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Wound Research

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What Really Matters in Paediatric Wound Healing:
Sustainability Comes First


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Manifesto

International Journal of Wound Research (IJWR) is an international peer-reviewed scientific journal that promotes the development and exchange of knowledge in wound care research and clinical practice. IJWR supports evidence-based interventions and encourages critical reflection on the science and innovation of wound management.

The journal particularly welcomes studies that evaluate complex wound care strategies and health policies, using rigorous research designs appropriate to clinical and interdisciplinary inquiry. IJWR also aims to strengthen research quality by publishing methodological papers on clinical tools, treatment protocols, and investigative techniques. The journal publishes original peer-reviewed articles of interest to the global wound care community.

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EDITORIAL

58

What Really Matters in Paediatric Wound Healing: Sustainability Comes First

Guido Ciprandi

COMMENT

64

Artificial Intelligence in Wound Care: From Experimental Promise to Clinical Reality

José Verdú Soriano

REVIEW

68

Clinical Use of Platelet-Rich Plasma in Neonatal and Pediatric Populations: A Scoping Review

Elisa Caneschi, Benedetta Difalco, Raffaele Barbato, Hugo Miguel Sousa

RESEARCH

80

Integration of Artificial Intelligence in Specialist Nursing Education: Experiences of an Innovative Pedagogical Strategy in Tissue Viability

Alexandre Marques Rodrigues, Alexandra Alves Cardoso, Inês Margarida de São Bento Coelho, Lucília da Silva Carvalho, Mariana Isabel Leal Pereira da Silva, Marina Margarido Ribeiro Santos, Paula Isabel Moura Pena, Rita Mariana Valente Figueiredo, Marta Susana Martins da Silva

RESEARCH

94

Nurses' Knowledge and Practice Gaps in Incontinence-Associated Dermatitis: Findings from a Cross-Sectional Survey

Serena Zecca, Marika Zappulla, Biagio Nicolosi

RESEARCH

106

Physiotherapy Management in Pediatric Burns: A Five-Year Experience Comparing Children and Adolescents at a Tertiary Burn Center

Margherita Cerboneschi, Marta Cervo, Giorgia Silli, Laura Baroni

QUALITY IMPROVEMENT REPORTS

116

A Corporate Model for the Prevention and Monitoring of Neonatal and Pediatric Skin Injuries: A Four-Year Quality Improvement Study

Eleonora Bastarelli, Elia Carbone, Serena Galluzzi

PROCEDURES UPDATE

128

Hyaluronic Acid in Wound Management: An Update on Formulations, Mechanisms, and Clinical Applications

Biagio Nicolosi, Karolina Kruszezwska, Viviana Gonçalves

The Extracellular Matrix

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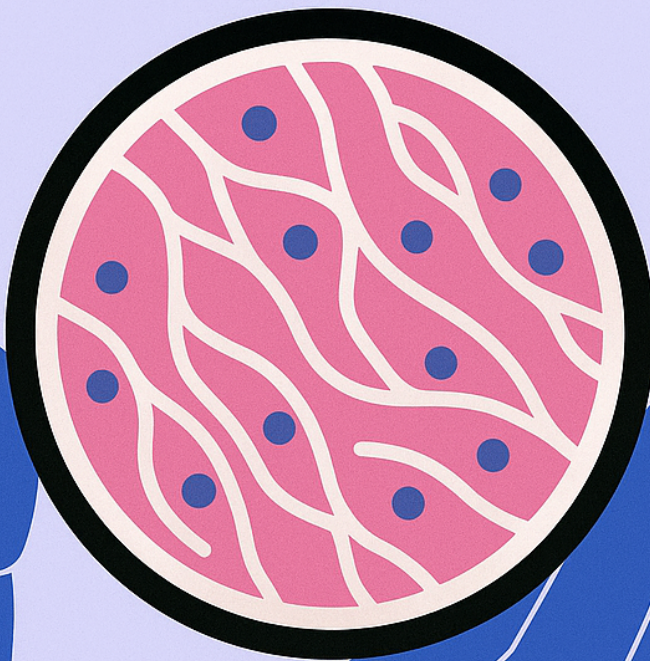
More Than a Scaffold

Once regarded as a passive scaffold, the extracellular matrix (ECM) of the skin is now recognized as a dynamic structural and signaling network that orchestrates cutaneous homeostasis¹. In the dermis, fibrillar collagens, elastic fibers, and proteoglycan-rich ground substance create a remodeled microenvironment that regulates adhesion, proliferation, and migration^{1,2}. Dermal fibroblasts adjust ECM composition through controlled secretion of collagens, elastin-associated proteins, and matrix-remodeling enzymes^{1,3}.

