Quality and Errors in the Intensive Care Unit

Introduction

The WHO defines[1] the Quality of Care as "the extent to which health care services provided to individuals and patient populations improve desired health outcomes." To reach the goal, the healthcare providers have to ensure that the care is safe, effective, timely, efficient, equitable, and people-centered." The WHO elaborates these components further: the health care provided should reduce risks and harm to patients, keeping away preventable injuries and reducing errors. The maintenance should be based on knowledge and evidence-based guidelines. The care provided should also maximize resource use, avoid waste, and be given without delay. The care provided should not be discriminatory based on gender, race, ethnicity, geographical location, or socioeconomic status. Finally, it should consider the preferences and aspirations of patients and the culture of their community. Thus, good quality enhances safety and minimizes errors in all areas of health care. It is imperative in intensive care units (ICU) since we treat critically ill patients in a complex technological environment, with a significant potential for errors. Good quality of care ensures patient and the family's satisfaction.[1]

Quality and safety in ICU are influenced by many variables, which were described in detail by the Report for Methods and Measures Working Group of WHO Patient Safety published in April 2009.[2] The human factors affecting patient safety are environmental, organizational, and job factors and human and individual characteristics, which influence behavior at work in a way, which can affect health and safety. Thinking about three aspects, the job, the individual, and the organization and how they impact people's health and safety-related behavior, is a simple way to view human factors. Since the errors adversely affect the patient's outcomes, institutions, governments, and medical institutions are forced to develop tools to measure the quality of health care.[3]

In the last two decades, in particular, quality of care and patient safety (i.e., avoiding errors, see below) has become the main area of interest. The commonly updated data in the United States are Crossing the Quality Chasm[4] and To Err is Human,[5] which increased awareness among the people about medical errors and their impact on health care. This prompted the health system to develop tools to evaluate health-care quality. Initially, it was started in all the major developed countries, and later, it was implemented in developing countries. The developing countries face a tough task to measure and provide quality health care of developed countries, taxing mentally and financially.[6-9]

Definitions of Safety and Errors

Freedom from an accidental injury is safety, and failure of a planned action to be completed as intended (i.e., error of execution) or use of a wrong plan to achieve a goal (i.e., error of planning) is Error.[3]

Resource Utilisation and Cost-effectiveness

Resource utilization is an important concept and desired in an ICU. The various resources such as physicians, nurses, respiratory therapists, physiotherapists, housekeeping, ward managers, ICU beds, and equipment are essential in delivering high-quality health care. Adequate staffing and the number of equipment are also equally important. Inadequate staffing lack of equipment also reduces the quality of health care. To plan the resource utilization, we should have an idea about the bed occupancy rate of the ICU, the average length of stay (LOS), number of patients ventilated, patients requiring renal replacement therapy or hemodialysis, need for prone ventilation, and extracorporeal membrane oxygenation. Staff and equipment requirements can be calculated with adequate backup based on the number of sick patients. Work overload also causes a decrease in health-care quality since stress on the health professionals leads to errors. Hence, optimal utilization of resources and admission of patients to ICU based on the staffing strength also plays an essential role in maintaining the quality of care. The present-day hospitals worldwide face high workloads due to the inadequacy of ICU resources. The cost of ICU services also increases day by day due to discrepancies between availability and utilization. The patients' ICU-LOS also will be reduced if the resources are utilized optimally and thus increase cost-effectiveness.[10]

Measurement of safety

Measurement of the safety of ICU care is one of the most challenging tasks. It is subjective, so it isn't easy to measure quantitatively. However, it can be measured based on qualitative variables. There are two main approaches to measure safety. In the first one, the room for improvement model, problems are identified, plans are devised to correct problems, and the plans' effectiveness is assessed. This approach is known as Plan-Do-Act-Cycle. The second method uses a monitoring system that detects problems and evaluates them periodically, utilizing the quality indicators. These methods are usually utilized concomitantly to balance the two to assess, monitor, and deliver quality health care.[3]

The quality indicators should undergo medical review regularly to keep track of the ICU's direction. Hence, a medical review should be carried out once a month of all the data collected daily and areas of need for alteration acted upon to correct the lacunae. This will ensure that the quality of care of that ICU is improving continuously. No ICU in the world delivers the highest quality of health care from day 1, and it takes a lot of time and dedication to reach the highest summit.[1,11]

Culture of safety in intensive care units

The safety culture is "the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management."[12]

This concept came into existence to decrease the incidence of medical errors and adverse events. Sexton *et al*. conducted a questionnaire-based survey in 203 clinical areas from three countries and found that the described six dimension model of provider attitudes fits the data for safety culture.[12] These six dimensions are depicted in Figure 1.[12]

The above six dimensions play a vital role in reducing errors and creating a comfortable environment for health-care professionals and patients.[13-15]

Due to serious concern about the rate of medication errors, institutions are prompted to use technology to improve safety. Many new technologies, such as electronic medical records, clinical decision support with or without a computerized provider order entry system, bar-code medication administration, and smart infusion pumps, are available.

The introduction of new technology is helpful, but it gives rise to new challenges and errors. In other words, the introduction of new methods and equipment gives rise to new errors and newer troubleshooting problems. Hence, before introducing a new method or equipment, it has to be tested before a protocol or guideline is finalized.[3]

A variety of reports are available in the literature to improve patient safety. One such report describes various patient safety measures, which is given in Table 1.[16,17]

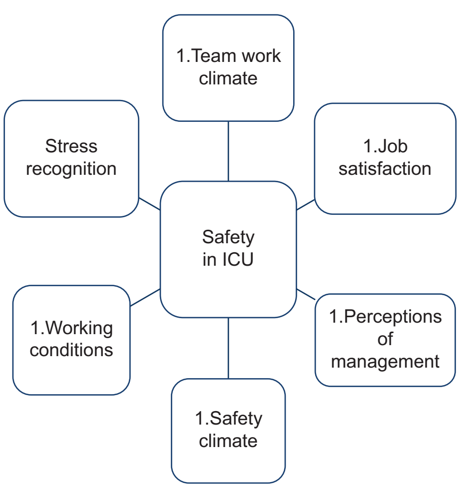

Figure 1: Sexton *et al*.'s six dimensions to reduce errors in intensive care units

Types of errors

Errors are classified in various ways based on many parameters. This section will try to mention the most commonly used classifications.

Errors can occur at any stage of patient management, including diagnosis, treatment, and prevention. There are two types of execution errors: errors of commission and errors of omission. Errors related to medications and procedures or the ICU environment are considered types of medical errors and adverse events.

Theories of error

1. In risk analysis and risk management, including aviation safety, engineering, health-care, emergency service organizations, the Swiss cheese model of accident causation is used. It is also used in depth as the principle behind layered security, in computer security and defense [Figure 2]
2. Clinical futile cycle and the traditional hierarchical referral model of care: The clinical futile cycle starts with the most junior level, at the bedside where the junior nurse and junior most doctor interact. When the nurse sees a clinical problem, she has to decide if she needs to tell a more senior team member, either a senior nurse junior doctor. This decision is affected by the work culture of the health-care system where they are working. If the problem is reported, it lands with the next doctor in the hierarchy, asking for further investigation or a specialist consult. Precious time is wasted by the time the fact is brought to the senior-most doctor's notice who can decide and initiate treatment [Figure 3][18]
3. Theory of chains of error: This theory suggests that errors occur because minor lapses or slips accumulate. Recognizing one mistake or lapse is usually sufficient to avert an error. Therefore, if involved, multiple people at multiple stages can prevent error at some stage. Sometimes, there is a failure to recognize/respond to "gut feelings" (this gut feeling is not going the way it usually does). This theory was described for errors in the aviation industry.

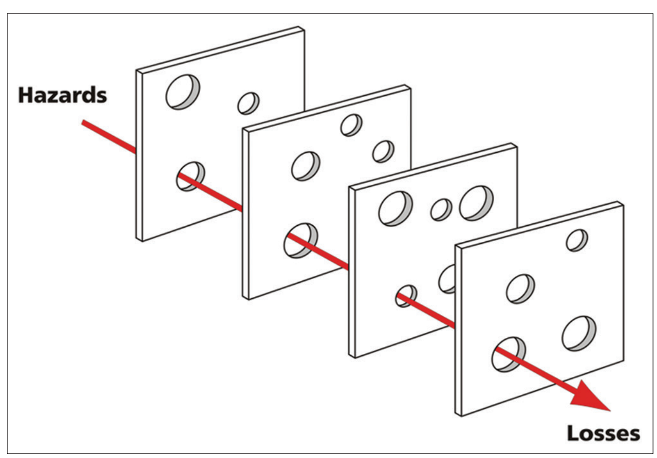

Figure 2: The Swiss cheese model of accident causation[19]

Table 1: How can patient safety be ensured?

