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Review Article

Medication safety in Indian critical care: Strategies, challenges, and best practices

Akshaya N Shetti[1]*

[1]*Dept. of Anaesthesiology and Critical Care, Dr. Balasaheb Vikhe Patil Rural Medical College, PIMS(DU), Loni, Maharashtra, India*

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ABSTRACT

Medication safety in intensive care units (ICUs) is of paramount importance due to the complexity of treatments and the vulnerability of critically ill patients. The use of high-risk medications, such as sedatives, anticoagulants, and vasopressors, combined with polypharmacy and rapid decision-making, increases the risk of medication errors. Such errors can lead to severe complications, including increased morbidity, prolonged hospital stays, and higher mortality rates. Ongoing education and simulation-based training for ICU staff further reinforce safe medication practices. However, challenges remain, including system-based errors and the need for continuous protocol evaluation. Promoting a culture of safety through teamwork and transparent communication is essential for sustaining improvements.

1. Introduction

Medication safety is a critical component of patient care, especially in high-risk environments like intensive care units (ICUs). Critically ill patients are often subjected to complex treatment regimens that involve high-risk medications such as sedatives, vasopressors, anticoagulants, and analgesics. These medications require precise dosing, careful monitoring, and timely adjustments due to the fragile health conditions of ICU patients. Even minor deviations in drug administration can lead to serious complications, including adverse drug reactions, prolonged hospitalization, and, in severe cases, increased mortality.[1–4]

The ICU presents unique challenges for maintaining medication safety. Patients in critical care often have altered pharmacokinetics due to impaired organ function, which affects drug metabolism and clearance. Polypharmacy is common, increasing the risk of drug interactions and errors. Moreover, the fast-paced nature of ICUs, combined with frequent shifts and interdisciplinary communication, heightens the potential for medication errors. These errors may stem from various points in the medication use process, such as prescribing, dispensing, administering, or monitoring.

Given the life-threatening implications of medication errors in the ICU, improving safety is a priority for healthcare providers and institutions. To address these challenges, numerous strategies have been developed, including the integration of technological tools like computerized physician order entry (CPOE), clinical decision support systems (CDSS), and barcode medication administration (BCMA). Additionally, involving clinical pharmacists in patient care, fostering a culture of safety, and ensuring ongoing staff training are essential components of comprehensive safety practices.

The National Health Policy (NHP) of India emphasizes the importance of patient safety as a cornerstone of quality healthcare, with specific implications for critical care medication safety. It advocates for regulatory frameworks to ensure the efficacy, quality, and safety of pharmaceuticals,

* *Corresponding author*.
E-mail address: aksnsdr@gmail.com (A. N. Shetti).

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alongside the rational use of medications. In critical care, where polypharmacy and high-risk drugs are prevalent, the NHP underscores the need for stringent pharmacovigilance systems, standardized treatment protocols, and adherence to evidence-based practices to minimize medication errors. It also promotes the integration of digital health technologies, such as e-prescribing and clinical decision support systems, to reduce human errors and enhance monitoring in high-pressure environments. Capacity-building initiatives, including the training of healthcare professionals in safe prescribing and administration practices, are prioritized. The NHP also supports the establishment of a National Patient Safety Framework to create awareness, foster accountability, and drive innovation in medication safety, aligning with global best practices to improve outcomes in critical care settings.[5]

The Indian Public Health Standards (IPHS) serve as a cornerstone for ensuring quality healthcare delivery across India, emphasizing safety, accessibility, and equity in public health. In the context of critical care, adherence to IPHS guidelines is pivotal for standardizing medication safety practices across diverse healthcare settings. These standards advocate for robust systems to monitor drug storage, administration, and disposal, particularly for high-risk medications frequently used in intensive care units (ICUs). Implementing IPHS-aligned protocols ensures the availability of essential medications, minimizes medication errors, and enhances the rational use of drugs through clearly defined processes. Additionally, IPHS encourages the use of technology-driven solutions such as e-prescriptions and inventory management systems, alongside mandatory training for healthcare professionals on safe medication practices. By medication safety strategies with IPHS, healthcare institutions can ensure uniformity in critical care delivery while improving patient outcomes and fostering trust in public health systems.[6]

2. Discussion

2.1. Present problems in medication safety in critical care

Medication safety in critical care remains a complex and pressing issue, despite advancements in healthcare technology and clinical protocols. Patients in critical care units are often in fragile health, requiring rapid decisions, multiple medications, and continuous monitoring, which heightens the risk of medication errors. These errors can lead to serious, sometimes life-threatening consequences, making it imperative to identify and address the current problems in ensuring medication safety in such high-stakes environments.[3]

One of the primary problems in medication safety in critical care is the high prevalence of polypharmacy. Critically ill patients often receive multiple drugs simultaneously to manage acute conditions, chronic illnesses, and coexisting complications. This increases the risk of drug interactions, adverse drug reactions (ADRs), and dosing errors. Managing multiple medications, especially in emergency situations, can be overwhelming for healthcare providers. Keeping track of each drug's pharmacokinetics, especially when organ functions such as the liver or kidneys are impaired, adds to the complexity, potentially leading to incorrect dosing or inappropriate drug combinations. The constant need to balance medications with narrow therapeutic indices, such as vasopressors, sedatives, or anticoagulants, further compounds the risk.[7]

Another significant challenge is communication breakdowns within the interdisciplinary care team. Critical care patients are typically managed by a diverse group of healthcare professionals, including physicians, nurses, pharmacists, and respiratory therapists. These professionals must work together efficiently, but the fast-paced and stressful nature of the critical care environment often leads to miscommunication, especially during handovers or shift changes.[8] Incomplete or unclear communication about medication changes, adjustments, or the patient's condition can result in delays, omissions, or administration errors. Furthermore, the lack of standardization in handoff procedures exacerbates the risk of errors during transitions of care.

Human factors and cognitive overload are also significant contributors to medication errors in critical care. The intense workload, combined with the need for quick decision-making, can lead to cognitive fatigue and distractions for healthcare providers. Nurses and doctors in critical care units are often required to multitask, manage complex medical devices, and respond to frequent alarms, which can interrupt medication preparation and administration processes. Studies have shown that interruptions during medication administration significantly increase the likelihood of errors, particularly when healthcare providers are required to manage multiple tasks simultaneously.

Time pressure is another crucial factor affecting medication safety. In critical care, decisions often need to be made rapidly to address life-threatening situations, and this urgency can lead to shortcuts or lapses in adhering to medication safety protocols. For instance, healthcare professionals may skip crucial steps such as double-checking medication doses or identifying patients to save time. This issue is compounded when the critical care unit is understaffed or operating with a high nurse-to-patient ratio, which increases the burden on individual providers and leaves less time for thorough medication safety checks.[8]

The lack of consistent use of safety checklists and protocols further exacerbates medication errors in critical care. While many hospitals have developed checklists for medication administration, such as verifying patient identity, drug name, dose, route, and timing, these are not

always used systematically, particularly in high-pressure situations. Some staff may view checklists as time-consuming or unnecessary, and when the workload is high, these safety protocols are often bypassed.[9] The inconsistent application of these checklists increases the risk of errors, particularly for high-risk drugs like anticoagulants or insulin, which require precise management.

Technological issues also present problems in critical care medication safety. While technologies like computerized physician order entry (CPOE) and barcode medication administration (BCMA) systems have been developed to reduce errors, they are not foolproof. In some cases, these systems may not be fully integrated into the clinical workflow, leading to bypasses or workarounds by clinicians under time pressure. Additionally, these technologies may generate too many alerts, leading to "alert fatigue," where clinicians become desensitized to important warnings and begin to ignore or override them without fully assessing their significance. Overriding these critical alerts can lead to medication errors that might have been prevented with proper attention.

