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Medical Device-Related Pressure Injuries: Understanding Etiology, Preventive Strategies, And Clinical Implications in Contemporary Healthcare Settings

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ABSTRACT

Medical Device-Related Pressure Injuries (MDRPIs) have emerged as a critical concern in modern healthcare, contributing significantly to patient morbidity, healthcare costs, and extended hospital stays. Unlike conventional pressure ulcers, MDRPIs occur when a medical device applies sustained pressure to the skin or underlying tissues, resulting in localized damage. These injuries are often underestimated due to their atypical anatomical locations and their association with necessary therapeutic devices. This paper explores the definition, epidemiology, risk factors, pathophysiology, clinical management, and preventive strategies of MDRPIs, highlighting their importance in patient safety and nursing care. Evidence from recent literature emphasizes the role of multidisciplinary interventions, advanced skin assessment techniques, and technology-driven solutions to reduce their incidence. The study also discusses current challenges, emerging technologies, and the future scope of MDRPI prevention in healthcare systems.

KEYWORDS: *Medical Device-Related Pressure Injuries, Pressure Ulcer, Nursing Care, Risk Factors, Prevention, Patient Safety, Clinical Management.*

INTRODUCTION

Pressure injuries have long been recognized as preventable adverse events in healthcare. However, the growing dependency on medical devices has introduced a distinct subset known as Medical Device-Related Pressure Injuries (MDRPIs). These injuries occur due to prolonged pressure from devices such as oxygen masks, endotracheal tubes, cervical collars, nasogastric tubes, splints, or catheters. According to the National Pressure Injury Advisory Panel (NPIAP), MDRPIs represent injuries where the device is the main causative factor, and the resultant wound pattern mirrors the device's shape. Despite advancements in pressure injury prevention, MDRPIs continue to challenge healthcare professionals globally, emphasizing the need for awareness, early detection, and preventive care protocols.

Table 1: Common Medical Devices Associated with Pressure Injuries

Medical Device	Common Site of Injury	Risk Factors	Notes
Endotracheal Tube	Mouth, lips, cheeks	Prolonged intubation, poor fixation	Ensure frequent tube repositioning
Nasogastric Tube	Nose bridge, nostrils	Thin skin, friction	Use padding or hydrocolloid dressings
Oxygen Mask	Nose bridge, ears	Tight fit, moisture	Regular skin inspection required
Cervical Collar	Chin, jawline, neck	Immobility, improper sizing	Soft padding recommended
Catheters	Genital area, thighs	Incontinence, skin fragility	Frequent assessment and repositioning

LITERATURE REVIEW

Historical background

Pressure injuries were historically attributed to immobility and inadequate repositioning. However, by the early 2000s, reports began to associate skin injuries with medical devices. With the increasing use of noninvasive ventilation and monitoring technologies, MDRPIs have gained recognition as a distinct clinical entity requiring focused attention.

Prevalence and impact

Studies indicate that MDRPIs account for approximately 30%–50% of all hospital-acquired pressure injuries. Intensive care units (ICUs), neonatal wards, and operating theatres exhibit the highest prevalence due to frequent device use and reduced patient mobility. Patients with critical illnesses, prolonged ventilation, or fragile skin are particularly susceptible.

Clinical characteristics

MDRPIs commonly appear on the ears, nose, cheeks, lips, neck, or extremities—regions that coincide with the application of devices. Unlike traditional pressure injuries, they may develop rapidly, sometimes within hours of device application. These injuries are often underreported, leading to delayed treatment and increased infection risks.

Nursing role and clinical prevention

Nurses play a pivotal role in MDRPI prevention through frequent inspection of device sites, proper padding, and timely repositioning. The introduction of risk assessment tools such as the Braden Scale and the addition of device-related criteria have enhanced prevention strategies. Additionally, innovations like silicone-based dressings and customized device fittings have demonstrated effectiveness in minimizing tissue damage.