Checklists (preoperative and anesthesia checklists)
To prevent operative and postoperative adverse events
To prevent central line-associated bloodstream infections
Bundles/interventions
That include head-of-bed elevation, sedation vacations, oral care with chlorhexidine, and subglottic-suctioning endotracheal tubes to prevent ventilator-associated pneumonia
To reduce urinary catheter use, including catheter reminders, stop orders, or nurse-initiated removal protocols
To reduce pressure ulcers
To improve prophylaxis for venous thromboembolism
To reduce falls
Infection control measures
Hand hygiene
Barrier precautions to prevent health-care-associated infections
Training and education
“Do not use” list for hazardous abbreviations
Team training
Use of simulation exercises in patient safety efforts
Procedural precautions
Use of real-time ultrasound for central line placement
Use of clinical pharmacists to reduce adverse drug events
Documentation of patient preferences for life-sustaining treatment
Obtaining informed consent to improve patients' understanding of the potential risks of procedures
Medication reconciliation
Practices to reduce radiation exposure from fluoroscopy and computed tomography scans
Use of surgical outcome measurements and report cards, like the American College of Surgeons National surgical quality improvement program
Rapid response systems
Utilization of complementary methods for detecting adverse events/medical errors to monitor for patient safety problems
Computerized provider order entry

Figure 2[19] illustrates that, despite the presence of many layers of defense, there are many flaws in each layer of hazards and accidents, allowing the accident to occur. This model was put forward by Dante Orlandella and James T. Reason of the University of Manchester. It is also called as “cumulative act effect”.

Applying the Six Sigma approach to intensive care and health care in general

Six Sigma uses the 5-step DMAIC approach, i.e., Define, Measure, Analyze, Improve, and Control. It is a structured problem-solving technique traditionally used in businesses. The following principles embraced by the aviation industry can be equally helpful in health care:

- Equipment reliability and redundancy
- Human performance predictability
- Hire for attitude, train for proficiency
- Train and credential as a team
- Collect safety data and monitor performance continuously
- Strong leadership at multiple levels
- Emphasis on human factors to manage threats and errors.

Successful application of Six Sigma can reduce the errors to = 3.4 errors per million opportunities (99.99966% accuracy), which will be a dream position. This concept is in its infancy in health care and needs further research and application.

Quality indicators in the intensive care units

The list of quality indicators, based on which protocol and methods can be devised to monitor the quality, is as follows[3]:

1. Mechanical ventilation: The 45° position (semi-recumbent) during mechanical ventilation and endotracheal tube cuff pressure
2. Sedation: it is monitored on four parameters, i.e., adequate depth of sedation, early weaning from ventilation, daily interruption of sedation and readiness for weaning, and adequate monitoring of sedation levels
3. Medication errors are the most typical errors. These are monitored based on an error in prescription, error in administration, and result of these errors (in the form of death or disability)
4. IV lines: This factor is the most important because every patient in the hospital has IV access, which may be peripheral or central. Hence, one should decide the need to remove the IV access as early as possible to reduce the incidence of associated complications
5. Early enteral nutrition is one of the most ignored aspects. Most surgical or nonsurgical patients are kept nil by mouth until complete recovery in our country. This may have a significant impact on morbidity and mortality
6. Gastrointestinal prophylaxis is an important parameter. However, overuse of the medications such as proton-pump inhibitors is equally harmful; hence, it needs to be monitored
7. Deep-vein thrombosis (DVT) prophylaxis is essential. Most of the critical care personnel are very much aware. Risk grading of DVT, administration of prophylaxis, and the data review are crucial
8. Early identification and management of sepsis and septic shock
9. Early and appropriate intervention of head injury patients (traumatic brain injury, subdural Hemorrhage, and epidural hematoma)
10. Neuromonitoring of patients with intracranial pathology (hemorrhage, infarct, and space-occupying lesion)
11. Monitor the delay in the surgical treatment and the impact on morbidity and mortality. It often happens everywhere
12. Change to oral route of medications as soon as possible. It also has a significant impact on morbidity
13. The incidence of adverse events during transport of ICU patients
14. Screening of patients for methicillin-resistant *Staphylococcus aureus*
15. Incidence of ICU-related complications, i.e., ventilator-associated pneumonia, catheter-related bloodstream infection, pneumothorax, rate of patients falling off the bed, incompatible blood transfusion,

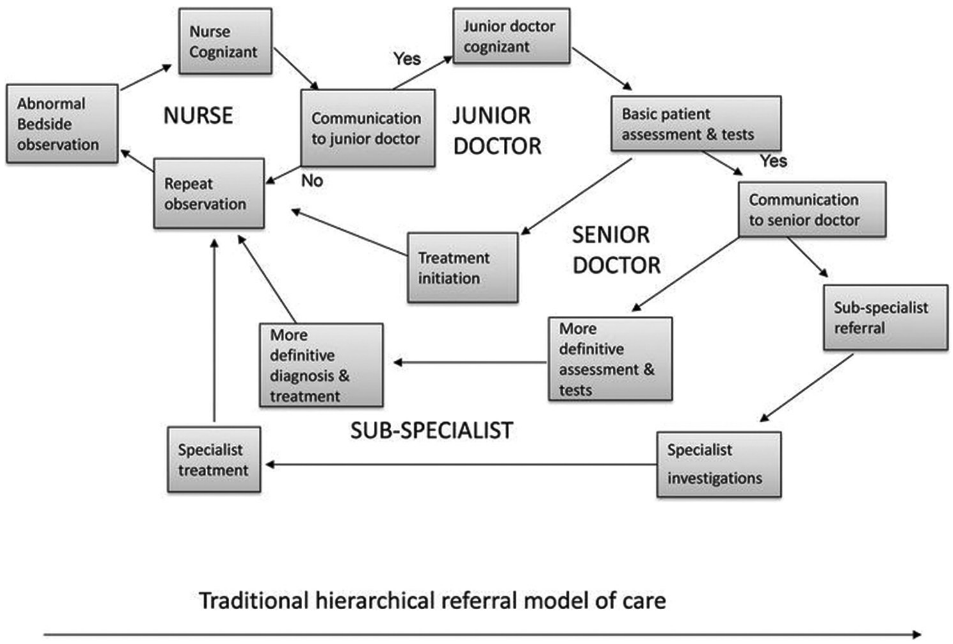

Figure 3: Clinical futile cycle and the traditional hierarchical referral model of care

multi drug resistant (MDR), Pan Drug Resistant (PDR), extended detection and response organisms, and finally, the bedsore incidence and its grading. The incidence of morbidity and mortality due to these complications

16. Outcome indicators in the form of ICU mortality rate, hospital mortality rate, % of ICU patients with ICU stays longer than 7 days, mean ICU-LOS, mean number of days on mechanical ventilation, rate of re-admissions within 48 h, and family satisfaction
17. Adverse-event reporting system
18. Device policies and protocols to improve the quality and maintenance standards
19. Team dynamics include several doctors, nurse-to-patient ratio, adequate staffing, and daily team meetings to address the everyday issues.

Root-cause analysis

Root-cause analysis helps to detect the causes of errors and solutions to prevent their recurrence. It also helps devise protocols to reduce the occurrence of these and other errors. There are five ways to perform root-cause analysis:

1. Pareto chart
2. The 5 Whys
3. Fishbone diagram
4. Scatter diagram
5. Failure Mode and Effects Analysis.

Depending on the system's problems, root-cause analysis is done using one of the above ways.

The root-cause analysis has been extensively described in the Joint Commission Resources document, and the interested reader is referred to the document.[20]

The root cause of the problems can improve the efficiency and effectiveness of ICU management. The aim of the Root cause analysis (RCA) should not be to blame an individual for error but to find if there is a system fault. Addressing the problems in the system will improve care and people volunteer information about events. This route aims to find and prevent sentinel events by taking corrective actions. This information from RCAs can be shared with all stakeholders, which will help prevent future sentinel events. It can also lead to proactive improvement efforts and improve patient safety and care.

Variables for assessment of quality

The care of critically ill patients is very demanding and a daunting task. The level of dynamic health services that need to be provided to critically ill patients is highest. The expectations from the patients and families are also high, with the hope of complete recovery of the patients. The quality and number of skilled professionals required, from doctors to housekeeping workers, escalate health-care costs. The demand for quality health care will likely outnumber the availability of infrastructure and skilled professionals available in the future. However, there should be no compromise on basic critical care. In India, due to an immense number of patients, there is a compromise in the quality of critical care. The financial burden the country has to bear to deliver quality critical care is costly. The quality indicator system should be tailor-made to the country individually.[21,22]

The medical and paramedical staff involved in delivering critical care services are morally and ethically bound to maintain international quality standards based on the available resources. The overall assessment of the quality of critical care is based on multiple variables. These variables have come into existence after years of research and practical experience. The

Table 2: Common quality indicators used in the intensive care unit

Indicator	Definition	Formula to calculate
Unplanned extubation[24]	Accidental or patient-induced ETT removal, occurring in 3%–16% of patients on mechanical ventilation[25] Unplanned extubation is one of the most common complications in the ICU. The incidence of unplanned extubations plays a significant role as a quality indicator. It is a severe complication having significant implications on the morbidity and mortality of the patients. It can be used as a quality marker of weaning care in the ICU[26]	Number of unplanned extubations per 1000 invasive mechanical ventilation days
Readmission to ICU[24]	It is defined as a second admission to the same ICU from which the patient was initially discharged during the same hospitalization[24] The duration varies from 48 h to 72 h based on the various studies done. As reported by a systematic review, the incidence of ICU readmissions in North America and Europe is 4% and 14%, respectively, in the last few decades, and the same has been relatively stable[27] Number of patients with unplanned readmission to ICU within 48-72 h of ICU discharge within the same hospitalization, calculated as a percent of live discharges	Readmission rate in ICU $= \frac{\text{Number of unplanned readmission to MICU}}{\text{Number of live discharges from ICU}} \times 100$
Incidence of VAP[24]	It is defined as the amount of pneumonia occurring in patients requiring a tracheostomy or endotracheal tube to assist respiration. The device must have been in place within the 48 h before the onset of infection and for at least 2 consecutive days, reported as VAP per 1000 ventilator-days The incidence of VAP ranging from 2-16 episodes per 1000 ventilator days with the estimated risk of VAP of 1.5% per day and decreasing to <0.5% per day after the 14th day of mechanical ventilation[28]	
Incidence of CLBSI[24]	A CLABSI is defined as a laboratory-confirmed bloodstream infection not related to an infection at another site that develops within 48 h of central line placement[29] The incidence of CLBSI rate in the United States is 0.8 per 1000 central line days. Similarly, the CLBSI rate is 4.1 per 1000 central line days as reported by the INICC between January 2010 and December 2015 (703 intensive care units in 50 countries)[30] The number of cases with a laboratory-confirmed bloodstream infection associated with a central venous catheter expressed per 1000 line days	CLBSI rate $= \frac{\text{Number of hospital-acquired infections associated with central line}}{\text{Number of central line days}} \times 1000$
CAUTI	CAUTI is defined as the number of catheter-associated UTIs per 1000 catheter days 25% of inpatients have a urinary catheter during hospitalization, many without associated signs and symptoms (American Association of Critical-Care Nurses, 2016)[31]	$\text{CAUTI rate} = \frac{\text{Number of urinary catheter-associated UTI in ICU}}{\text{Number of urinary catheter days}} \times 1000$
Prevalence of MRSA	Number of patients identified as MRSA positive from surveillance or clinical samples obtained within 24 h of ICU admission, calculated as cases per 1000 ICU discharges[24]	Prevalence of MRSA $= \frac{\text{Number of MRSA positive from surveillance in} < 24\text{ h of ICU}}{\text{Number of ICU discharges}} \times 1000$
Incidence of ICU Acquired MRSA	The number of MRSA patients negative on admission with subsequent isolation of MRSA from any sample obtained 24 h or more after ICU admission, calculated as cases per 1000 ICU discharges[24]	$\text{Incidence of MRSA in ICU} = \frac{\text{Number of patients with positive MRSA} \geq 24\text{ h after admission}}{\text{1000 patient days}}$
Occupancy	Average occupancy is calculated as the sum of the average maximum census and average minimum census divided by twice the number of ICU beds. An ICU bed is defined as the number of beds regularly available for patient care, regardless of staffing. Occupancy is expressed as a percent[24]	$\text{ICU bed occupancy rate} = \frac{\text{Utilized bed days in ICU}}{\text{Available beds for the calender year}} \times 100$

