

Determining pediatric intensive care unit quality indicators for measuring pediatric intensive care unit safety

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Introduction: The measurement of quality and patient safety continues to gain increasing importance, as these measures are used for both healthcare improvement and accountability. Pediatric care, particularly that provided in pediatric intensive care units, is sufficiently different from adult care that specific metrics are required.

Body: Pediatric critical care requires specific measures for both quality and safety. Factors that may affect measures are identified, including data sources, risk adjustment, intended use, reliability, validity, and the usability of measures. The 18-month

process to develop seven pediatric critical care measures proposed for national use is described. Specific patient safety metrics that can be applied to pediatric intensive care units include error-, injury-, and risk-based approaches.

Conclusion: Measurement of pediatric critical care quality and safety will likely continue to evolve. Opportunities exist for intensivists to contribute and lead in the development and refinement of measures. (*Pediatr Crit Care Med* 2007; 8[Suppl.]:S3–S10)

KEY WORDS: medical errors; patient safety metrics; pediatric intensive care unit; quality; safety

Although the issue of quality in health care is not new, the focus on quality measurement has heightened with increased public reporting, information about preventable medical harm, and the “pay for performance” movement (1–3). The Institute of Medicine’s two reports, *To Err Is Human: Building a Safer Health System* (4) and *Crossing the Quality Chasm* (5), reframed the definition of healthcare quality to explicitly include patient safety. As a result, measures of quality have expanded to include measures of patient safety in healthcare settings. For instance, the Leapfrog Group’s initial three measures for hospital quality focused on measures intended to represent the safety of patients (6).

As is true of other aspects of health care, quality and safety measures that apply to

adult populations may not be appropriate for application to pediatric settings. One illustration of the inappropriateness of adult quality measures for children is the Agency for Healthcare Research and Quality’s Patient Safety Indicators. This tool is intended to identify potential safety issues by using administrative data. Two studies have demonstrated that an early iteration of the Patient Safety Indicators tool (v.2, r.1) included measures that were inappropriate for use in pediatrics either because of false-positive screening, lack of preventability, or incorrect inclusion and exclusion criteria to ensure evaluation of a correct population (7, 8).

Similar to safety-critical industries such as aviation, nuclear power, and the military, the high-intensity, high-stress environments within health care are more susceptible to medical error. Most frequently cited areas include the intensive care unit, operating room, and emergency department (9). Furthermore, patients in the critical care setting exhibit a greater vulnerability to human error secondary to multifaceted medical problems, an increased severity of illness, and requirement for more frequent intervention (4, 10–12). In addition, errors are most likely to occur in environments in which processes are tightly coupled and in which the interaction among system components is often unseen by the healthcare provider (13).

Pediatric critical care medicine is unique because of the heterogeneity of critically ill patients based on age, size, diagnoses, and treatment modalities, including type and dosing range of medications. These same factors, combined with the complexity of pediatric intensive care unit (PICU) healthcare processes, result in a system that is potentially dangerous. Thus, identification of both real and potential sources of harm to patients or of poor care quality is crucial to ensuring safe care in PICUs. To this end, this article describes specific quality and safety metrics that may be of value to pediatric critical care providers and their administrative counterparts.

Issues to Consider in Identifying Quality and Safety Measures

Data Sources. Understanding the availability and limitations of data is central to the development of robust quality measures. Presently, administrative databases and clinical databases are the main sources of data used to generate quality metrics. Administrative data are generally created for reimbursement processes and are attractive for use because these data are often readily available at minimal cost. However, these same data sets have limitations, including coding inaccuracies, variation in coding both between individual coders and different institutions, limitations in the ability to adjust

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for risk, and challenges associated with capturing a chronic illness that caused an acute medical problem (14–16).

Clinical databases, on the other hand, may offer a greater level of reliability and detail. Potential sources of clinical data for use with quality measures include medical record data and clinical research databases. However, the abstraction of data from the medical record is costly and time consuming. Clinical research databases are often maintained well and provide reliable data, although they may be limited in accessibility for quality and safety use, they may only contain certain data elements, and they are prone to limitations in the longevity of the data.