PATHOPHYSIOLOGY OF MDRPIS

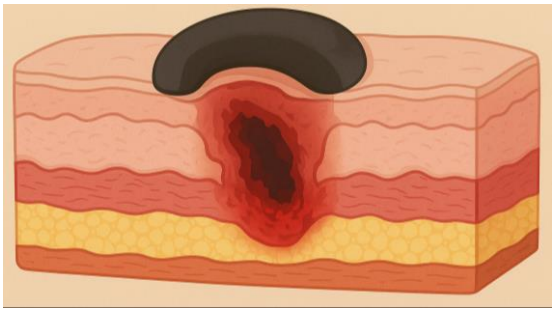

Figure 1: Conceptual Illustration of MDRPI Development

Pressure and ischemia

MDRPIs result from localized tissue compression, which impedes blood flow and lymphatic drainage, leading to ischemia and subsequent tissue necrosis. The mechanical load exerted by medical devices over bony prominences exacerbates the condition.

Shear and friction

In addition to pressure, shear and friction forces contribute to tissue deformation. For instance, tight oxygen masks or neck collars may cause skin shearing during movement or repositioning, accelerating injury progression.

Microclimate factors

Moisture, temperature, and humidity around device contact sites influence skin integrity. Excessive sweating or fluid leakage under the device can macerate skin, lowering its resistance to pressure and friction.

RISK FACTORS ASSOCIATED WITH MDRPIS

Table 2: Risk Factors for Medical Device-Related Pressure Injuries

Risk Factor Category	Examples	Impact on MDRPI Development
Patient-related	Age >65, diabetes, malnutrition	Increases susceptibility to tissue injury
Device-related	Rigid materials, improper sizing	Direct mechanical pressure on skin
Care-related	Poor staff training, infrequent inspection	Delayed detection and intervention
Environmental	Moisture, friction, heat	Skin maceration and tissue compromise

Patient-related factors.

Elderly individuals, neonates, and critically ill patients have thinner skin and reduced tissue perfusion, predisposing them to MDRPIs. Nutritional deficiencies, poor perfusion, diabetes, and prolonged sedation further increase risk.

Device-related factors.

Rigid materials, improper sizing, and poor fixation of devices are key contributors. The design of certain devices lacks ergonomic consideration for prolonged use, increasing the risk of skin

compromise.

Environmental and care-related factors.

Inadequate staff training, prolonged device use without repositioning, and limited skin assessment protocols amplify MDRPI development in clinical settings.

ASSESSMENT AND DIAGNOSIS

Clinical assessment.

A thorough skin inspection should be conducted every 2–4 hours, focusing on device contact areas. Any visible erythema, indentation, or blister formation should prompt device adjustment or removal. The use of pressure mapping systems has enhanced the ability to detect high-risk areas before visible injury appears.

Documentation.

Accurate documentation of device type, duration of use, and injury characteristics is crucial. Photographic evidence and staging using the NPIAP classification aid in consistent monitoring and treatment planning.

PREVENTIVE STRATEGIES

Image 2: Preventive Strategies for MDRPIs

Device modification and innovation.

The development of softer, flexible materials and pressure-redistributing interfaces can reduce tissue stress. Manufacturers are incorporating 3D printing and biocompatible materials to improve ergonomic designs.

Clinical protocols.

Routine assessment protocols emphasizing device repositioning every 2 hours have shown to reduce incidence rates. Incorporating MDRPI risk into standard care plans ensures continuous vigilance.

Protective dressings.

Silicone foam dressings, hydrocolloid films, and gel-based barriers applied under devices help to minimize friction and shear. Their use is particularly effective in high-pressure zones like the nasal bridge and ears.

Education and training.

Regular staff training sessions on early identification and preventive techniques significantly reduce MDRPI rates. Simulation-based education programs have shown promising outcomes in nursing skill enhancement.

CHALLENGES IN MANAGEMENT

Underreporting and misclassification.

Many MDRPIs go unreported due to lack of awareness or fear of blame. Some injuries are misclassified as traditional pressure ulcers, leading to inappropriate treatment strategies.

Limited evidence-based guidelines.

Although organizations like NPIAP provide general recommendations, comprehensive, device-specific guidelines remain scarce, particularly in low-resource settings.

Resource constraints.

In developing countries, limited availability of advanced dressings, monitoring technologies, and trained personnel hinders effective MDRPI prevention.

Patient compliance.

In conscious patients, discomfort from repositioning or device adjustment can lead to non-cooperation, complicating preventive measures.

TECHNOLOGICAL ADVANCEMENTS AND INNOVATIONS

Sensor-based monitoring.

Smart devices integrated with pressure sensors and skin temperature monitors can provide real-time alerts for pressure redistribution, significantly enhancing early prevention.

Artificial intelligence (AI) applications.

AI algorithms can predict high-risk patients using data from electronic health records, enabling proactive preventive interventions.

Telemonitoring and remote assessment.

Telehealth systems allow specialists to evaluate skin integrity remotely, especially beneficial for patients using home medical devices such as CPAP or oxygen concentrators.

SCOPE AND FUTURE DIRECTIONS

The future of MDRPI prevention lies in multidisciplinary collaboration, combining clinical expertise with technological innovation. Integration of AI-driven predictive models, personalized device fittings, and patient-centered care approaches can revolutionize prevention. Furthermore, promoting global reporting systems and standardized documentation can facilitate comparative studies and improve clinical outcomes. Nursing education curricula should incorporate MDRPI awareness as a core component to strengthen clinical competency in prevention.

CONCLUSION

Medical Device-Related Pressure Injuries represent a preventable but underrecognized healthcare issue with significant implications for patient safety and quality of care. Their prevention requires a multifaceted approach encompassing risk assessment, device innovation, and staff education. Nurses play a central role in identifying early signs and implementing preventive measures. As healthcare systems increasingly rely on medical devices, proactive strategies and continuous research are essential to minimize MDRPI occurrence. By integrating technology, education, and evidence-based practice, healthcare professionals can ensure safer, more patient-centered care environments.

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Medical Device-Related Pressure Injuries: Understanding Prevalence, Pathophysiology, Prevention Strategies, And Nursing Implications For Improved Patient Safety In Healthcare Settings

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ABSTRACT

Medical Device-Related Pressure Injuries (MDRPIs) have emerged as a significant and preventable healthcare concern in modern clinical practice. These injuries occur due to prolonged contact between the patient's skin and medical devices such as oxygen masks, endotracheal tubes, nasogastric tubes, cervical collars, and splints. MDRPIs contribute to increased morbidity, longer hospital stays, and elevated healthcare costs. This paper explores the etiology, risk factors, clinical manifestations, and preventive strategies associated with MDRPIs. It also highlights the role of nurses in early identification, prevention, and management of these injuries. Emphasis is placed on evidence-based practices and interprofessional collaboration aimed at minimizing the occurrence of such preventable harm in healthcare facilities.

KEYWORDS: *Medical Device-Related Pressure Injuries, Skin Integrity, Patient Safety, Nursing Management, Prevention, Hospital Care.*

INTRODUCTION

Pressure injuries have long been recognized as a major patient safety issue in healthcare. Among these, *Medical Device-Related Pressure Injuries (MDRPIs)* are distinct in etiology and presentation, as they result from pressure exerted by therapeutic or diagnostic devices rather than traditional immobility. The increasing use of medical devices in both critical and non-

critical care settings has amplified the incidence of MDRPIs, particularly among vulnerable populations such as critically ill, elderly, and neonates.

The National Pressure Injury Advisory Panel (NPIAP) defines MDRPI as localized damage to the skin and/or underlying soft tissue that results from sustained pressure by a medical device. Unlike conventional pressure ulcers, these injuries often mirror the shape or contour of the causative device. MDRPIs can appear on various anatomical sites, including the face, nose, ears, neck, or extremities, depending on the device's application site.

With the ongoing emphasis on patient safety and quality of care, MDRPIs have become an essential area of focus for nursing professionals, requiring a comprehensive understanding of their mechanisms, prevention, and management.

LITERATURE REVIEW

Epidemiology and Prevalence

Recent literature highlights a growing concern regarding the prevalence of MDRPIs in acute care settings. Studies have reported that 10–30% of all hospital-acquired pressure injuries are related to medical devices. Critically ill patients, those in intensive care units, and individuals receiving prolonged oxygen therapy are at particularly high risk.

The face and ears are the most common anatomical sites affected, primarily due to noninvasive ventilation masks and oxygen tubing.

Pathophysiology

The development of MDRPI involves a combination of mechanical and physiological factors. Sustained pressure from the device impairs capillary blood flow, resulting in tissue ischemia and cellular necrosis. Friction, shear, and moisture further aggravate skin breakdown. Unlike traditional pressure injuries, MDRPIs can develop rapidly, often within a few hours of continuous device contact.