Contd...

Table 2: Contd...

Indicator	Definition	Formula to calculate
ICU discharges that occur at night	Number of patients discharged alive to a ward, step-down, high-dependency, high observation, or another non-ICU patient area in the same hospital, between the hours of 22:00 and 06:59, calculated as a percent of all live ICU discharges[24]	
Avoidable days in ICU	The amount of time that a patient occupies an ICU bed when ICU care is no longer required. The number of times patients occupy an ICU bed for more than 4 h after a written transfer order is considered avoidable. Avoidable days (24 h) are expressed as a percent of total patient days[24]	$\text{Avoidable days in ICU} = \frac{\text{Number of avoidable days in ICU}}{\text{Total patient days}} \times 100$
Patient flow	Patient flow indicates patient throughput and reflects case mix and efficiency. It is calculated as the number of admissions per bed per year	
Ventilated patient flow	Mechanical ventilation is the primary marker that differentiates a patient who needs complete ICU care and high dependency unit care or intermediate level of care. It is expressed as the number of patients receiving mechanical ventilation (invasive or noninvasive for an acute indication) per ICU bed per year	
Ventilator utilization ratio	Ratio of ventilator days (invasive or noninvasive for an acute indication) to total patient days corrected for avoidable days[24]	$\text{Ventilator utilization ratio} = \frac{\text{Number of ventilator days}}{\text{Number of patient days}}$
Interfacility patient transfers	Refers to transfers to another hospital during ICU admission. Transfers may be required for medical reasons (need for a medical service/intervention not available at the initial hospital) or as part of ICU bed management, calculated at the percent of live ICU discharges[24]	Interfacility transfer $= \frac{\text{Number of patients transferred to another hospital}}{\text{Number of ICU discharges}} \times 100$
ICU length of stay	Calculated from the date/time of ICU admission and discharge. The length of stay encompasses avoidable days[24]	
Extubation failure rate	The number of patients requiring reintubation within 48 hours of planned extubation, calculated as percent of invasively ventilated patients[24]	Extubation failure rate $= \frac{\text{Number of reintubations} < 48\text{ h after extubation}}{\text{Number of patients extubated}} \times 100$
Bed fall rate	it is defined as the number of bed falls of patients per 1000 patient bed days	$\text{Bed fall rate} = \frac{\text{Number of patients fall in ICU}}{\text{Number of patient bed days}} \times 100$
ICU mortality	Number of patients who died while under the care of the ICU team, calculated as percent of all ICU discharges[24]	$\text{ICU mortality} = \frac{\text{Number of deaths in ICU}}{\text{Number of ICU discharges}} \times 100$
Hospital mortality	Number of patients that died while under the care of the ICU team or following discharge from ICU during the same hospitalization, calculated as percent of all ICU discharges[24]	Hospital mortality $= \frac{\text{Number of deaths under ICU care both in ICU and ward}}{\text{Number of ICU discharges}} \times 100$
Consent rate for solid organ donation	The number of NDD patients for whom consent was obtained for solid organ donation. Calculated as a percentage of eligible NDD patients[24]	
Patient/family satisfaction	Total score and decision-making and care subscales from the family satisfaction-24 survey[24]	
Staff turnover	Number of nurses leaving ICU, calculated as percent of the total number of nurses working in the ICU[24]	
Overtime	Number of nursing overtime hours, calculated as a percent of total hours worked[24]	
Absenteeism	Number of nurse's sick hours, calculated as percent of a total number of hours[24]	

VAP: Ventilator-associated pneumonia, CLBSI: Central line-related bloodstream infections, INICC: International Nosocomial Infection Control Consortium, CAUTI: Catheter-associated urinary tract infection, MRSA: Methicillin-resistant *Staphylococcus aureus*, NDD: Neurologic determinations of death, CLABSI: Central line-associated bloodstream infections, ICU: Intensive care units, UTIs: Urinary Tract Infections small changes noted during the timeline have given rise to many methods and variables of assessing health-care quality. We discuss quality indicators that indicate the quality of care provided by a particular ICU in Table 2.[4,23]

Key points

1. The quality of ICU care plays a vital role in the patient's outcome
2. Safety is also equally crucial for the patient and health care professionals
3. Measurement of quality and safety is a daunting task, and both are difficult to measure with a lot of confounding and external influencing factors
4. The work culture of the ICU team, including doctors, nurses, and other supporting staff, is very important
5. Safety and quality indicators are interrelated and influence each other. A safe ICU improves quality, and quality health care enhances safety
6. Implementation and monitoring of safety indicators, quality indicators, and avoiding errors in ICU requires a dedicated team 24/7
7. A team to monitor the quality and safety indicators in the ICU is of utmost importance
8. Educating every individual of the ICU team about the quality and safety indicators of the ICU is essential
9. Feedback about the practical difficulties faced to implement the quality and safety indicators is very important to make amendments to the indicators
10. New quality and safety indicators will get added with time and more experience in the ever-changing medical field.

