet and phone call issues did not help. The surge capacity of receiving NICUs was not predictable. It was fortunate that receiving NICUs could absorb the surge. When this was not practical, improvisations were the PICU, anesthesia recovery

rooms, and the ED (20, 32).

- Preparatory discussions can identify alternate neonatal admission sites within or with receiving hospitals.

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Staffing

Increasing staff. Staff requested more information as they balanced work, the safety of their family, the threat to their home, and the ability to travel on the roads to the hospital. Some were trapped in their neighborhoods. Some staff were called home to help the family. Fire trapped one nurse evacuating her family, resulting in a fatality and severe burns (2).

Isolation from family and the expectations to care for premature babies in austere conditions became a severe problem. Staff felt less connected with hospital management during the prolonged isolation (33). Staff provided mutual assistance to each other and the families of patients (3, 14, 16, 18, 19, 22, 33).

Convergent volunteers and returning staff will overwhelm the physical space and the ability of healthcare providers to perform (27). This can occur in public safety incidents also (34). No NICU reported this as a problem.

Clinical Management

Parental contact suffered from power and cell tower outages. This also created distractions for staff working in the NICU concerned about their relatives (3).

Thermoregulation. Keeping babies warm during a tropical cyclone may seem counterintuitive, except thermoneutral temperatures for neonates are around 90° F. Several NICUs placed multiple neonates in the same incubator for warmth or to use the proximity for nursing care (14, 18). Solutions utilized included using polyethylene bags, chemically activated warming or perineum pads, and skin-to-skin contact using kangaroo mother care if possible (3, 14, 16, 18, 19). Neonates would benefit from better charting and education on thermoregulation of preterm infants during disaster management (14).

Supplies and Equipment

Hand disinfectant was a problem for all NICUs.

The availability of oxygen cylinders for one NICU during an earthquake was quickly solved when the infants shared a cylinder (17).

Supplies are damaged during an internal disaster. Evacuating patients internally without accompanying supplies creates shortages in the new unit. Referring to evacuations as transfers rather than an evacuation may trigger normal transfer behaviors and etiquette. Accustomed to moving the patient and not taking supplies from the originating unit, staff carry the same behavior into an evacuation.

Transportation

Neonatal transport with incubator support is not readily available through EMS (20, 27). One NICU used general ambulances to evacuate some of their neonates (17). Neonates are susceptible to environmental stressors such as vibration and cold and kinetic activity or vibration affecting cerebral circulation or the security of endotracheal tubes and vascular access (17, 20).

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Equipment. It is not feasible to pack a bag at the moment for every patient (21).

Medical records. Some patients evacuated with incomplete records due to the limited preparation time (10).

Distance. For an internal evacuation, distance creates a problem because of the smaller response magnitude. That is, the time for transport to an adjacent building is nearly the same as driving to a hospital in the same city. We see this in the decision of whether to move neonates internally or seek receiving hospitals (20). For longer distances, driving three hours increases the risk of adverse events, including hypothermia in a neonate and death (17).

Time. Seeking receiving facilities and the medical handover of complex patients can occupy significant time for the Neonatologist. In some cases, internal evacuation reduced this load (20, 27). We can appreciate transport time in several ways – the actual transport, loss of bedside staff, and complete evacuation. Transport time within a hospital or to an adjacent building was often 40 minutes or more (20, 27). Internal, controlled evacuations occupy 3-7 people for each infant. The time away from bedside care is doubled for preparation and return to the NICU (20, 27). When evacuating infants out of the region, flight times of 40 minutes (32) or driving times of several hours (17) are to be expected.

Bed availability. Most receiving NICUs accepted 2-4 neonates, while a few could accommodate more. The acuity level of the infant affects bed availability. The placement of neonates receiving HFO, mechanical ventilation, and CPAP is a problem. One solution was to change the mode of respiratory support from HFO to conventional ventilation or decrease the classification for oxygen administration to 'infant status' (20).

- Preparatory discussions can identify methods to make neonates more accommodating for transfer, such as reducing the support level to create emergency early discharge criteria.

Adult standards.

The uncontrolled environment can rapidly change neonatal physiology. The environment then becomes an independent pathology, increasing neonatal mortality and reducing neonatal survivability. Unfortunately, triage systems in use during disasters derive from

adult pathology and physiology (17), creating a gap in understanding by disaster professionals for supporting the NICU.

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Government agencies.

Constrained use of helicopters and ambulances in two earthquake disasters demonstrate government control of transportation resources (32, 35). Government agencies generally coordinate activity and control out-of-area resource allocation during a disaster. Transportation vehicles are resources controlled by these agencies. Hospitals with a previous contract for transportation vehicles may be exempt from this control.

- Preparatory discussions can educate Neonatologists about the duties and responsibilities of disaster agencies and agencies at federal, state/provincial, county, and municipality levels of government.

In the experience of NICUs in different countries, government agencies do not reliably support NICUs during a disaster (17, 32). In several wildland fire disasters, Neonatologists contacted receiving NICUs, and administrators coordinated transportation for the neonates. They did not have government regional coordination (21). During recovery from a hurricane, contacting NICUs was local to pre-existing personal relationships.

- Preparatory discussions can develop relations between NICUs that may transfer or receive neonates during a large disaster.

Infrastructure of Disaster

A disaster brings together diverse infrastructures, but they are infrastructures of organizations and disciplines accustomed to collaborating. When viewed as relations, infrastructure builds a community. New for NICU sheltering or evacuation are the types of organizations and infrastructures they utilize. For example, air transport will be controlled by a central government agency, and FAA rules and procedures will become more visible.

More commonly identified as shared organizational, physical structures for the operations of organizations, infrastructures may better be understood by how society uses the infrastructure. This "inverted" approach demonstrates that infrastructure emerges for people in practice and is connected to activities and structures. The organization uses infrastructure as a set of techniques and classification systems to apply science and technology for operations, problem-solving, and connecting people in practice to activities and structures. Infrastructure is the invisible glue that holds the system together (36). Understanding the change in infrastructure brought on by a disaster brings better integration of medical care into disaster operations. An adverse, hostile, and austere environment will compromise effective and efficient healthcare without such integration.

Neonatologists operating in the NICU focus on reducing *mortality and death due to disease*. A disaster brings death from physiological, physical, social, or behavioral threats within the disaster environment. This functional and ecological definition directs our attention to the abrupt change in the NICU environment. No longer does the Neonatologist control the environment around the infant. *Survivability is the reduction of death after the event.* Survivability describes the effect of the environment on mortality as a comorbidity or the impedance connecting necessary medical care to the victim (34). Our goal in the NICU is survivability, preventing deaths resulting from post-disaster events.

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Translating the risks that extended travel poses to a premature infant is problematic for various reasons, but it can be reduced by understanding the various missions in a disaster and the use of 'boundary objects' (29, 37, 38). Description of the consequences, including *how* death could occur, and accurately describing what is necessary to prevent death, along with private anecdotes, can facilitate collaborative action by making it a common problem (39).

Boundary Objects

'Boundary objects' facilitate communication across disciplines and organizations while operating in a new boundary infrastructure. Boundary objects are ambiguous yet constant objects shared by adjacent categories, allowing their use by several communities of practice. Boundary objects facilitate local understanding by reframing the object into a broader context of joint activity. Boundary objects contribute to cooperation and communication across borders, often without the need for different groups to communicate, and can help manage the tension between divergent viewpoints (37, 38).

Government agencies focus on survivability and the reduction of death *after* the event. Survivability describes the effect of the environment on mortality as a comorbidity or to impede connecting necessary medical care to the victim (34). Neonatologists focus on reducing mortality and death *due to disease*. Death, then, becomes an effective boundary object for communication.

Structured Lessons Learned

A Lesson Learned must have *significance*, *validity*, and *applicability* and *reduce potential failures*. Significance comes from its usefulness in influencing everyday operations. It gains validity in that it is factually and technically correct. Applicability identifies a specific process to address. Reducing or eliminating the potential for failures or reinforcing a positive result is the purpose of a Lesson Learned (5).

Functions of a Lessons Learned Capability

While the military describes six basic functions of a Lessons Learned program (Collect, Analyze, Share, Archive, Resolve, and Assess), we find three elements will help healthcare professionals better understand Lessons Learned: Analysis of observed data, Corrective actions/recommendations, and the Process of Lessons Learned.

Analysis of observed data. Different perspectives bring a better understanding of the data collected from a complex event such as a disaster. By appreciating different perspectives, we discover what happened and why it happened (5).

A disaster is a product of pink noise; therefore, the Gaussian distribution does not apply. More data increases variance, confounding the ability to generate conclusions. Decomposing the disaster to different segments does not support using the Gaussian distribution for statistics and probabilities. The inability to combine different probability distributions into a joint probability distribution is known as *contextuality* in quantum theory (40).

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The effect of sequence is significant in red or pink noise environments. *When* an action occurs has a significant effect on the outcome, making some assumptions or questions incompatible. This is not unsurmountable as incompatible questions provide different perspectives of an event, perspectives we need to understand the world (40).

It is relevant for us to know a person's understanding of two events in sequence. This could be understanding the beliefs or experiences of two different people working together in the same situation or the individual processing two different perspectives of the same matter. We must switch between points of view, which may not be compatible. We cannot process both perspectives simultaneously. We cannot decide a matter from more than one perspective – to decide from one perspective you are making your cognitive state dispersed (making indefinite) for the other (40).

In addition to different perspectives, a practical Lessons Learned program consults subject matter experts, deference to expertise in an HRO. Integrating Neonatology with other sciences will also advance Neonatology, extending the field into the disaster space while improving collaboration and improving care of the neonate. William Harvey, the English physician who first described the complete systemic circulatory system and the heart as its pump, believed that "the best fertilizer for medicine is the progress of other and quite different sciences" (41).

The analysis is incomplete when viewed through constrained perspectives. Having medical, nursing, allied health, and administrative perspectives is not enough. A common problem was the use of helicopters – the NICU is accustomed to calling for helicopters to transport the neonate, while the disaster infrastructure uses helicopters for disaster survey, rescue, and delivery of vital supplies. The NICU will not integrate into the disaster infrastructure without an appreciation of the perspectives of FAA regulations, air traffic controllers, the duties of the disaster Incident Commander, and the professionalism of pilots.

"Government agencies focus on survivability and the reduction of death after the event. Survivability describes the effect of the environment on mortality as a comorbidity or to impede connecting necessary medical care to the victim (34). Neonatologists focus on reducing mortality and death due to disease. Death, then, becomes an effective boundary object for communication."

Corrective actions/recommendations. We now organize the results of the analysis and develop recommendations. With diverse perspectives and a requisite diversity of experts, the recommendations should be intuitive. We should say what needs to be done(5).

The Process of Lessons Learned. A Lesson Learned uses knowledge acquired after an adverse experience, processes the experience, and then provides actionable recommendations causing the organization to improve. The intent is to reduce or eliminate the potential for failures or to reinforce a positive outcome. The analysis discovers what happened and why it happened. Incorporating knowledge from outside subject matter experts supports a better, effective understanding of data acquired from the disaster. Ideally, informed recommendations become intuitive, making them more readily incorporated into the organization's culture (5).

Conclusion

The intent of a Lesson Learned is to reduce or eliminate the potential for failures or to reinforce a positive outcome. This standard limited the use of published experience describing effective adherence to normative standards. In those articles, we could not identify *how* the adherence was achieved nor *how* that adherence improved disaster response. Lessons that support normative standards readily become a concept, an abstraction, something that has not, and cannot, be contextualized. Such lessons risk "conceptual arrest" (42), acceptance of concepts independent of the ability to use the concepts as contextual actions.

Creation of Lessons Learned from outside events, the spectator-observer view, relies on causation, precision, definitions, and diagnostic testing. The spectator sees no details, feels no experi-

ence, readily drawing on abstract specifications.

- Spectators outside operations focus on what they already know.
- Operators within operations focus on context and what they can learn.

Within events, the operator is pulled by the flow of local evens not visible to spectators. From these intense experiences come the vibrant published descriptions we found informative for Lessons Learned. These informed recommendations are more readily incorporated into the organization's culture (5).

We distinguished Problems Encountered from Lessons Learned in the published experienced. The published Lessons Learned did not have commentary from Subject Matter Experts nor did the use the formal structure found in military Lessons Learned. We identified Problems Encountered hidden within the articles. For the most part, the authors did nor recognize the situations as problems because the authors solved the problem. Or the authors did not recognize their solutions or the science supporting their work.

"In addition to different perspectives, a practical Lessons Learned program consults subject matter experts, deference to expertise in an HRO. Integrating Neonatology with other sciences will also advance Neonatology, extending the field into the disaster space while improving collaboration and improving care of the neonate. "

These articles brought out the debilitating physical nature of the disaster environment. They described the quandary and confusion of staff figuring out how to do their job and what to do for their families. They captured the difficulty of evacuate-or-shelter decisions and the ambiguity of information. Most significant is the *value* of information: *Does* it help or hurt the neonate? *Will* it help or hurt the neonate?

"Within events, the operator is pulled by the flow of local evens not visible to spectators. From these intense experiences come the vibrant published descriptions we found informative for Lessons Learned. These informed recommendations are more readily incorporated into the organization's culture (5)."

However, the most vital lesson from these articles is the performance of staff solving problems at the bedside. Their problems, concerns, actions, and improvisations are not found in the literature from experts. Their articles have kept their voices from becoming hidden.

Better questions for disaster response planning and research: How do we learn from the richness of their experience? Why aren't we reasoning and thinking how they reasoned and thought? Why aren't we treating each other every day like they treated each other?

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