Table 1: Common Medical Devices Associated with Pressure Injuries and Their Typical Sites of Occurrence

Medical Device	Common Sites of Injury	Type of Pressure Applied	Examples of Resulting Injury
Oxygen mask / Nasal cannula	Bridge of nose, cheeks, behind ears	Continuous localized pressure	Skin redness, ulceration
Endotracheal tube / Bite block	Lips, corners of mouth, tongue	Sustained compression	Oral mucosal breakdown
Cervical collar	Chin, occiput, shoulders	High interface pressure	Deep tissue injury
ECG electrodes / Pulse oximeter probes	Chest, finger, toe	Low but prolonged pressure	Circular or oval skin lesions
Orthopedic splints / Casts	Ankles, heels, wrists	Uneven device contact	Skin maceration, necrosis
Nasogastric / Feeding tubes	Nostrils, nasal bridge	Continuous friction	Nasal erosion or ulceration

Risk Factors

Several patient and device-related factors contribute to the development of MDRPIs:

- **Patient-related factors:** Immobility, poor nutrition, edema, moisture, impaired sensation, advanced age, and critical illness.
- **Device-related factors:** Inadequate padding, tight application, poor design, and prolonged use without repositioning.
- **Environmental factors:** High humidity, improper fixation techniques, and lack of staff awareness.

Impact on Patient Outcomes

MDRPIs increase patient discomfort, prolong hospital stays, raise the risk of infection, and escalate healthcare costs. In addition, they negatively affect patient trust and institutional reputation, often leading to financial penalties in hospitals where such injuries are classified as preventable adverse events.

PATHOGENESIS OF MDRPIs

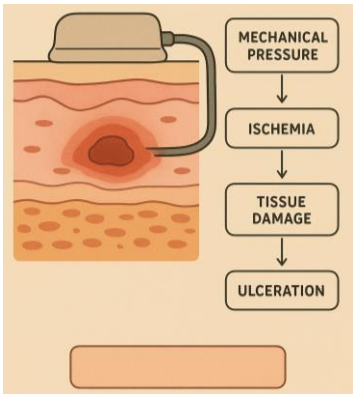

Image 1: Conceptual Diagram of the Pathophysiology of Medical Device-Related Pressure Injury

Pressure and Ischemia

When medical devices exert sustained pressure on the skin, especially over bony prominences or cartilage, the blood flow to the area becomes restricted. This hypoxia leads to cellular injury, inflammation, and eventual tissue necrosis.

Shear and Friction

During patient repositioning or due to improper device adjustment, shear forces can distort capillary structures. Friction between the device and skin surface further damages the stratum corneum, compromising skin integrity.

Moisture and Microclimate

Moisture accumulation beneath medical devices, particularly under oxygen masks and tracheostomy tubes, softens the skin and increases susceptibility to breakdown. The local microclimate plays a crucial role in determining skin resilience against mechanical stress.

ASSESSMENT AND IDENTIFICATION

Early Detection

Nurses play a pivotal role in early identification of MDRPIs. Frequent skin assessments, especially under medical devices, are essential. Visual inspection for redness, blanching, or device-shaped marks should be part of every nursing shift assessment.

Assessment Tools

Several standardized tools, such as the Braden Scale and the NPUAP Staging System, can aid in assessing risk and categorizing the severity of MDRPIs. However, specific tools tailored for device-related injuries are still under development.

PREVENTION STRATEGIES

Table 2: Preventive Nursing Interventions for Common Device-Related Pressure Injuries

Device Type	Preventive Nursing Actions	Frequency of Monitoring	Additional Measures
Oxygen mask / Tubing	Reposition tubing every 2 hours, apply foam dressing under pressure points	Every 2 hours	Check for skin moisture
Endotracheal tube	Alternate fixation side, assess oral mucosa integrity	Every 4 hours	Maintain adequate humidification
Cervical collar	Remove for skin inspection if clinically safe, use soft padding	Every 6 hours	Reassess collar fit daily
IV lines / Catheters	Secure gently with non-adhesive tapes, inspect for redness	Every shift	Keep site dry and clean
Pulse oximeter probe	Rotate probe site between fingers/toes	Every 2 hours	Use transparent barrier film
Orthopedic splint	Assess padding adequacy, monitor distal circulation	Every 8 hours	Educate patient on warning signs