Mechanical forces—such as tension and micro-deformation—are transmitted through integrins and focal adhesion complexes, activating YAP/TAZ-dependent programs that shape ECM architecture⁴. When this circuitry is disrupted, as in inflammation or photoaging, collagen disorganization and loss of elastic fiber integrity reduce dermal resilience^{2,4}.

Single-cell and spatial transcriptomic studies also reveal multiple fibroblast subtypes with specialized matrix-building or remodeling roles³. These subsets integrate mechanical and inflammatory cues to coordinate ECM renewal, scarring, or regenerative repair^{1,3}.

Together, these insights redefine the ECM as a central dermal hub, integrating structure, mechanotransduction, and inflammatory signaling rather than functioning as a passive scaffold^{1,2}.



in Focus: Key Discoveries

Key Scientific Highlights

Consensus Maps of Dermal Fibroblast Subtypes and ECM Niches

A recent single-cell and spatial genomics atlas of human skin has identified multiple dermal fibroblast subpopulations with distinct transcriptional programs and disease-associated phenotypes³. These subsets localize to specific ECM niches and differ in collagen synthesis, matrix-remodeling capacity, and cytokine production, providing a mechanistic framework for how the dermis balances homeostasis, scarring, and chronic inflammation^{3,5}. This work establishes fibroblast lineage diversity and microanatomical positioning as key determinants of ECM behavior in health and disease.

YAP/TAZ-Centered Mechanotransduction as a Master Regulator of Dermal Architecture

Breakthrough studies have shown that fibroblast responses to matrix stiffness and mechanical load are coordinated through integrin–FAK complexes and YAP/TAZ activation, which together regulate genes controlling collagen deposition, contractility, and fibrotic remodeling^{4,6}. In human skin, age- and disease-related alterations in YAP/TAZ signaling are now linked to changes in dermal ECM integrity and elastic fiber organization⁶. These findings position YAP/TAZ-mediated mechanotransduction as a central switch that couples physical forces to long-term structural remodeling of the dermal matrix.

ECM-Targeted Therapies and Decellularized Matrix Scaffolds in Skin Repair

Updated reviews and preclinical studies demonstrate that the ECM is not only a structural framework but also a bioactive regulator of wound healing, shaping cell recruitment, angiogenesis, and scar formation¹. Building on this concept, next-generation ECM-based biomaterials and decellularized extracellular matrices (dECM) have been engineered to preserve key matrix cues and growth factor-binding sites^{7,8}. In skin models, dECM dressings have been shown to accelerate re-epithelialization and shorten the healing time of chronic wounds, highlighting ECM-informed scaffolds as promising therapeutic tools that harness the matrix itself as a driver of regeneration^{1,8}.

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What Really Matters in Paediatric Wound Healing: Sustainability Comes First

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After seven years since the first “Garden Class”, built around the benefits of a more natural and ecological approach to wound healing, particularly in Paediatric Wound Care, sustainability has now become fashionable.¹

From the EPUAP Annual Conference in Rome in 2018 to today, industry has at last begun to move in this direction. Yet it is worth recalling that sustainability is, above all, about sustaining: providing support to clinicians and to vulnerable patients, in ways that are environmentally respectful but, above all, rooted in prevention.²

The World Health Organization estimates that children under five years of age account for 88% of the global disease burden attributable to climate change. Owing to their physiological and neurodevelopmental immaturity, elevated metabolic rate, lower body mass, and pronounced dependence on caregivers, children constitute a population disproportionately susceptible to the adverse health effects arising from a rapidly changing climate.³

Avoiding any form of resource waste is essential, diverting funds away from war-related markets would, on its own, bring us closer to a real solution. And children would no longer draw attention for becoming angels, but for enjoying a better future, one where paediatric wound healing plays a more active and responsible role in education and culture.⁴