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References

1. Available from: https://www.who.int/maternal_child_adolescent/topics/quality-of-care/definition/en/. [Last accessed on 2019 Nov 30].
2. Available from: https://www.who.int/patientsafety/research/methods_measures/human_factors/human_factors_review.pdf. [Last accessed on 2019 Aug 28].
3. Garrouste-Orgeas M, Philippart F, Bruel C, Max A, Lau N, Misset B. Overview of medical errors and adverse events. Ann Intensive Care 2012;2:2.
4. Institute of Medicine (IOM). Crossing the Quality Chasm: A New Health System for the 21st Century. Washington DC: National Academies Press; 2001.
5. Kohn LT, Corrigan JM, Donaldson MS, editors. To Err is Human: Building a Safer Health System. Washington DC: National Academies Press (US); 2000.
6. Runciman WB. Lessons from the Australian Patient Safety Foundation: Setting up a national patient safety surveillance system – Is this the right model? Qual Saf Health Care 2002;11:246-51.
7. JCAHO: Sentinel Events, June 06, 2000. Available from: http://www.jcaho.org. [Last accessed on 2019 Aug 28]
8. Mayor S. English NHS to set up new reporting system for errors. BMJ 2000;320:1689.
9. Relating to the procedures for the event reporting experiment serious adverse events related to the care provided during investigations, treatment or preventive action other than infections nosocomial Official Journal of the French Republic mdlsedls, decree of April 25, 2006.
10. Golestani Eraghi M, Beigmohammadi MT, Soleimani AA, Mojtahedzadeh M. Intensive care unit staff and resource utilization: Is it an effective factor? Iran J Public Health 2013;42:1021-5.
11. WHO (World health Organization) Delivering Quality Health Services: A Global Imperative for Universal Health Coverage. Geneva: World Health Organization, Organisation for Economic Co-operation and Development, and the World Bank; 2018.
12. Sexton JB, Helmreich RL, Neilands TB, Rowan K, Vella K, Boyden J, *et al.* The safety attitudes questionnaire: Psychometric properties, benchmarking data, and emerging research. BMC Health Serv Res 2006;6:44.
13. Auriant I, Reignier J, Pibarot ML, Bachat S, Tenaillon A, Raphael JC. Critical incidents related to invasive mechanical ventilation in the ICU: Preliminary descriptive study. Intensive Care Med 2002;28:452-8.
14. de Lassence A, Timsit JF, Tafflet M, Azoulay E, Jamali S, Vincent F, *et al.* Pneumothorax in the intensive care unit: Incidence, risk factors, and outcome. Anesthesiology 2006;104:5-13.
15. Needham DM, Thompson DA, Holzmueller CG, Dorman T, Lubomski LH, Wu AW, *et al.* A system factors analysis of airway events from the Intensive Care Unit Safety Reporting System (ICUSRS). Crit Care Med 2004;32:2227-33.
16. Phansalkar S, Hoffman JM, Nebeker JR, Hurdle JF. Pharmacists versus nonpharmacists in adverse drug event detection: A meta-analysis and systematic review. Am J Health Syst Pharm 2007;64:842-9.
17. Making Health Care Safer II: An Updated Critical Analysis of the Evidence for Patient Safety Practices, Shekelle PG, Wachter RM, Pronovost PJ, Schoelles K, McDonald KM, Dy SM, Shojania K, *et al.* Making Health Care Safer II: An Updated Critical Analysis of the Evidence for Patient Safety Practices. Comparative Effectiveness Review No. 211. (Prepared by the Southern California-RAND Evidence-based Practice Center under Contract No. 290-2007-10062-I.) AHRQ Publication No. 13-E001-EF. Rockville, MD: Agency for Healthcare Research and Quality. March 2013. Available from: www.ahrq.gov/research/findings/evidence-based-reports/ptsafetyuptp.html. [Last accessed on 2019 Aug 28].
18. Buist, M. Adverse Events in Hospitals: "Swiss Cheese" Versus the "Hierarchal Referral Model of Care and Clinical Futile Cycles". In: Stawicki, S. P. , Firstenberg, M. S. , editors. Vignettes in Patient Safety - Volume 3 [Internet]. London: IntechOpen; 2018 Available from: https://www.intechopen.com/chapters/60108. [Last accessed on 2022 Mar 28] doi: 10.5772/intechopen.75380.
19. Available from: https://en.wikipedia.org/wiki/Swiss_cheese_model#CITEREFReason1990. [Last accessed on 2019 Aug 28].
20. Available from: https://www.jcrinc.com/assets/1/14/EBRCA15 Sample.pdf. [Last accessed on 2019 Aug 28].
21. Ewart GW, Marcus L, Gaba MM, Bradner RH, Medina JL, Chandler EB. The critical care medicine crisis: A call for federal action: A white paper from the critical care professional societies. Chest 2004;125:1518-21.
22. Levy MM, Dellinger RP, Townsend SR, Linde-Zwirble WT, Marshall JC, Bion J, *et al.* The surviving sepsis campaign: Results of an international guideline-based performance improvement program targeting severe sepsis. Crit Care Med 2010;38:367-74.
23. Centers for Disease Control and Prevention. Estimates of Healthcare Associated Infections. Available from: http://www.cdc.gov/ncidod/dhqp/hai.html. [Last accessed on 2007 Oct 15].
24. Chrusch CA, Martin CM, Project TQ. Quality improvement in critical care: Selection and Development of quality indicators. Can Respir J

2016;2016:2516765.
25. de Groot RI, Dekkers OM, Herold IH, de Jonge E, Arbous MS. Risk factors and outcomes after unplanned extubations on the ICU: A case-control study. Crit Care 2011;15:R19.
26. Peñuelas Ó, Frutos-Vivar F, Esteban A. Unplanned extubation in the ICU: A marker of quality assurance of mechanical ventilation. Crit Care 2011;15:128.
27. Rosenberg AL, Watts C. Patients readmitted to ICUs: A systematic review of risk factors and outcomes. Chest 2000;118:492-502.
28. Timsit JF, Esaied W, Neuville M, Bouadma L, Mourvillier B. Update on ventilator – Associated pneumonia. F1000Res 2017;6:2061.
29. Hallam C, Jackson T, Rajgopal A, Russell B. Establishing catheter-related bloodstream infection surveillance to drive improvement. J Infect Prev 2018;19:160-6.
30. Haddadin Y, Annamaraju P, Regunath H. Central Line Associated Blood Stream Infections. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan. Available from: https://www.ncbi.nlm.nih.gov/books/NBK430891/. [Last accessed on 2021 Aug 22].
31. Carr A, Lacambra V, Naessens J, Monteau R, Park S. CAUTI prevention: Streaming quality care in a progressive care unit. MEDSURG Nurs 2017;26:306-8.

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