Inadequate staffing and resources further contribute to medication safety problems in critical care. Many critical care units operate with limited nursing staff relative to patient acuity levels, which strains the capacity of nurses to safely manage medications. When healthcare professionals are overburdened, errors related to medication timing, dose calculations, or administration can increase. Furthermore, critical care units often face shortages of trained pharmacists who specialize in critical care pharmacology. The absence of clinical pharmacists in these settings means that opportunities for real-time review and intervention in the medication process are missed, leading to higher risks of errors going unnoticed.

Medication reconciliation remains a persistent problem in critical care, particularly during transitions of care, such as when patients are transferred from one unit to another or discharged from the ICU. Medication lists are frequently incomplete or not updated in real-time, leading to discrepancies in what the patient is actually taking. These inconsistencies can result in either the omission of necessary medications or the administration of inappropriate drugs, both of which can have detrimental effects on patient outcomes. Despite efforts to standardize medication reconciliation processes, critical care units often struggle to maintain accurate records due to the complexity and volume of medications involved.

Lastly, the lack of continuous education and training for healthcare professionals on evolving best practices in medication safety presents a challenge. Critical care settings often deal with new drugs, evolving protocols, and cutting-edge treatments that require updated knowledge and skills. However, due to the demands of the job, healthcare professionals may not have adequate time for ongoing training and development in safe medication practices.[10] This gap in education leads to variations in practice and increases the risk of preventable errors.

2.2. Challenges in medication safety in critical care

Critical care environments are fast-paced and high-pressure, which inherently increases the risk of medication errors. Patients admitted to these units are often critically ill, with unstable conditions requiring continuous monitoring and frequent adjustments to treatment plans. A major challenge lies in the administration of high-alert medications, such as sedatives, vasopressors, anticoagulants, and opioids, which require precise dosing and careful monitoring due to their potential for severe adverse effects.[2,3] Miscalculations in dosage, timing errors, or administering the wrong drug can lead to life-threatening complications such as respiratory depression, hypotension, or uncontrolled bleeding.

Moreover, critical care patients often have altered pharmacokinetics due to organ dysfunction, such as impaired liver or kidney function, which makes drug metabolism and clearance unpredictable. This adds complexity to dosing decisions, requiring individualized calculations and frequent reassessments. Polypharmacy is another significant issue, as critically ill patients frequently receive multiple medications simultaneously, increasing the risk of drug interactions, adverse effects, and confusion in medication management.[11]

The involvement of multiple healthcare professionals in the care of critically ill patients—physicians, nurses, pharmacists, and respiratory therapists—also presents challenges in maintaining medication safety. Miscommunication or lack of coordination between team members during medication reconciliation or transitions of care can lead to serious medication errors. The high acuity of patients in critical care, coupled with frequent interruptions, alarm fatigue, and understaffing, further exacerbate these risks.

2.3. Strategies for enhancing medication safety in critical care

To mitigate these challenges, healthcare systems must implement comprehensive strategies designed to reduce medication errors and improve patient outcomes. One of the most effective approaches is the adoption of standardized protocols and guidelines for medication administration.[12,13] These protocols should be developed based on the best available evidence and should provide clear instructions for high-risk medications, including dosage ranges, timing, and routes of administration. Standardization helps reduce variability in practice, making it easier for healthcare teams to adhere to safety procedures consistently.

Technology plays a pivotal role in promoting medication safety in critical care. Computerized Physician Order Entry (CPOE) systems, integrated with Clinical Decision Support Systems (CDSS), are essential tools that reduce human error during the prescribing process. CPOE allows physicians to electronically input medication orders, eliminating handwriting misinterpretations, while CDSS provides real-time alerts for potential drug interactions, allergies, and dosing errors. These systems can automatically flag medications that require dosage adjustments based on patient-specific factors such as age, weight, and organ function, enhancing the accuracy of prescriptions.

Another important strategy is the involvement of clinical pharmacists as key members of the critical care team. Pharmacists can provide invaluable expertise in drug dosing, monitoring, and interaction management. By reviewing medication orders, adjusting doses for renal or hepatic impairment, and providing guidance on drug compatibility in intravenous (IV) therapies, pharmacists help to optimize medication regimens and prevent errors. Additionally, they play a crucial role in conducting medication reconciliation during patient transitions between care settings, which is a known high-risk period for medication discrepancies.[14]

Effective communication among healthcare team members is essential for medication safety. Implementing structured communication tools such as the SBAR (Situation, Background, Assessment, Recommendation) technique can help ensure that critical information is conveyed clearly and accurately during handoffs, consultations, or during rounds. Multidisciplinary team meetings and huddles can further improve coordination, ensuring that all team members are aware of the current treatment plan and any changes in the patient's condition.

2.4. Best practices in medication safety in critical care

Best practices in medication safety in critical care units are fundamental to reducing errors and improving patient outcomes, given the high-stakes nature of treatment in these settings. These practices encompass the entire medication management process, from prescription and preparation to administration and post-administration monitoring. Due to the critical condition of patients, adherence to best practices helps mitigate risks associated with high-alert medications, drug interactions, and the dynamic nature of a patient's health status.

One of the most effective best practices is the use of double-check systems, especially for high-risk medications such as insulin, anticoagulants, and neuromuscular blockers. In these cases, two healthcare providers (typically nurses) independently verify the medication, its dose, and the patient's identity before administration.[13] This practice helps to eliminate human errors, especially in environments where stress and workload can lead to lapses in judgment. Such double checks ensure that the correct medication is administered, reducing the risk of life-threatening overdoses or medication errors that could lead to serious complications.

Another crucial practice involves barcode medication administration (BCMA) systems. BCMA is a technology that uses barcodes on both the patient's identification band and the medication packaging.[15–18] Before administering any drug, healthcare professionals scan both barcodes to ensure a match between the prescribed medication and the patient. This system minimizes the chance of errors like administering the wrong drug or giving it to the wrong patient, particularly in a busy critical care setting where multiple medications are often being administered simultaneously. BCMA is highly effective at catching potential errors and ensuring the accuracy of medication delivery.

Standardized medication preparation protocols are also vital. In critical care units, drugs often need to be prepared at the bedside, particularly intravenous (IV) medications. Ensuring that drugs are prepared using standardized, evidence-based guidelines is key to maintaining safety. For example, consistent practices in diluting medications, using the correct concentration, and adhering to proper aseptic techniques reduce the likelihood of dosing errors or contamination, which can lead to infections. Pre-prepared, pharmacy-labeled syringes for high-risk medications can further streamline processes and reduce errors associated with manual preparation.[12]

Continuous education and competency training for healthcare professionals, especially those involved in critical care, are indispensable to maintaining a high level of medication safety. Critical care settings often use advanced, high-risk medications that require specialized knowledge about dosing, pharmacokinetics, and potential drug interactions. Regular training sessions, workshops, and updates on evolving best practices can help ensure that staff are well-versed in these areas. Simulation-based training, in particular, can be highly effective in preparing staff to handle complex scenarios, such as medication administration during cardiac arrests or managing adverse reactions to drugs under time pressure.[19,20] Such training provides a safe environment for learning without putting patients at risk.

A vital best practice is the integration of clinical pharmacists into the critical care team. Pharmacists play a pivotal role in optimizing medication management by reviewing prescriptions, ensuring appropriate dosing, preventing drug interactions, and adjusting drug regimens based on patient-specific factors, such as renal or hepatic function. Their involvement helps reduce the workload on physicians and nurses while improving the accuracy of drug administration. Pharmacists can also provide valuable insights during interdisciplinary team meetings, contribute

to medication reconciliation, and assist in educating the rest of the healthcare team on drug safety.

Medication reconciliation, particularly during transitions of care (e.g., when patients are admitted, transferred, or discharged), is a critical practice that helps avoid errors such as omissions, duplications, or dosing discrepancies. Patients in critical care often transition between various care units or levels of care, and maintaining an accurate and updated list of medications is essential to ensuring continuity and safety. This process should involve a thorough review of all medications the patient is taking, including over-the-counter drugs, to prevent adverse interactions or incorrect dosing upon transfer.

Post-administration monitoring is another key component of medication safety, particularly for high-alert drugs. In critical care, many medications have a narrow therapeutic index, meaning the margin between a therapeutic and a toxic dose is very small. Continuous real-time monitoring of patients' vital signs, drug levels, and organ function (e.g., liver, kidney, and heart function) is crucial for detecting early signs of adverse reactions or toxicity. For example, anticoagulants such as heparin require frequent blood tests (e.g., activated partial thromboplastin time) to ensure the drug is maintaining the desired anticoagulant effect without leading to excessive bleeding. Similarly, IV vasopressors, which are commonly used to support blood pressure, require constant hemodynamic monitoring to avoid hypotension or hypertension, both of which can lead to life-threatening complications.[21]

Additionally, smart infusion pumps represent an advanced technological tool that significantly enhances medication safety in critical care. These devices are programmed with drug libraries that contain dosage limits and infusion rates for various medications. When a medication is administered via an infusion pump, the device ensures that the dose or rate of administration does not exceed safe limits. These pumps can automatically alert healthcare professionals if there is an error in programming or if the medication being administered falls outside the pre-set safety parameters. Smart pumps help prevent dosing errors and allow for precise delivery of medications that have a narrow therapeutic window, such as sedatives, vasopressors, or insulin drips.

Finally, creating a culture of safety within critical care units is fundamental to promoting medication safety. This involves fostering an environment where team members feel empowered to speak up about potential safety concerns without fear of retribution. Encouraging open communication, reporting of near-misses or errors, and implementing non-punitive systems for addressing mistakes can significantly improve overall safety practices. Multidisciplinary rounds and huddles can further enhance team coordination, ensuring that all staff members are on the same page regarding the patient's treatment plan and medication regimen. In such an environment, every team member, from nurses to pharmacists to physicians, shares the responsibility of ensuring safe medication administration and is proactive in identifying and mitigating risks.

2.5. Challenges and recommendations for medication safety in critical care

Critical care environments present unique challenges to ensuring medication safety, including the complexity of care, high patient acuity, and the frequent use of high-risk drugs. Common challenges include inadequate staffing, lack of standardization in medication protocols, frequent interruptions during drug administration, and insufficient training in medication safety practices. Errors related to polypharmacy, improper storage of medications, and insufficient use of technology further compound the risks. To overcome these challenges, healthcare facilities must prioritize the development and enforcement of standardized protocols, including checklists and guidelines for drug administration.[22] Investing in staff training programs on safe prescribing, dispensing, and administration practices is essential. A culture of safety through regular audits, feedback mechanisms, and non-punitive error reporting systems will enhance accountability and learning. Establishing dedicated medication safety committees to monitor compliance and drive continuous improvement is also recommended. These measures, when implemented, can mitigate risks and ensure safer outcomes in critical care settings.

3. Conclusion

Medication safety in critical care is vital due to the complexity of managing critically ill patients and the risks associated with polypharmacy, cognitive overload, and communication breakdowns. Despite advancements like computerized physician order entry (CPOE) and barcode medication administration (BCMA), systemic issues and human factors continue to pose challenges. Best practices, such as double-check systems, pharmacist involvement, and standardized protocols, are essential but often inconsistently applied. Improving medication safety requires a multidisciplinary approach, integrating technology, continuous education, and a strong safety culture to reduce preventable harm and improve patient outcomes in critical care settings.

4. Conflict of Interest

None.

5. Source of Funding

None.

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Author's biography

Akshaya N Shetti, Professor and HOD https://orcid.org/0000-0002-4688-8071

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