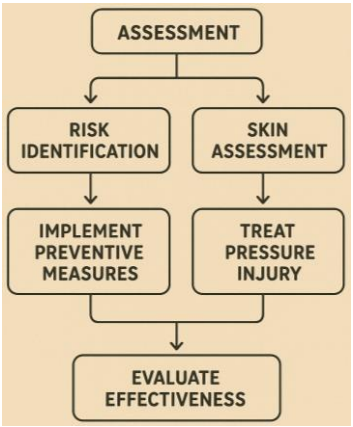

Image 2: Nursing Prevention and Care Flowchart for MDRPIs

Device-Specific Preventive Measures

1. **Respiratory Devices:** Use soft, silicone-based oxygen tubing and ensure periodic repositioning of nasal cannulas.
2. **Endotracheal Tubes and Masks:** Secure devices with minimal tension and regularly alternate fixation sites.
3. **Cervical Collars:** Apply correctly sized collars and insert protective dressings under pressure points.
4. **Orthopedic Splints:** Monitor for tightness and ensure adequate padding around edges.

Nursing Interventions

- Conduct regular skin assessments and document any early signs of injury.
- Educate healthcare teams about MDRPI risks and prevention protocols.
- Use transparent dressings or hydrocolloid barriers beneath devices to reduce friction and distribute pressure.
- Reposition and adjust medical devices at least every 2 hours or as clinically feasible.
- Maintain proper skin hygiene and manage moisture effectively.

Education and Training

Continuous education and competency-based training for nurses and caregivers significantly reduce the incidence of MDRPIs. Simulation-based learning and case studies enhance awareness and practical application of preventive techniques.

CHALLENGES IN MANAGEMENT

Limited Awareness and Training

Despite increased attention, MDRPIs are often underreported due to lack of awareness or inadequate assessment skills among healthcare workers.

Complexity of Device Application

Balancing effective device function with skin protection remains challenging, particularly in critical care, where devices are essential for survival.

Documentation and Monitoring

Inconsistent documentation practices can lead to delayed recognition and intervention.

Integration of electronic health record alerts for skin assessments may improve monitoring efficiency.

Patient Compliance

Patients with cognitive impairment or severe illness may not report discomfort, delaying detection and treatment.

SCOPE FOR FUTURE PRACTICE AND RESEARCH

Innovation in Device Design

Collaboration between clinicians, engineers, and manufacturers is vital to design skin-friendly medical devices with adjustable pressure distribution and soft materials.

Development of Specialized Dressings

Research into advanced biomaterials such as hydrogel or silicone-based protective interfaces can provide long-term protection against pressure injuries.

Artificial Intelligence and Predictive Analytics

Emerging technologies using AI can help predict high-risk patients and recommend preventive measures based on individual risk profiles and device data.

Policy Development and Standardization

Healthcare organizations must adopt evidence-based protocols, integrate MDRPI assessment into routine care standards, and establish institutional accountability for prevention.

ROLE OF NURSES IN MDRPI MANAGEMENT

Patient Advocacy

Nurses are central advocates for patients' skin safety. Their vigilance ensures early identification, timely intervention, and consistent preventive care.

Multidisciplinary Collaboration

Working closely with physicians, respiratory therapists, and biomedical engineers, nurses can coordinate care that balances therapeutic device efficacy with skin protection.

Data Collection and Quality Improvement

Nurses contribute to hospital quality initiatives by reporting MDRPI cases, participating in root cause analyses, and implementing improvement projects.

Education of Patients and Families

Involving patients and caregivers in device care, such as recognizing early signs of redness or discomfort, helps in timely reporting and intervention.

CONCLUSION

Medical Device-Related Pressure Injuries are preventable yet prevalent complications that significantly impact patient well-being and healthcare costs. Recognizing their distinct etiology and risk factors is crucial for effective prevention and management. Nurses, being at the forefront of patient care, hold the responsibility to monitor, educate, and advocate for preventive strategies in all clinical settings. Interdisciplinary collaboration, technological innovation, and policy reinforcement are essential to achieving sustainable reductions in MDRPIs. Ultimately, integrating evidence-based prevention into everyday nursing practice represents a major step toward ensuring patient safety, promoting comfort, and improving the quality of care across healthcare systems.

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