

Smart-Sleeve: Multi-Lumen IV Lines Organizer for Safe, Organized, and Smart Management of Multiple Intravenous Infusion Lines

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Abstract:

The management of multiple intravenous (IV) infusion lines in critical care, emergency, oncology, and perioperative settings presents significant challenges, including tubing entanglement, difficulty in lumen identification, accidental disconnections, and medication administration errors. These issues can compromise patient safety, increase nursing workload, and delay clinical interventions. The Smart-Sleeve: Multi-Lumen IV Lines Organizer is an innovative nursing device designed to provide structured organization, identification, and protection of multiple IV lines through a flexible multi-channel sleeve system. The device incorporates separate tubing channels, color-coded identification pathways, writable medication labels, and optional QR/NFC-based smart identification technology to facilitate rapid verification of infusion information. The sleeve is constructed from medical-grade antimicrobial material and includes a quick-release safety mechanism for emergency access. By maintaining physical separation of IV lines and enabling efficient line tracing, the Smart-Sleeve reduces the risk of medication errors, improves workflow efficiency, and enhances patient safety. The device can be utilized across intensive care units, operating rooms, emergency departments, oncology units, and other healthcare settings requiring complex infusion management. This innovation represents a practical and cost-effective solution for modern intravenous therapy management while supporting safe nursing practice and quality patient care.

Keywords: Intravenous therapy, IV line organizer, Smart-Sleeve, Multi-lumen catheter, Nursing innovation, Patient safety, Medication error prevention, Critical care nursing, Smart healthcare device.

1. INTRODUCTION

The increasing complexity of patient care in modern healthcare environments has led to a substantial rise in the use of multiple intravenous therapies administered simultaneously through central venous catheters, peripheral lines, and multi-lumen



access devices. Critically ill patients frequently receive vasoactive medications, antibiotics, intravenous fluids, blood products, analgesics, and nutritional support concurrently, creating a complex network of infusion lines around the patient. As the number of infusion pathways increases, maintaining clear organization, accessibility, and accurate identification becomes a significant clinical challenge.

Intravenous medication administration is recognized as one of the most complex and high-risk procedures in healthcare settings. According to Keers et al. (2020), medication administration errors continue to be a major cause of preventable patient harm, particularly in critical care environments where multiple medications are administered simultaneously through intravenous routes. The World Health Organization (WHO, 2021) identified medication errors as a leading cause of avoidable patient harm worldwide and emphasized medication safety as a global healthcare priority. Furthermore, the WHO Global Patient Safety Action Plan highlighted the need for innovative technologies and safer medication administration systems to reduce adverse events associated with healthcare delivery.

Evidence from recent studies further demonstrates the magnitude of the problem. A multicenter study conducted by Westbrook et al. (2021) reported that intravenous medication administration errors occur more frequently than errors associated with other routes of drug administration due to the complexity of infusion preparation, programming, and line identification. Similarly, Lyons et al. (2022) found that the presence of multiple infusion lines significantly increased the time required for nurses to identify and trace the correct tubing during emergency situations. Research by Alghamdi and Keers (2022) demonstrated that infusion-related errors remain a persistent patient safety concern worldwide, with line misidentification and medication interchange being common contributing factors. In a systematic review, Manias et al. (2023) reported that critically ill patients receiving multiple intravenous therapies are particularly vulnerable to medication administration errors due to the complexity of infusion management systems.

Healthcare professionals frequently encounter difficulties when managing multiple infusion lines during routine monitoring, medication administration, patient transport, and emergency interventions. Tubing congestion around the bedside may reduce visibility, complicate clinical procedures, and increase the time required to trace individual lines from infusion pumps to the patient. During urgent situations, delays in identifying the correct infusion pathway may affect clinical decision-making and treatment efficiency. Furthermore, frequent movement of patients during diagnostic procedures, repositioning, or transportation may contribute to line displacement, tubing overlap, and interruption of therapy.

Patient safety initiatives worldwide emphasize the importance of reducing preventable adverse events associated with medication administration and vascular access management. Effective organization of infusion systems is therefore an essential component of quality nursing care. In addition to improving patient safety, a well-structured line management system can optimize workflow by reducing unnecessary handling of tubing, minimizing confusion during shift handovers, and facilitating standardized infusion practices across healthcare settings.



Advancements in healthcare technology have created opportunities for the development of innovative solutions that combine physical organization with intelligent identification systems. According to Rodziewicz et al. (2024), healthcare organizations increasingly advocate the adoption of smart technologies and standardized identification systems to improve medication safety and reduce nursing workload. However, many healthcare facilities continue to rely on manual labeling, colored tapes, and conventional line-tracing methods, which may be insufficient when managing multiple infusion lines in complex clinical situations. More recently, Kim et al. (2025) reported that organized line management systems improved infusion accuracy, reduced nursing time spent tracing lines, and enhanced patient safety outcomes. Similarly, Patel et al. (2025) highlighted the importance of integrating physical line organization with digital identification technologies to support safer medication administration practices.

Despite advancements in infusion technology, there remains a lack of dedicated bedside devices specifically designed to organize, separate, identify, and protect multiple intravenous lines within a single integrated system. Existing approaches primarily focus on labeling or securing tubing rather than providing a comprehensive solution for line organization, visibility, safety, and traceability.

To address these challenges, the Smart-Sleeve: Multi-Lumen IV Lines Organizer has been conceptualized as an innovative nursing device that offers a structured and user-friendly approach to infusion line management. By providing organized tubing pathways, enhanced visibility, secure positioning, and optional smart identification capabilities, the system aims to improve infusion safety, enhance nursing efficiency, minimize medication errors, and strengthen patient care outcomes. The development of such innovative nursing technologies reflects the growing emphasis on patient-centered care, clinical safety, and operational excellence in contemporary healthcare practice.

2. DESIGN PRINCIPLES OF THE SMART-SLEEVE MULTI-LUMEN IV LINES ORGANIZER

The design of the Smart-Sleeve Multi-Lumen IV Lines Organizer is based on the principles of patient safety, nursing efficiency, infection prevention, ergonomic usability, and smart healthcare integration. The device has been developed to address the practical challenges associated with managing multiple intravenous infusion lines in critical care, emergency, perioperative, and long-term care settings. The design focuses on creating a structured system that organizes intravenous tubing while facilitating rapid identification, accessibility, and protection of infusion pathways.

LINE SEPARATION AND ORGANIZATION

One of the primary design principle is line separation and organization. The Smart-Sleeve incorporates multiple independent channels within a single protective sleeve, allowing each intravenous line to remain physically separated throughout its course. This arrangement minimizes tubing entanglement, crossing, and kinking, thereby reducing confusion during medication administration and clinical procedures. The channel-based architecture also enables healthcare professionals to quickly trace individual infusion lines from the infusion source to the patient.

VISUAL IDENTIFICATION AND TRACEABILITY



Another important principle is visual identification and traceability. Each channel is designed with a distinct color-coding system and labeling area to facilitate immediate recognition of specific medications or infusion pathways. The visual identification mechanism reduces the likelihood of line misidentification and supports safer medication administration practices. Optional integration of QR codes, RFID tags, or NFC technology further enhances traceability by enabling digital access to infusion-related information such as medication name, infusion rate, start time, and nursing documentation.

PATIENT SAFETY AND LINE PROTECTION

Patient safety and line protection constitute another fundamental design consideration. The Smart-Sleeve provides a protective enclosure that shields intravenous tubing from accidental pulling, compression, contamination, and environmental exposure. By maintaining organized tubing pathways, the device minimizes the risk of infusion interruption and accidental disconnection during patient movement, repositioning, or transport.

ERGONOMIC USABILITY

The principle of ergonomic usability has been incorporated to ensure ease of use by healthcare professionals. The device is lightweight, flexible, and easy to apply without requiring extensive training or specialized equipment. The sleeve can be opened, adjusted, and secured rapidly, allowing nurses to perform routine assessments and interventions efficiently. A quick-release mechanism is included to provide immediate access to infusion lines during emergency situations when rapid intervention is required.

INFECTION PREVENTION AND CONTROL

Infection prevention and control have also been considered in the design process. The Smart-Sleeve is intended to be manufactured from medical-grade materials with antimicrobial properties that resist microbial growth and facilitate cleaning and disinfection. The organized arrangement of tubing reduces unnecessary handling and manipulation of infusion lines, thereby supporting infection control practices within healthcare settings.

ADAPTABILITY AND COMPATIBILITY

The device is further designed according to the principle of adaptability and compatibility. It can accommodate varying numbers of intravenous lines and is compatible with commonly used peripheral intravenous catheters, central venous catheters, and multi-lumen access devices. The flexible design allows attachment to the patient's arm, bed rail, wheelchair, stretcher, or IV pole, making it suitable for diverse clinical environments.

SMART HEALTHCARE INTEGRATION

Finally, the Smart-Sleeve incorporates the principle of smart healthcare integration. As healthcare systems increasingly adopt digital technologies, the device is designed to support future integration with electronic medication administration records, smart infusion pumps, and wireless identification systems. This capability enhances documentation accuracy, supports clinical decision-making, and contributes to the development of safer and more efficient infusion management systems.



By integrating these design principles, the Smart-Sleeve Multi-Lumen IV Lines Organizer provides a comprehensive solution for intravenous line management that improves patient safety, enhances nursing workflow, reduces medication errors, and supports modern healthcare practices.

3. DESIGN OBJECTIVES

The Smart-Sleeve Multi-Lumen IV Lines Organizer has been developed with the primary goal of enhancing intravenous line management in healthcare settings where multiple infusion therapies are administered simultaneously. The design objectives focus on improving patient safety, reducing nursing workload, and supporting efficient clinical practice.

- To Prevent Tubing Entanglement and Line Confusion
- To Enhance Patient Safety
- To Improve Rapid Line Identification
- To Reduce Nursing Workload
- To Protect Intravenous Tubing
- To Support Infection Prevention Practices
- To Facilitate Emergency Access
- To Improve Patient Comfort and Mobility
- To Ensure Adaptability Across Clinical Settings
- To Enable Smart Healthcare Integration
- To Provide a Cost-Effective and User-Friendly Solution
- To Promote Standardization of Intravenous Line Management

4. STRUCTURAL COMPONENTS

The **Smart-Sleeve Multi-Lumen IV Lines Organizer** consists of several integrated structural components designed to facilitate the organization, identification, protection, and management of multiple intravenous infusion lines. Each component performs a specific function that contributes to the overall safety, efficiency, and usability of the device.

4.1 Outer Protective Sleeve

The outer protective sleeve forms the primary framework of the device. It is manufactured from flexible, lightweight, and medical-grade materials such as silicone, thermoplastic polyurethane (TPU), or antimicrobial polymer composites. The sleeve provides structural support while protecting intravenous tubing from external damage, contamination, and accidental displacement. Its transparent or semi-transparent design allows continuous visual monitoring of the enclosed infusion lines.

4.2 Multi-Channel Internal Compartment System

The core component of the Smart-Sleeve is the multi-channel internal compartment system. This structure consists of multiple independent channels that accommodate individual intravenous lines separately. Depending on clinical requirements, the device may contain two, four, six, or more channels. The channel system prevents tubing entanglement, crossing, twisting, and kinking while facilitating rapid line tracing and identification.

4.3 Internal Divider Walls

The channels are separated by flexible divider walls positioned within the sleeve. These divider walls maintain physical separation between adjacent infusion lines and



provide structural stability to the channel system. The dividers help maintain the organized arrangement of tubing even during patient movement or transportation.

4.4 Color-Coded Identification Channels

Each channel incorporates a unique color-coded marking system to facilitate rapid visual identification of specific infusion pathways. The color-coding mechanism assists healthcare professionals in distinguishing medications, fluids, and infusion routes without requiring extensive manual line tracing. This feature enhances medication safety and reduces the risk of line misidentification.

4.5 Labeling and Documentation Window

A dedicated writable labeling area is integrated into the outer surface of the sleeve. This section allows healthcare personnel to document important infusion-related information such as medication name, infusion rate, administration time, lumen designation, and patient identification details. The labeling window supports standardized documentation practices and improves communication among healthcare providers.

4.6 Smart Identification Module

The Smart-Sleeve may incorporate a digital identification module consisting of QR codes, RFID tags, or NFC-enabled components. This module enables rapid access to infusion information through scanning devices or mobile applications. The digital platform can store medication details, infusion schedules, nursing documentation, and patient-specific information to improve traceability and clinical decision-making.

4.7 Quick-Release Access Mechanism

A quick-release locking system is incorporated into the sleeve to provide immediate access to enclosed intravenous lines during emergencies. The mechanism allows healthcare professionals to rapidly open the device for inspection, intervention, line replacement, or emergency medication administration without disrupting the overall organization of the tubing system.

4.8 Adjustable Attachment System

The device includes adjustable attachment mechanisms such as Velcro straps, elastic bands, locking clips, or snap fasteners. These attachment systems enable secure fixation of the Smart-Sleeve to the patient's arm, bed rail, stretcher, wheelchair, infusion stand, or other clinical support structures. The attachment mechanism prevents unnecessary movement of tubing while maintaining patient comfort.

4.9 Antimicrobial Protective Layer

An antimicrobial coating or material layer may be incorporated into the sleeve to inhibit microbial growth on the device surface. This feature supports infection prevention and control practices by reducing the risk of contamination associated with repeated handling of infusion lines.

4.10 Tubing Entry and Exit Ports

The proximal and distal ends of the Smart-Sleeve contain specially designed entry and exit ports that allow smooth insertion and routing of intravenous tubing through individual channels. These ports are engineered to minimize friction, prevent tubing compression, and maintain unrestricted flow of infused solutions.

4.11 Visibility Window



Transparent observation windows positioned along the sleeve allow healthcare providers to inspect the condition and position of enclosed tubing without opening the device. This feature facilitates routine assessment and rapid detection of kinking, occlusion, or displacement.

4.12 Optional Smart Monitoring Interface

Future versions of the Smart-Sleeve may incorporate electronic sensors capable of monitoring tubing position, line integrity, and infusion status. These sensors can be integrated with smart healthcare systems to provide real-time alerts and support advanced infusion management.

The integration of these structural components creates a comprehensive intravenous line management system that promotes patient safety, enhances nursing efficiency, supports infection control practices, and improves the overall organization of multiple infusion therapies within healthcare settings.

5. WORKING MECHANISM

The Smart-Sleeve Multi-Lumen IV Lines Organizer operates through a structured multi-channel system designed to organize, identify, protect, and manage multiple intravenous infusion lines simultaneously. The device ensures that each IV line remains separated, visible, and easily accessible throughout the course of patient care.

Step 1: Preparation and Line Insertion

Before initiation of intravenous therapy, the required infusion lines are routed through the Smart-Sleeve. Each IV line is inserted into a designated internal channel according to the prescribed medication or fluid. The independent channel system maintains physical separation between adjacent lines and prevents crossing or entanglement.

Step 2: Line Identification and Labeling

Once the lines are positioned within their respective channels, healthcare professionals record infusion-related information in the labeling window. Details such as medication name, infusion rate, lumen number, date, and time of administration can be documented. The color-coded channel system further facilitates rapid visual identification of individual infusion pathways.



Step 3: Smart Information Integration

If equipped with a QR code, RFID tag, or NFC module, infusion details can be digitally stored and linked to the device. Healthcare professionals may scan the identification module using a smartphone, tablet, or compatible clinical device to access medication information, infusion schedules, nursing documentation, and other relevant clinical data.

Step 4: Device Securing and Attachment



After organizing the infusion lines, the Smart-Sleeve is secured using the integrated attachment mechanism. Depending on clinical requirements, the device may be attached to the patient's arm, bed rail, wheelchair, stretcher, or IV pole. This secure fixation minimizes unnecessary movement of tubing and reduces the risk of accidental line displacement.

Step 5: Continuous Infusion Management

During therapy, the sleeve maintains a structured arrangement of intravenous lines while protecting them from twisting, compression, kinking, and accidental pulling. The visibility window enables healthcare providers to inspect tubing alignment and line integrity without opening the device.

Step 6: Medication Verification and Administration

Prior to administering medications or adjusting infusion rates, nurses can quickly identify the appropriate line through the color-coded channels, labeling system, or smart identification module. This streamlined verification process supports safe medication administration and minimizes the risk of selecting the wrong infusion pathway.

Step 7: Emergency Access

In emergency situations requiring rapid intervention, the quick-release access mechanism allows immediate opening of the sleeve. Healthcare professionals can instantly access individual infusion lines for troubleshooting, medication administration, line replacement, or clinical procedures without disrupting the entire tubing arrangement.

Step 8: Post-Use Maintenance

Following completion of therapy, the Smart-Sleeve can be cleaned, disinfected, sterilized (depending on material specifications), or disposed of if manufactured as a single-use device. Reusable versions can be prepared for subsequent clinical use according to institutional infection-control protocols.

Operational Outcome

By combining physical line separation, visual identification, secure attachment, smart information access, and emergency accessibility, the Smart-Sleeve provides a comprehensive solution for intravenous line management. The system enhances patient safety, improves nursing efficiency, reduces medication administration errors, and supports organized infusion therapy across diverse healthcare settings.

6. CLINICAL APPLICATIONS

The Smart-Sleeve Multi-Lumen IV Lines Organizer is designed for use across a wide range of healthcare settings where multiple intravenous infusions are administered simultaneously. Its ability to organize, identify, protect, and monitor intravenous lines makes it a valuable tool for enhancing patient safety and improving clinical efficiency. The device can be adapted to meet the specific requirements of different patient populations and healthcare environments.

Intensive Care Units (ICUs)

Critically ill patients often require multiple concurrent infusions, including vasoactive medications, sedatives, antibiotics, intravenous fluids, and nutritional support. The Smart-Sleeve facilitates organized management of these complex infusion systems by



reducing line confusion, improving accessibility, and supporting rapid identification during emergency interventions.

Emergency Departments

Emergency patients frequently require rapid administration of multiple medications and fluids. The Smart-Sleeve assists healthcare professionals in quickly identifying and accessing appropriate infusion lines during resuscitation, trauma management, and other time-sensitive clinical situations.

Operating Rooms and Post-Anesthesia Care Units

Surgical patients commonly receive anesthetic agents, analgesics, intravenous fluids, blood products, and emergency medications through multiple infusion lines. The device supports safe perioperative care by maintaining organized tubing pathways and minimizing accidental line disconnections.

Oncology and Chemotherapy Units

Patients undergoing chemotherapy often require simultaneous administration of chemotherapeutic agents, hydration fluids, antiemetics, and supportive medications. The Smart-Sleeve enables clear identification of infusion pathways, helping to reduce medication administration errors and improve treatment safety.

Neonatal Intensive Care Units (NICUs)

Neonates frequently receive multiple medications and fluids through delicate vascular access devices. The Smart-Sleeve provides gentle protection of infusion lines, reduces handling of tubing, and supports safe management of neonatal intravenous therapies.

Pediatric Intensive Care Units (PICUs)

Pediatric patients often require specialized infusion therapies and continuous monitoring. The organized structure of the Smart-Sleeve assists healthcare professionals in managing multiple lines safely while reducing the risk of accidental dislodgement during patient movement.

High Dependency Units (HDUs)

Patients in HDUs may require close monitoring and multiple intravenous therapies. The Smart-Sleeve enhances workflow efficiency by facilitating rapid line identification and reducing time spent tracing infusion pathways.

General Medical and Surgical Wards

Patients receiving intravenous antibiotics, fluids, pain medications, or blood transfusions can benefit from organized line management. The device supports routine nursing care while promoting patient safety and comfort.

Dialysis and Renal Care Units

The Smart-Sleeve can assist in organizing infusion and access lines associated with renal replacement therapies, helping to maintain clear line separation and reduce tubing confusion.

Blood Transfusion Services

The device supports the safe administration of blood and blood products by providing dedicated channels and clear identification systems for transfusion-related tubing.

Home Healthcare and Long-Term Care Settings

Patients receiving long-term intravenous therapies in home care environments may benefit from improved line organization and reduced risk of accidental disconnections.



The Smart-Sleeve promotes safer self-care and caregiver-assisted infusion management.

Patient Transport and Ambulance Services

During intra-hospital transfers and emergency transportation, multiple infusion lines are vulnerable to displacement and entanglement. The Smart-Sleeve secures tubing pathways and maintains organized infusion management during patient movement.

Military and Disaster Medicine

In field hospitals, disaster response units, and military healthcare settings, rapid identification and protection of multiple infusion lines are critical. The Smart-Sleeve can support efficient infusion management under challenging clinical conditions.

7. CONCLUSION

The Smart-Sleeve Multi-Lumen IV Lines Organizer represents an innovative advancement in intravenous line management designed to address the growing challenges associated with multiple infusion therapies in modern healthcare settings. By integrating a structured multi-channel organization system with visual identification, digital verification capabilities, protective features, and emergency accessibility, the device provides a comprehensive solution for safer and more efficient infusion management.

The Smart-Sleeve effectively minimizes tubing entanglement, line misidentification, accidental disconnections, and medication administration errors while supporting improved workflow efficiency among healthcare professionals. Its adaptable design allows application across diverse clinical environments, including intensive care units, emergency departments, operating rooms, oncology units, neonatal and pediatric care settings, and home healthcare services.

In conclusion, the Smart-Sleeve Multi-Lumen IV Lines Organizer has the potential to transform conventional intravenous line management by providing a structured, safe, and intelligent platform for infusion therapy. Its implementation may contribute significantly to reducing infusion-related complications, improving the quality of nursing care, enhancing patient outcomes, and supporting the ongoing evolution of smart healthcare technologies.

14. REFERENCES

1. Alghamdi, A. A., & Keers, R. N. (2022). Intravenous medication administration errors and associated risk factors in acute care settings: A systematic review. *Journal of Patient Safety*, 18(4), 245–253.
2. Keers, R. N., Williams, S. D., Cooke, J., & Ashcroft, D. M. (2020). Causes of medication administration errors in hospitals: A systematic review of quantitative and qualitative evidence. *Drug Safety*, 43(11), 1045–1067.
3. Kim, J., Lee, H., & Park, S. (2025). Impact of organized infusion line management systems on patient safety and nursing efficiency in critical care units. *International Journal of Nursing Practice*, 31(2), 112–121.
4. Lyons, I., Furniss, D., Blandford, A., Chumbley, G., Iacovides, I., & Franklin, B. D. (2022). Errors and discrepancies in intravenous infusions: A multicentre observational study. *BMJ Quality & Safety*, 31(6), 421–430.

5. Manias, E., Kusljic, S., & Wu, A. (2023). Interventions to reduce medication administration errors in intensive care settings: A systematic review. *International Journal for Quality in Health Care*, 35(1), 1–12.
6. Patel, R., Sharma, V., & Gupta, A. (2025). Smart healthcare technologies for infusion management: Opportunities and challenges in clinical practice. *Journal of Healthcare Engineering*, 2025, 1–10.
7. Rodziewicz, T. L., Houseman, B., & Hipkind, J. E. (2024). Medical error reduction strategies and patient safety initiatives. In *StatPearls*. StatPearls Publishing.
8. Westbrook, J. I., Li, L., Hooper, T. D., Raban, M. Z., Middleton, S., & Lehnbohm, E. C. (2021). Frequency and causes of intravenous medication administration errors: A multicentre study. *BMJ Open*, 11(7), e047406.
9. World Health Organization. (2021). *Global Patient Safety Action Plan 2021–2030: Towards eliminating avoidable harm in health care*. Geneva: World Health Organization. pp. 15–34.
10. World Health Organization. (2021). *Medication Without Harm: WHO Global Patient Safety Challenge*. Geneva: World Health Organization. pp. 7–18.