In the event that the above databases cannot generate the required data elements to track a particular measure, then primary data will need to be collected. Primary data are usually prospectively collected clinical data, which are obtained solely for the purpose of quality measurement (17). These data are the most specific and have the opportunity to be explicitly audited to ensure validity and reliability, but accordingly, they are the most expensive to collect and maintain. Well-developed primary data systems can be structured in such a way that data are collected during the daily routine of care and captured in standardized documentation collection tools. It has been noted by several authors that this may be the most complete method to track process measures and decrease missing data (17).

Risk Adjustment. A recurring complaint of quality metrics has been the inability to accurately compare across different hospitals due to the unique nature of patients seen in different institutions. Larger centers have traditionally thought that their mortality, length of stay, and other such measures are not comparable with smaller facilities due to their patients' presumed increased severity of illness. Risk adjustment is a methodology that attempts to account for severity of illness and case mix and allow valid comparisons between institutions. Several risk-adjustment models, for both adult and pediatric patients, have been developed to account for mortality differences and differences in the utilization and intensity of care. The Pediatric Risk of Mortality Score III (PRISM-III) and Pediatric Index of Mortality 2 (PIM2) are the two most commonly utilized severity-of-illness adjusted mortality scores in pediatrics (18, 19). Both scores predict mor-

ality by adjusting for severity of illness through physiologically based criteria. Institutions are able to determine their standardized mortality ratio, which is a ratio of observed to predicted mortality, to allow for comparisons between different PICUs (20).

In addition to mortality adjustment, the case mix of a patient population may be obtained through the All Patient–Refined Diagnosis Related Groups (APR-DRG). These groups are derived from 316 base APR-DRGs, to which severity of illness and risk of mortality subclasses are added to arrive at the more comprehensive APR-DRGs (21).

Intended Use and Framework. Donabedian's (22) classic framework of health-care measures includes categories of structure, process, and outcome. Another approach to classifying quality measures is by their intended use. Based on this approach, measures can be for improvement or accountability. Improvement measures may not be sufficiently valid and reliable for public dissemination yet still be useful for benchmarking to identify best practice or as part of quality improvement initiatives. Measures intended to advance provider and patient/family knowledge may also be placed in the improvement category. In contrast, accountability measures are metrics used for purposes that include credentialing of organizations or providers, public reporting, contracting, or pay-for-performance. Quality measures should evolve from the Institute of Medicine's well-publicized quality aims of timeliness, efficiency, effectiveness, safety, equity, and patient-centeredness (5). The framework for applying these quality aims to pediatric critical care was recently developed by Slonim and Pollack (23) and forms a backbone for the development of quality measures.

Reliability. The reliability of a measurement system relates to its ability to perform similarly under stated conditions for a period of time. In health care and in the social sciences, reliability is often used to describe the concept of precision. Precision is the degree of agreement among independent measurements of a quantity under specified conditions. Precision refers to the ability of a measurement process to reproduce its own outcome. Precision is usually defined in terms of the criteria for repeatability and reproducibility. To achieve precision, a reliable system requires clear and concise definitions of the data fields to be collected, an effective approach to train data

collectors, and a robust method for data coding and entry (20). In addition, the reliability of a system needs to be intermittently assessed within or between observers over time to ensure consistency.

Validity. The concept of validity refers to the range of inferences that are suitable when evaluating the attribute of interest from a measurement system (24). A measure is considered to be valid if it can be used to distinguish between good and bad quality and if the measure adequately represents the attribute of interest (25). Validity can be thought of and evaluated in several ways and is difficult to accomplish. Internal validity refers to the soundness of the developed indicator and can be determined utilizing the techniques of data splitting, cross-validation, or bootstrapping (20, p. 68). External validity refers to the ability of the indicator to be applied to a broader population. Criterion validity refers to the ability of the proposed measure to accurately reflect the outcome of interest and is frequently validated with statistical analyses by comparing the measure with an accepted standard. Finally, content validity refers to the simple ability of the measure to seem to be related to the outcome of interest.

Usability. The intended audience for a given measure must be able to grasp the findings of the measure and utilize it in an appropriate fashion. A usable measure is compelling to the user, subject to statistical validation, and able to uncover meaningful differences between groups and present results consistent with the intended use (25). A compelling measure may be factored into the decision of consumers, purchasers, physicians, regulators, and health systems. Statistical validation is important to understand that any changes, both over time and between organizations, reflect real differences. However, it is equally important to be mindful of changes that have practical significance to the user and may warrant a change in practice. The requirements of the manner of measure presentation will vary by the intended audience and should facilitate decision making and conclusion reaching by its intended target.

Feasibility. The method in which measures are to be obtained must be feasible. Information that is routinely obtained on the front lines that can then be used for quality measurement readily passes the feasibility test. Other methods of obtaining information may similarly be feasible, but feasibility should be assessed during

measure development and then reassessed at intervals as the measure's use broadens. Practically speaking, if a group of providers commit the majority of their time and resources to simply collecting data for quality and safety measures, then it is unclear whether any of the work will result in actual improvement of PICU safety and quality.

Proposed National PICU Measures

Although pediatric care providers may understand that children are not simply small adults, the quality and safety communities have been slow to recognize that this necessitates pediatric-specific consideration for quality and safety measures. To address the deficiency of pediatric-sensitive and pediatric-appropriate measures, the Pediatric Data Quality System (Pedi-QS) Collaborative Measure Workgroup was formed. This workgroup is composed of the Child Health Corporation of America, National Association of Children's Hospitals and Related Institutions, Nemours Foundation, National Initiative for Children's Healthcare Quality, Nemours, and Medical Management Planning (26). The workgroup initially developed a set of pediatric asthma measures, which underwent pilot testing by the Joint Commission on Accreditation of Healthcare Organizations in 2005, with planned implementation of the four asthma measures as the Joint Commission on Accreditation of Healthcare Organizations' ORYX measures in 2007 (27).

In 2004, work began on a second set of quality and safety measures focused on PICU care (28). This work began with the formation of a multidisciplinary expert panel that included pediatric critical care physicians, nurses, pharmacists, infection control experts, and administrators. Next, a national request for measures was issued, with 51 potential measures submitted in response. The submitted measures underwent a systematic assessment and review that included specification of components. To aid in this review, six subgroups were established in the areas of risk adjustment (mortality and length of stay), central catheter infection, mechanical ventilation, unplanned readmissions, pain assessment, and medication safety. Of note, throughout the review and specification process, there was specific discussion of the feasibility and potential burden of collecting and reporting potential measures, issues of risk adjust-

ment, when applicable, and that any measure selected should be acceptable for public reporting.

In February 2005, seven candidate measures were released for public comment, resulting in >290 responses from 135 hospitals and organizations. The feedback was incorporated in a final review process that led to the seven measures that were submitted to the Joint Commission on Accreditation of Healthcare Organizations in June 2005. The seven measures included:

1. PICU standardized mortality ratio.
2. PICU severity-adjusted length of stay.
3. PICU unplanned readmission rate with systematic review of readmissions.
4. PICU pain assessment at admission and periodically.
5. PICU medication safety practice adoption.
6. PICU central venous catheter infection prevention practice adoption.

Full specifications of the measures are beyond the scope of this article but are publicly available (29). Ongoing work related to the proposed PICU measures includes planning for pilot testing and review of a subset of the measures by the National Quality Forum.

Several of the proposed measures are intended for use as a group and not in isolation. Because length of stay as a lone measure may be subject to issues of the presence or absence of stepdown units and to demand for PICU beds, the proposed severity-adjusted length of stay is coupled with unplanned PICU readmission within 24 hrs. However, unplanned readmission to a PICU may be the result of numerous factors, including patient deterioration, problems in care delivery on the healthcare unit that received the patient from the PICU, or fundamental systems issues in care delivery at the PICU level. Because of this, the proposed measures include an expectation of systematic review of unplanned PICU readmissions with the intent of identifying systems-level problems that may be amenable to quality improvement efforts.

The proposed PICU quality measures are not perfect and, like most healthcare quality measures, may be viewed as a mix of process and outcome measures. To this end, the panel approached the seven measures as a first-attempt process for further defining and refining

measures of PICU quality and safety for public reporting.

Other Potential PICU Quality Measures

The recent 100K Lives Campaign by the Institute for Healthcare Improvement highlighted six important changes to prevent avoidable deaths (30). Two of the changes were the prevention of both central catheter infection and ventilator-associated pneumonia. Efforts at reducing these infections have required measurement of baseline rates and will continue to require future measurement to determine effectiveness of the interventions.

Central catheter infections have typically been reported as infections per 1,000 catheter days. This rate is accepted by the Centers for Disease Control and Prevention and is the basis of National Nosocomial Infections Surveillance System reporting of catheter infections (31). The general consensus from the adult patient safety literature is that central catheter infections are preventable and that a goal of zero catheter infections is attainable and should be an institution's aim. It is unclear if sustained zero infections is attainable in pediatrics, but the acceptance of zero catheter infections will drive institution-level change. Cross-center comparisons continue to be difficult due to the use of catheter-associated bloodstream infection definitions instead of the more robust and much harder to obtain catheter-related bloodstream infection. The former does not require quantitative evidence of catheter infections and may increase the number of catheter infections in an institution that has large numbers of immunocompromised and hemodynamically unstable patients.

Ventilator-associated pneumonias are reported as a rate per 100 ventilator days. This rate has again been touted as being able to be zero, and accordingly, this effort should be equally applied in PICUs. This rate is also difficult to compare across institutions due to variability in application of the Centers for Disease Control definitions.

Measuring Safety in PICUs

Measuring safety has gained heightened interest with the aforementioned Institute of Medicine's report, *To Err Is Human* (4). Unfortunately, no standard-

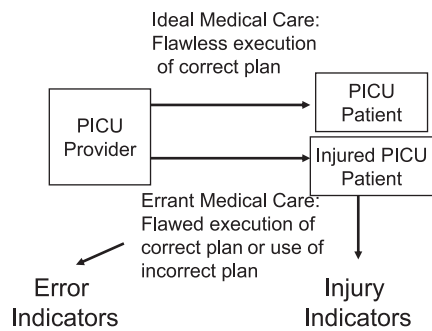


Figure 1. Error- and injury-based safety measures. *PICU*, pediatric intensive care unit.

ized method exists to report, investigate, and disseminate information related to preventable adverse events (32). One approach has been to translate qualitative concepts—for example, patient safety—into quantitative metrics. To this end, we will consider three frameworks for measuring patient safety that have recently been utilized as indicators of patient safety: measuring errors, measuring patient injuries, and measuring risks.

Error-Based Patient Safety Metrics and PICUs. Much of the systems-based approach to improving patient care is primarily based on work by psychologist James Reason and rooted in the fields of human factors engineering and cognitive psychology. Premised on the idea that the goal of medicine is to successfully implement the correct plan of care, Reason defines an error as a failure of a planned action to be completed as intended—an error of *execution*—or the use of a wrong plan to achieve an aim—an error of *planning* (9). Thus, the identification of errors is one potential framework for measuring safety in PICUs (Fig. 1).

The measurement of errors in health care may seem to be an attractive method for assessing safety. Errors in the delivery of health care are common. Estimates using pediatric data suggest that medication errors occur at a rate of 4.49 per 1,000 patient days (8) and that potential adverse drug events occur at a rate of 2.2% (33, 34). This relatively high frequency of occurrence leads to a second advantage of measuring errors in health care: errors are easy to find.

Unfortunately, the preoccupation of finding errors in medical care is problematic for a number of reasons. Above all, very few of the purported measures of errors represent true rates. To use errors as a meaningful patient safety metric beyond simply counted data, there must be

a numerator and denominator. Thus, an error rate would consist of:

$$\frac{\text{Identified errors}}{\text{Potential opportunities for that error to occur}} \quad [1]$$

In the example of incident or occurrence reports for medication errors at a hospital, a denominator can readily be determined as the number of medications dispensed or administered. However, the numerator is far more elusive. In the case of reported events, one is left knowing only the number of events reported and not the actual number of events that occurred. The fear of reprisal or legal action may lead to underreporting (35, 36). As a result, any measures that are created based on reported events over number of medications dispensed or administered are inherently nothing more than rates of reporting and not true rates of medication errors.

In addition to chart review, two other potential sources of data beyond reported events exist: chart review and ethnographic study. Chart review has been used in a number of studies to identify errors. Although chart review is treated as a reasonable means of approximating errors, it too is fundamentally flawed as a source of true measurement. To identify errors through chart review, the following sequence of events must occur: error occurs → every error is recognized by a provider → error is documented by a provider → chart is reviewed → reviewer recognizes event during review → error is attributed correctly.

Although possible, with each additional step, it is less likely that chart review can provide a true numerator to establish an error rate. Ethnography, or direct observation of people, is similarly problematic. Independent of the implications of directly observing staff for the purpose of identifying errors, determination of a numerator of error rates is contingent on a series of events: error occurs → every error is witnessed by observer → errors are recognized by the observer as errors → observer correctly attributes event as error.

When these three methods of medication error measurement have been compared, two important findings have occurred. First, the different techniques seem to have different yields based on the phase of the medication process that is being measured (37–39). Second, the

events found by the reporting, chart review, and direct observation seem to be complimentary rather than redundant. The net effect is that there is no valid or reliable method for establishing error rates in most healthcare settings.

Beyond the fundamental lack of credible methods for measuring errors, safety science has described several other issues related to focusing on errors. First, there is a fundamental problem with hindsight bias in both understanding and attributing events that created the error (40). As a result, retrospective analysis of error creates the potential for incorrect or simplistic identification of causes for events. Given the unpredictable interactions between components of a complex system, such as the PICU, “subsystem failures” are difficult to identify as a contributing cause to an adverse event. The incorrect or inadequate attribution of causality then creates the potential for misguided actions to “solve” the wrong problem, resulting in more complicated and less safe systems. This “cycle of error” described by Cook (40) creates the medical equivalent of the arcade game Whack-A-Mole: events occur, inadequate evaluation leads to incorrect actions, which give the misperception of fixing a problem until a new event, potentially created by the actions, pops up in a new setting. Ultimately, the use of flawed retrospective analysis to drive implementation of new safety measures may serve to only further increase the system’s complexity and, subsequently, the risk for patient harm or it may only prevent the same adverse event from re-occurring as opposed to improving overall system safety.

A focus on errors as a credible form of measurement is further limited by shortcomings of judgment based on the outcome of events. Caplan et al. (41) have described how the perception of a sequence of events associated with the administration of anesthesia was significantly influenced by the outcome of the case, irrespective of the actual actions and judgments of the provider. In other words, a bad outcome in the face of correct decision making and care provision is more likely to result in a determination of fault by the provider.

Although an adverse event is proximally caused by the individual clinician, organizational factors create the circumstances in which a failure of judgment occurs. *Active errors* occur at the level of

the bedside provider and their effects are felt almost immediately, whereas *latent errors* are system designs or organizational structures that create an environment in which an active error is more likely (42, 43). For example, a critical care nurse administering a medication to the wrong patient may be considered an active error; on the hand, a hospital's decision to reduce costs by decreasing the number nursing staff and the subsequent increase of the nurse-to-patient ratio may be considered a latent error. Focusing solely on the active errors allows latent failures to persist and the system prone to future adverse events (44). In the aforementioned example, not increasing nursing resources may lead to another similar medication administration error.

The final and potentially most dangerous problem associated with attempts to measure errors comes from the psychology literature (45). In the face of an error, it is a normal human response to blame someone. If to err is human, so is to blame. Despite a statement that unsafe health care is a problem of systems of care delivery, the tendency to blame people in the face of errors provides a final reason why attempts to measure errors should be done with great caution.

None of these limitations are intended to suggest that the identification of errors has no value. In fact, identified errors can serve several important roles. First, trends in reported events, though not a valid or reliable form of measuring rates, are potentially a barometer for an organization's culture as it relates to patient safety. Second, errors that are identified provide powerful learning opportunities that may allow for intervention before future harm to patients.

Examples of commonly cited errors in the intensive care unit environment include those related to medication administration, specifically dosing errors of cardiovascular, anticoagulant, and anti-infective drugs; communication among healthcare providers; and inaccurate interpretation of diagnostic studies (10, 11, 46, 47).

Injury-Based Patient Safety Metrics and PICUs. An alternative approach to utilizing error rates as a measure of safety is the measurement of patient injuries (Fig. 1). Unlike errors, which often do not result in patient harm, this metric focuses on unintended outcomes; for example, catheter-related bloodstream infection, ventilator-associated pneumonia, in-hospital cardiac arrests, and patient

deaths. By evaluating unintended outcomes, improvement efforts are more likely to focus on system vulnerabilities with a high potential for adverse events. In addition, focusing on injuries is inherently consistent with public health efforts (48). Proponents of this perspective advocate that the application of public health methodologies to patient safety will lead to the reduction of patient harm.

To this end, several organizations have proposed *quality indicators* that are intended to identify injuries. After administrative database analysis, the Agency for Healthcare Research and Quality put forth a set of potential in-hospital complications that may represent patient safety events (49). Applying these adult-centered patient safety indicators to pediatric patients, however, would be inadequate given the differences in disease epidemiology, dependence on adult caregivers, patient demographics, and stages of development; as a result, in February 2006, the Agency for Healthcare Research and Quality published pediatric-specific quality indicators, 13 of which pertain to inpatient care (50) (Table 1).

Similarly, the aforementioned 100K Lives Campaign focuses specifically on strategies to reduce the prevalence of patient injuries, specifically, in-hospital cardiac arrest, inadequate treatment of acute myocardial infarction, adverse drug events, surgical site infection, central venous catheter infection, and ventilator-associated pneumonia. The latter two goals are achieved by combining several practice changes into a condition-specific "bundle" (30).

Like error-based patient safety metrics, there are some limitations of injury-based measurement. This strategy involves retrospective analysis and therefore is weakened by the previously

mentioned vulnerability of system complexity, attribution, blaming, and hindsight bias. Further, not all patient harm is preventable. Depending on the potential to prevent types of harm that is identified by a given methodology, resources may be spent identifying or even trying to improve unpreventable injuries. Of note, the relative preventability of an injury may be subject to ongoing advancements in processes for healthcare delivery. Examples of the change of preventability over time include side effects of medications that are eliminated with newer formulations. For instance, the lower frequency of seizures associated with meropenem compared with imipenem or the lower risk of arrhythmias that is achieved by using parenteral fosphenytoin instead of phenytoin. These side effects were previously not preventable; however, safer alternatives now make the side effects arguably preventable.

Another important limitation of injury indicators is the positive and negative predictive values of injury triggers. These characteristics of screening tools take on greater importance in light of the potential stakes associated with false-positive or false-negative triggers. False-positive triggers may result in misallocation of patient safety resources to nonexistent or unpreventable problems. Further, if the triggers are used for public reporting or pay-for-performance efforts, false-positive triggers could have serious negative implications for a healthcare organization.

A related potential problem with screening triggers for patient harm is the correct attribution of cause and effect. For instance, a tertiary hospital may accept the transfer of a patient who had sustained a decubitus ulcer at the referring center. If the tertiary facility documents and codes the injury, it may result in an Agency for Healthcare Research and Quality Patient Safety Indicator for the accepting facility, although the injury was unrelated to care provided at this facility. An unpublished chart review of the Agency for Healthcare Research and Quality Pediatric Quality Indicators suggests that substantial numbers of "injuries" are present at the time of admission to the hospital to which the injury was attributed (Harris, personal communication).

The issues of false-positive or false-negative identification and incorrect attribution of causality potentially undermines the value of using injuries as a patient safety metric. That is, to use in-

Table 1. Agency for Healthcare Research and Quality pediatric quality indicators measure (inpatient)

Accidental puncture or laceration
Decubitus ulcer
Postoperative hemorrhage or hematoma
Postoperative respiratory failure
Foreign body left during procedure
Postoperative sepsis
Iatrogenic pneumothorax in neonates at risk
Postoperative wound dehiscence
Iatrogenic pneumothorax in nonneonates
Selected infections due to medical care
Transfusion reaction
Pediatric heart surgery mortality
Pediatric heart surgery volume

juries as a meaningful measure, there is a rate of events that can be tracked:

$$\frac{\text{Identified injuries}}{\text{Potential opportunities for those injuries to occur}} \quad [2]$$

As with error measures, correct identification of injuries as a numerator is inherently problematic. Thus, changes in the rate may reflect true changes in occurrence or changes in injury identification, leading to potentially misleading safety metrics.

The final limitation of measuring patient harm as a primary metric for patient safety efforts is admittedly philosophical. By design, the measurement of injuries requires that first a patient be injured before the method has potential utility. Although medical injury is very much a reality in healthcare circles, it is worth raising the question of whether healthcare metrics should be premised on waiting for harm to occur rather than attempting to proactively prevent patient injury. Thus, a focus on injuries in patient safety is critically important, as they are indeed what are to be prevented. However, depending on the exact metric used and the potential for incorrect numerators, injury-based patient safety metrics may have limited utility in PICUs or any healthcare setting.

Risk-Based Patient Safety Metrics. A third approach to measuring patient safety is via measurements of hazards or risks. As patient safety has been identified as a problem with healthcare systems (4), then applying a systems view to PICU care suggests that errors and injuries are ultimately the result of hazards or risks within systems of care (Fig. 2). Focusing on hazardous conditions that increase the likelihood of downstream errors (and injuries) is consistent with safety models in other industries, including workplace hazards described in industrial engineering and the concept of threats illustrated in the field of aviation. In these indus-

tries, safety efforts are centered on three core activities: systematic risk identification, risk assessment, and risk reduction/elimination (51, 52). The focus of non-healthcare industries on identification, analysis, and reduction of risks is premised on the understanding that this approach proactively addresses systems factors that contribute to errors and injuries. In turn, the need to commit extensive resources to the reactive approach of counting errors and injuries becomes less important. In addition, the risk-based approach is consistent with hierarchies of hazard or risk controls. One widely used industry hierarchy of control focuses on elimination of risks, substitutions of less risky alternatives, development of administrative controls, and individual protection, in decreasing order of effectiveness. Another approach (in decreasing order of effectiveness) calls for redesign of processes to eliminate risks, barriers to prevent harm, alarms or alerts, and education as a protection.

The risk-based approach readily lends itself to healthcare delivery and patient safety. A well-known illustration of this approach is the unintended delivery of potassium chloride (KCl) to patients leading to cardiac arrest. In this example, the error is incorrect administration of KCl. The injury would be the patient experiencing cardiac arrest secondary to errant KCl administration. However, the associated systems risk underlying both errors and injuries related to KCl are the availability of KCl and other concentrated electrolytes on nursing units. The risk-based approach would call for identifying risks (the presence of KCl on a nursing unit) and performing analysis of risk (KCl on a medical floor compared with KCl locked in a satellite pharmacy in a PICU) and then eliminating the risk (removing KCl from nursing units) (53).

The corresponding metric using this risk-based framework becomes:

$$\frac{\text{Eliminated risks}}{\text{Identified risks}} \quad [3]$$

This metric focuses on positive, proactive actions and can leverage identified errors and injuries to feed the denominator. This approach is strengthened by incorporating information gathered from individuals at the “sharp end”—the bedside providers. At the same time, this focus on risk reduction might eventually decrease the need to quantify error rates or injury prevalence.

The greatest barrier to adopting such a risk-based approach to patient safety metrics in PICUs is the required shift in thinking away from reactively counting errors and injuries to proactively identifying risks. However, many known risks have been identified and eliminated in PICU settings, including prevention of medication overdoses by implementation of free-flow protection, prevention of wrong-patient procedures through the implementation of procedural “time outs,” elimination of medication errors because of illegible handwriting through the use of computer order entry, and the reduction in frequency of central catheter infections through the systematic use of central catheter bundles.

The concept of risk-based patient safety metrics in a PICU is not to be at the exclusion of learning from errors and injuries. Instead, both knowledge of errors and injuries is critical to identifying risks. However, the shift from reacting to past events to proactive elimination based on what is learned from events (both locally and at other organizations) is potentially a powerful tool for improving care to critically ill children.

Conclusion

The science and art of measuring safety and quality, both in health care at large and specifically in pediatric critical care environments, is in a state of evolution. However, the growing demand for measures for both improvement and accountability suggest that the rate of evolution will only increase. The development and adoption of measures that enable improvement efforts will continue to support the transformation of traditional quality assurance to one of quality improvement. The performance of pediatric critical care providers and their PICUs are likely to be measured, regardless of whether they agree to or participate in the process of measurement.

To date, organizations, including the Joint Commission on Accreditation of Healthcare Organizations and the National Quality Forum, have been receptive to pediatric intensivists leading efforts in identifying appropriate quality metrics. Similarly, pediatric intensivists have an opportunity to lead efforts in measuring patient safety by moving beyond attempts to use measures of errors and injuries to the systematic identification, analysis, and elimination of risks to patient care.

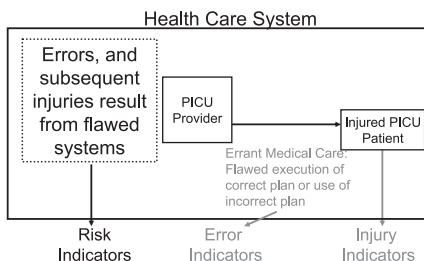


Figure 2. Risk-based safety measures. PICU, pediatric intensive care unit.

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