Wound healing in paediatric patients is of critical clinical, familial, and social significance, as outcomes such as hypertrophic and keloid

scarring can entail functional, aesthetic, and psychological consequences from early childhood through to late adolescence, consequences not typically observed in adults.⁵ When the fourth dimension, namely growth, is taken into account, scars and likewise the sustainability of care, constitute a lifelong temporal trajectory, unlike in later stages of life.⁶

Wound healing therefore represents a regenerative and reparative response, orchestrated at the tissue, cellular, molecular, and submolecular levels, directed towards restoring the injured tissue. This process calls for procedures, dermo-epidermal substitutes, matrices, advanced dressings, and mechanical devices, all of which demand a mature and responsible approach to environmental impact, owing to the long-term nature of both immediate and future care pathways.

There must be a shift towards a healthier balance between supporting the economy and safeguarding the social and environmental systems on which healthcare depends. In wound healing, sustainability means improving outcomes so that fewer resources are required, developing efficient and eco-friendly products, and ensuring timely access to care to reduce waste and unnecessary travel. Only innovation that is fully aware of its risks can deliver meaningful benefits for clinicians, patients, the economy and the natural world.

Sustainable wound care focuses above all on faster healing, which reduces the

volume of dressings, packaging and clinical waste. Reusable options, such as two-layer compression stockings, and smart technologies that monitor healing can further cut waste and prevent needless product changes. More efficient care pathways, including remote consultations (i.e. telemedicine), without an in-person visit, help minimise patient travel and associated emissions.

Equally important is the development of greener products: sourcing materials from renewable resources, applying principles of green chemistry, and designing biodegradable polymers that break down safely while supporting healing. Within healthcare systems, approaches such as Lean Six Sigma (and its own framework, DMAIC, Define, Measure, Analyze, Improve, Control) strong preventative strategies and continuous staff education are essential to embed sustainable practice.⁷

Recent advances in materials science have enabled the engineering of wound dressings comprising polymers, nanocomposites, contact layers, foams, hydrocolloids, hydrogels, hydrofibres, alginates, composite dressings, occlusive dressings, Ag and Cu dressings, antimicrobials, transparent films, growth-factor delivery systems, collagen matrices, xenograft and synthetic matrices, biological dressings, enzymatic debridement scaffolds, NPWT dressings, bioengineered dressings.

In addition multifunctional platforms appeared incorporating drugs, with or without biosensors, or with both therapeutic and diagnostic elements. Despite these innovations, systematic integration of green chemistry principles remains limited. Lifecycle considerations—‘cradle to grave’—necessitate renewable feedstocks, energy-efficient and benign manufacturing routes, and post-use biodegradability.

Emerging strategies to embed sustainability include biopolymer utilisation, enzymatic catalysis in the place of chemical catalysts, green solvents (DES), cheap, less toxic and with a recyclable nature. Not to mention the microwave-assisted synthesis as a unique and simple technique which offers fast and efficient processing of materials with higher reproducibility and the continuous-flow catalysis allowing for an efficient and non-stop production.^{8,9}

The clinical history teach us that pediatric malnutrition resulting from disrupted food

supplies adversely affects wound healing. Prenatal exposure to extreme heat, air pollution, and infectious diseases is associated with low birthweight, preterm birth, and congenital anomalies. Climate-related alterations in air pollutants and aeroallergens increase the incidence of respiratory disease and influence perioperative risk. Furthermore, access to surgical care is frequently compromised by climate-related disasters and ecological change.

More recently, the term sustainability is widely used for wound care programmes and actions aimed at preserving resources, but it actually covers four scientific chapters: human, social, economic and environmental.

Human wound healing sustainability focuses on maintaining and enhancing society's human capital. It includes investment in health-economics, basic and advanced education, rapid access to public health services, good and regular nutrition, acquaintance and interactive skills. As natural resources and space are limited, growth must be balanced with public health and shared economic wellbeing.

In wound care business, a responsible growing market organisations promotes values that respect human capital and its ethical and moral integrity, especially when it fully involves family units.

This includes everyone involved in producing goods or providing services, as well as wider stakeholders. Communities worldwide may benefit from—or be harmed by—business practices and sourcing methods. Human sustainability therefore involves building skills and capacity to support organisational performance while promoting the wellbeing of communities and society. And greater sensitivity must be felt when discussing wounds in fragile patients, at both ends of life, often fully dependent on family or social caregivers and suffering from severe comorbidities that ultimately represent the underlying pathology.

Social sustainability preserves social capital by supporting the services and structures that hold society together. It considers the wider impact of our actions on communities, cultures and future generations. Its focus is on social quality—cohesion, trust, reciprocity and strong relationships—supported by laws, shared rights and equality. It aligns with the UN Sustainable Development Goals, recognising that social, economic and environmental wellbeing are

interdependent.

Economic sustainability seeks to maintain capital and improve living standards. Critics argue that traditional accounting ignores environmental damage. New economic thinking incorporates natural and social capital, challenging the assumption that continuous growth is always beneficial.

Environmental sustainability aims to protect natural capital—land, air, water and minerals—so present needs are met without harming future generations. Environmentally sustainable businesses pursue economic success while avoiding environmental harm, and integrate all four pillars of sustainability equally.

Together, the four pillars highlight that genuine sustainability requires addressing each dimension and making strategic choices about which approach a business will prioritise.^{10,11} And finally, Sustainability is far more than a fashionable term. It is a way of living that helps safeguard the future of our planet and the generations to come. By encouraging sustainable habits in children from an early age, we set them on the path to becoming responsible citizens who value and protect the environment.

But how can we make such an important concept both accessible and engaging for young learners? Through simple, everyday actions and routines, we can introduce children to the principles of sustainability in ways they can easily grasp and genuinely enjoy. Respect for oneself, for others, and for everything around us begins with adults, and extends to teenagers and adolescents, along with the desire to manage a wound without waste, without throwing away excessively and irresponsibly produced packaging. We increasingly live on "special" waste, which is abundant for wound healing and represents an enormous cost to current society and unsustainable for the future. But sustainability is last on our minds, and one need only consider the dozens of books that discuss AI and its connections to understand how Reduction, Reuse, and Recycling don't even involve respect for trees.

Sustainability that fails to value life is, by definition, unsustainable.

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Artificial Intelligence in Wound Care: From Experimental Promise to Clinical Reality

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The Global Burden of Wounds and the Need for Transformation

Wounds constitute a major global healthcare challenge, affecting millions of individuals and consuming substantial healthcare resources. Chronic wounds, in particular, are associated with prolonged healing times, high recurrence rates, and significant impacts on patient quality of life.¹ Despite advances in dressings, biomaterials, and multidisciplinary care models, wound assessment and management remain highly dependent on subjective visual inspection and clinician experience.

This reliance on subjective assessment contributes to inter-observer variability and inconsistent clinical decision-making. As healthcare systems face increasing pressure from aging populations and chronic disease, there is a clear need for tools that improve objectivity, efficiency, and standardization in wound care.

Artificial intelligence (AI) has emerged as a promising candidate to address these challenges. By leveraging machine learning (ML), deep learning (DL), and computer vision, AI systems can analyse complex wound data at scale and support more consistent clinical evaluation.²⁻⁴

Current Applications of AI in Wound Care

The most mature applications of AI in wound care are image-based. AI models have demonstrated the ability to detect wounds, segment wound boundaries, classify wound types, identify tissue components, and quantify wound size and depth.²⁻⁴ These capabilities are particularly relevant in conditions such as diabetic foot ulcers, pressure injuries, venous leg ulcers, and burns.

Beyond static assessment, AI has increasingly been applied to **longitudinal monitoring and prediction**. Predictive models integrating wound images with clinical and electronic health record data have been developed to estimate healing trajectories and identify wounds at risk of delayed healing or complications.³ Such approaches support earlier intervention and more personalized care planning.

A notable recent development is the framing of AI within **wound repair theragnostics**, integrating diagnosis, monitoring, prediction, and treatment guidance into a closed-loop system.⁵ This paradigm emphasizes the continuous interaction between data acquisition, algorithmic analysis, and therapeutic decision-making, highlighting AI's potential to move beyond isolated tasks toward holistic wound management.

Remote wound monitoring is another rapidly expanding application. Smartphone-based AI systems allow patients or caregivers to capture wound images for automated analysis, facilitating telemedicine and home-based care.^{3,6} