Advanced Technology and High Sensibility in Providing Safe Neonatal Care in Intensive Care Units

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Education Gaps

Clinicians need to recognize that the main causes of medical errors are related to complex systems and human fallibility. However, providers have alternatives to avoid errors, by creating better coordinated systems, improving reliability, and granting special attention to human factors engineering.

Abstract

Possibly no other field of medicine has undergone such dramatic progress in reducing mortality and morbidity as the care of preterm newborns. In recent years, remarkable advances in the care of pregnant women and their children have led to an increase in infant survival. However, advances in neonatal care need to be accompanied by mechanisms that help us deliver care safely to this most vulnerable population.

Objectives   After completing this article, readers should be able to:

1. Recognize that patient safety is a top priority in medicine.

2. Review reasons for the occurrence of errors in the NICU and describe strategies to prevent these errors.

3. Explain the importance of individualized developmental care and assessment in the NICU.

4. Describe how to educate future leaders about patient safety.

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PATIENT SAFETY: THE MORAL COMPASS

As defined by Sir Liam Donaldson, envoy of the World Health Organization (WHO), safe patient care involves performing the right action for the right person at the right time and in the right place, and avoiding adverse events. Adverse outcomes are outcomes that occur as a result of actions (or lack of actions) by the medical team rather than due to patient illness. As stated by Sir Liam Donaldson: *"To err is human, to cover up is unforgivable, and to fail to learn is inexcusable."*

The technical skills and complexity of medical practice have grown significantly over the years; however, these same technologies, medications, and life saving surgeries can potentially cause harm to patients, and the next generation of health-care providers should be taught how to prevent injury. (1)(2) Physicians rely on the support of medical care systems (which are often very complex) to enable them to carry out their tasks. However, errors can occur during each stage of patient care.

Harm to patients is not absolutely unavoidable, but can and must be prevented. Therefore, measures to promote patient safety are crucial. To achieve this goal, systems, institutions, physicians, and other allied health-care personnel must learn from past errors and learn how to avoid them in the future. Clinicians have to adapt their work flow to achieve safe health care, which should be a fundamental and achievable goal.

People who work in health care are privileged to be in a field that cares for human beings, reduces suffering, and saves lives. This care does not always produce results according to the plan, and sometimes causes suffering, impairments, and/or deaths. Medical errors can result in injury to patients, which are both physical and psychological, and can unfortunately be lifelong in some instances. Not all "costs" can be quantified; in addition to the financial costs, medical errors have an important cost in terms of loss of confidence in the medical system, decrease in patient satisfaction, and potential physician dissatisfaction with their professional work. The difficulties in managing and implementing health-care systems also contribute to suboptimal conditions for the development of safety programs, and sometimes become a hindrance in developing safe medical practices.

It is important to determine the causes of adverse events as well as potential methods of reducing their occurrence by performing a root cause analysis. As defined by the Institute of Safe Medication Practices Canada, a root cause analysis is "a systematic process of investigating a critical incident or an adverse outcome to determine the multiple, underlying contributing factors. The analysis focuses on identifying the latent conditions that underlie variation in performance and, if applicable, developing recommendations for improvements to decrease the likelihood of a similar incident in the future." (3) The State Claims Agency suggests that this analysis "can provide a retrospective review of a patient safety incident to identify what, how, and why it happened. The analysis is then used to identify areas for change, recommendations, and sustainable solutions to help [minimize the recurrence] of the incident type in the future." (4)

As Dr Frank Morris emphasizes (5), adverse medical events are not uncommon during the care of preterm infants in the NICU. It is important to determine the causes of these events, as well as identify potential methods to reduce their occurrence. Both human fallibility as well as the complex organization of the medical system in the NICU are major contributors of errors related to attention. Preterm newborns in the NICU are especially fragile and are subject to multiple interventions.

The environment in the NICU is often chaotic, with multiple admissions, often unscheduled, of unstable patients. Health-care clinicians in NICUs, therefore, face multiple urgent problems at the same time, and their tasks are frequently interrupted. Intensive care must be performed accurately throughout the day; thus, it is essential that the hand off of each newborn's care from one team to the next be accurate and strictly controlled. Each shift change is an occasion that can give rise to errors due to a failure to implement planned actions. Simplifying steps during clinical practice and thereby decreasing the need for problem-solving can potentially decrease the chance of errors. Streamlining can include decreasing the need for multiple steps of data entry.

Injury suffered by preterm infants is sometimes not as evident as that noted in older children or adult patients. One of the most common adverse events associated with preterm infants are nosocomial infections, but complications related to intravascular catheters and accidental extubations also occur. Indirect hyperbilirubinemia is an extremely frequent issue in the premature infant and it is important to manage this complication in a timely manner. (6) Preventable adverse events as a result of errors associated with the indication for medications as well as actual medication administration are also observed in the NICU setting.

Dr Frank Morris also suggests that most medical errors occur because humans simply cannot perform all expected tasks perfectly at all times. (5) Research estimates that humans have a short period of immediate memory for only 7 items, that the minimum attainable rate for default errors is 1 per 100 tasks, and that the minimum attainable rate for errors per commission is 3 per 1,000 tasks. Multiplying the number of tasks required for the care of a preterm newborn hospitalized for several months in the NICU by those error rates and then by the number of patients in the NICU during that time gives us an estimate of probable errors over that period. This total will very quickly reach a very high number of errors, many of which have the potential to harm a patient.

PREVENTION OF MEDICAL ERRORS

WHO states that to prevent errors in medicine, basic strategies must be pursued: (7)

- Providers must identify human behavioral factors responsible for errors, and redesign the work flow in NICUs to minimize errors.
- Providers must designate and employ reliable systems that prevent errors or block them before they reach the patient.

In practice, there is a critical and repeated interaction between these strategies. In addition, information technology specialists can design systems to avoid human error, such as software systems for medication order entry and indications for medication use. However, these specialists must also observe how prescribers actually use or misuse the system to identify new opportunities for error that are inadvertently created. Process reliability can be improved by decreasing the number of consecutive steps or by increasing the reliability of individual steps. Dr Frank Morris also emphasizes (5) that high-reliability organizations are characterized as those that exhibit a state of mindfulness about potential error and are constantly concerned about:

- Identifying errors
- Dedicating time to observe workers performing tasks
- Training workers to perform skills using the best approaches
- Enabling workers to identify and solve problems

In October 1846, after women in a maternity hospital died despite receiving care from physicians, Dr Ignaz Semmelweis thought that the cause of the deaths could be related to the hands of physicians who came to the hospital after working in the morgues. Based on this hypothesis, he decided to implement a handwashing lavatory for physicians for the first time in medical history. Initially, his idea was criticized, but after some years, it was officially implemented.

Proper handwashing is, and must be emphasized as, the most important action (in spite of being a very old proposal) for decreasing nosocomial infections in the NICU. Proper handwashing must be practiced consistently and with the same technique by all team members, as the pioneer Dr Semmelweis tried to implement more than 150 years ago.

MEDICATION ERRORS

The WHO publication "Medication without harm: third global patient safety challenge" summarizes that "unsafe medication practices and medication errors are a leading cause of avoidable harm in health-care systems across the world. Medication errors occur when weak medication systems and/or human factors (such as fatigue, poor environmental conditions, or staff shortages) affect prescribing, transcribing, dispensing, administration, and monitoring practices. These errors can then result in severe harm, disability, and even death. Although errors occur most frequently during administration, there are risks at different stages of the medication process." (8) WHO provides a list of several types of medication errors. (9)

Types of Errors

- Dosage problems or incorrect dosage
- Prescription errors
- Missing or incorrect weight
- Prescribing policies not followed
- Medication omissions
- Absent or wrong prescription date
- Drug/drug interaction; medication given to known allergic patient; medication duplication

The process of administering a medication is a complex one that involves a system with many sequential steps developed by multiple people, and each step is subject to human error. Hospitals must focus their attention on information technology systems, but also on the human factors that are involved. The following list provides recommendations for avoiding errors related to medication administration:

- Standard concentrations for infusion
- Order sets or preprinted orders
- Avoidance of the use of dangerous abbreviations
- "TALLman" lettering for drugs that have lookalike names to call attention to the critical differences
- Removal of certain high-alert drugs from "ward stock" and requiring dispensing only by the pharmacy
- Restriction of verbal orders to emergency situations
- Requirement for double-checking by a second professional at each step of the medication process
- Special color-coded labels for high-alert medications
- Storage of high-alert medications separately from other drugs in each location where drugs are stored, including the NICU
- Labels on infusion pumps that list the name of a high-alert drug being infused
- Requirement for handoff verification checks from one caregiver to the next for a patient receiving a high-alert drug infusion (5)

VENTILATION STRATEGIES

The main objective of having different ventilation strategies is to achieve the least degree of lung injury while achieving

adequate lung function. It is, however, difficult to assess the superiority of any specific ventilation strategy over others. If neonatologists use specific ventilation strategies and/or ventilators with which they are not familiar, this can lead to increased errors, with subsequent higher risk of pulmonary injury. A weakness of current studies is the difficulty of evaluating and comparing the ability of the operators in using different strategies of respiratory assistance. Promoting research in this area is necessary to determine the best ventilator strategies, with less possibility of errors in its application by different operators. (8) (9)(10)

FATIGUE AND HUMAN ERROR

Fatigue is an important aspect of human fallibility that contributes to the occurrence of adverse events. The probability of an error increases with clinician fatigue and decreases when the clinician has an opportunity to rest. Parshuram (11) has described 4 sources of fatigue in healthcare staff:

- Acute sleep deprivation
- Accumulated sleep debt
- Work overload and physical exhaustion
- Circadian rhythm disruption

Clinician fatigue leads to a decrease in performance and an increase in the risk of error and adverse events. Dawson and Reid (12) compared the psychomotor cognitive performance of 40 individuals under 2 separate conditions: 1) staying awake for 28 hours, and 2) drinking alcohol at intervals until the blood alcohol concentration reached 0.10%. Using a computer-assisted eye-hand coordination test at 30-minute intervals, the researchers plotted the performance decline on the test as a percentage of the initial performance in each condition. Similar decreases in performance were observed after sustained wakefulness and ingestion of alcohol.

After 17 hours of sustained waking, the performance was equivalent to that demonstrated by a person who had a blood alcohol concentration of 0.05%; after 24 hours of waking, the cognitive psychomotor performance was similar to that observed when the concentration of alcohol in the blood was 0.10% (an individual impaired by alcohol to this degree would not be allowed to operate a motor vehicle, but is allowed to care for a patient). A meta-analysis of 60 studies concluded that lack of sleep reduced overall physician performance by more than 1 standard deviation and significantly increased error rates.

STRESS AND PERFORMANCE

Psychologists Robert Yerkes and John Dodson created the inverted-U model (also called the *Yerkes-Dodson law*) in 1908. (13) This model shows the relationship between stress and performance (Fig). Based on this model, maximal performance is obtained when people experience a moderate level of stress. If people have a task associated with minimal stress, they are often bored and have no incentive to put more effort into the task, leading to a decline in performance (left side of the graph). However, extremely high stress (right side of the graph) can be associated with high anxiety, which is associated with poor performance. Ideally, if the task is associated with a midlevel stress, the performance is optimal (middle of the graph).

FAILURE IN COMMUNICATION

Shortening physician work hours to reduce the risk of error in a NICU requires a greater number of physicians and more frequent physician shifts, resulting in an increased number of handoffs. Streitenberger and collaborators (14) recommend the following strategies to improve the quality and accuracy of information provided during handoffs:

- Standardize and simplify the process using a checklist
- Avoid/minimize interruptions
- Limit the use of intermediate persons performing the handoffs
- Use a common communication style
- Implement a restating/relistening process
- Maintain patient-centered communication

Figure. The inverted-U model showing the relationship between stress and performance. Reprinted with permission from Yerkes RM, Dodson JD. The relation of strength of stimulus to rapidity of habit-formation. *J Comparative Neurol Psychol.* 1908;18:459–482

Another approach for establishing safer medical communication is described in detail by Catchpole and colleagues. (15) To improve handoffs by the surgical team to the ICU staff after cardiac surgery in infants, this group adapted the methodology of the support team in the pit stop of Formula 1 cars and aviation models. The researchers visited a Formula 1 team to observe pit-stop practice sessions and then developed new handoff practices for anesthetists, surgeons, intensivists, and nurses by incorporating safety measures learned from the work of the pit-stop crew. These included:

- Leadership in conducting the practice
- Planning according to special requirements
- Definition of sequence of tasks
- Assignment of tasks according to team skills
- Discipline in the execution of tasks
- Checklists of testing

The investigators reported reductions in technical errors, information failures, and time required to perform tasks.

INDIVIDUALIZED DEVELOPMENTAL CARE AND ASSESSMENT

Better understanding of the role of early sensory experience and environmental influences leads to a new goal in NICUs, which is the survival of infants without disabilities while also preserving their full potential. Attention must focus on the role of chronic stress of infants receiving intensive care. Repetitive painful procedures as well as early experiences of overstimulation or inadequate stimulation during early life can alter the programming of the hypothalamic hypophyseal adrenal axis, thus increasing the risk of developing cardiovascular disease, hypertension, and glucose intolerance later in life.

Individualized developmental care, as proposed by Heidelise Als, (16) is based on the infant's degree of maturity, and aims at reducing stress and promoting physiologic stability in preterm infants. The most important interventions to reinforce positive outcomes must be those that not only have immediate direct effects, but continue to have an impact even after discharge. Stimulation of the interaction between a mother and her child and the mother-child bond in the early stages of life likely has long-term effects. It is unlikely that a single intervention, though effective, will achieve the well-being of preterm newborns and their families, because health difficulties in these infants are multifactorial, as suggested by Als. (16) The design of future studies must account for all of these factors to obtain real and convincing evidence about the benefits of specific therapies.

The medical actions that lead to actual advances must be programmed according to the contemporary sociocultural context, and guided by moral and ethical principles from which clinicians must never depart. In del Salvador University, Buenos Aires, Argentina, I spearheaded a Special Prevention and Anticipatory Program called "An Invitation to Life," which is based on educating parents and expectant parents. (17) This program provides families and pediatric health-care professionals with a summary of recent advances in science, how to see the world through the eyes of children, and how childhood memories persist and could diminish or increase stress levels. This program encourages and leads parents and pediatric health-care clinicians to modify their goals and try to optimize results.

Clinicians in NICUs have the remarkable opportunity of participating in the dream of a new beginning alongside parents of premature infants, accompanying families to find a new perspective in their lives, to increase their self-esteem, and to have faith in their own strength. (18) The philosophy of any parenting program for premature infants should be based on the belief that physicians do not always know what parents need. Rather, physicians should humbly listen to parents, creating a climate where parents truly *feel* that clinicians are interested in them as people and not as numbers, and that their emotions and feelings are important. This will enable parents to willingly share their feelings (stresses, frustrations, and joys) and needs with clinicians so that families can receive appropriate help and support. Clinicians need to learn what families really feel, what families do NOT want clinicians to do, as well as what they are hoping clinicians would have *done* but never did. (17) Actions to promote human values include the following (1)(2):

- Actively encourage parents of preterm newborns and medical staff to share information
- Show empathy, honesty, and respect
- Communicate clearly and precisely
- Develop the ability to listen permanently
- Obtain informed consent for clinician actions
- Show respect for each patient's differences
- Pay attention to the patients' perceptions of reality and their individual needs
- Invite parents to discuss details and meet their gaze
- Explore emotions and deliver empathy
- Coordinate these steps to follow with parents and their family

This approach can lead to several benefits including, as noted by WHO: "Patients who know what to expect can help identify potential incidents before they occur. Telling a

patient story can allow reflections that are not based on statistical reports."(7)

Responding to patient safety incidents is an ethical and moral imperative for physicians and other health-care professionals. The appropriate response to a patient safety incident and/or medical error is not easy, but must include a blame-free environment and the corrective action must be incorporated into routine medical care. Emphasizing a policy of permanent transparency is an important goal for medicine. Furthermore, the ability to learn quickly from mistakes, respond appropriately, and modify practices based on research to improve safety and quality in the care of patients is critical. The culture of safety must clearly replace the old culture of guilt, which only engenders shame and walls of silence. (18)

THE SEVEN PILLARS

The University of Illinois has outlined the guiding principles for behaviors that foster safe care of patients. This approach is called the "Seven Pillars" (19) and is an excellent tool to implement a safe and just culture in medicine; it consists of the following:

1. Report of incidents
2. Investigation
3. Communication and information
4. Apologies and repair
5. Improvements in the system
6. Data tracking
7. Education and training

Working as a team means that individual needs must conform with those of the group, resulting in a positive emotional balance. In addition, clinicians must learn how to substitute roles and to appreciate the perspectives of others.

EDUCATING FUTURE LEADERS ABOUT PATIENT SAFETY

Students/trainees in the health science field are extremely vulnerable during the first years of their learning period. If the concepts of patient safety outlined in this review are introduced early, the culture of patient safety can improve dramatically. The WHO multiprofessional medical school curriculum (2) is an important step forward to assist with this approach. However, this is not the only priority. At present, hospital systems are sometimes poorly designed to prevent and/or manage medical errors. We must consider some proactive strategies to help the next generation of clinicians be prepared, some of which are highlighted below:

- Motivation: Help students realize that they are a critical part of instituting a culture shift in patient safety
- Positive attitude: Encourage students to apply the best of the old system in addition to creating new processes
- Anticipation of slow changes: Implementing new approaches and innovations is often associated with an initial period of uncertainty and doubt but it is important to persist toward the goal
- Focus on both the microsystem and macrosystem: This bilevel approach is critical for effective and sustaining change

Clinicians need to recognize early in their career that while advances such as new drugs and new technology can help to provide more effective care, reducing the risk of adverse events is the most important action to improve patient safety. While human mistakes may be impossible to eliminate completely, students need to be taught that prevention of errors is a priority. An important guiding principle for students and trainees is that patient safety involves doing the right thing, based on evidence, in the right moment, for the right person, and honestly learning from mistakes and permanently stimulating proactive approaches. Patient safety is the responsibility of all clinicians with different degrees of responsibility, who together should develop strategies that lead to improvements. To progress, safety needs to rely on human factors engineering and systems, as well as incorporate strategies from other disciplines such as aviation and nuclear medicine. It is a top priority to maintain a balance between high technology and high sensibility when providing medical care.

At our Institute of Safety and Quality in Health Sciences at del Salvador University, Argentina, we initiated connections with other disciplines in health care to implement teaching and learning activities focused on understanding how teamwork is effective and organized appropriately. In the School of Medicine, we have developed an official program of patient safety for medical students, which lasts from the first to the last year of their curricula, with a pedagogical design based on the WHO patient safety curriculum guide. The goal is to create future leaders on safety by introducing this young audience to realistic scenarios.

As noted by Sir Liam Donaldson during his presentations: "Years after the Institute of Medicine report we are still struggling as a global community [about] how to explain to patients and families if health care is safe." This is because it is difficult to measure baseline patient safety and quantify improvements. Fortunately, the field of patient safety is maturing. Proof of this is that students are being trained in safety; clinicians and researchers are designing

interventions; health-care systems are implementing programs; regulators are evaluating practices; governments are launching national agencies, and the WHO is implementing safety projects with international partners. Collectively, this is a significant effort, but there is limited evidence that patient safety results have improved. We have learned that there are no quick solutions.

Looking ahead, we need to define scores with valid measurements guided by science and make a commitment to work together. We must teach clinicians how to standardize data collection with strict quality control, and it is essential to collect data in multiple sites. The challenge that health-care systems face is to ensure that patient safety is at the heart of how we think, how we work, and how we educate so that it is deeply incorporated into medical organizations.

CONCLUSION

"It may be part of human nature to err, but it must also be part of human nature to create solutions, find better alternatives and face the challenges ahead." [20]

Great progress has been made in neonatal care, but the health-care system must do much more. Clinicians must consider a priority those changes that, because of their efficiency, have long-term relevance and are applicable anywhere in the world without any limitations. The health-care system faces a great challenge, the era of reflection between real progress and innovations (ie, what we are doing and what we should actually do). This new paradigm needs to be adopted universally.

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- Know the issues in the organization of perinatal care (eg, regionalization, transport, practice guidelines, benchmarking data, quality improvement).

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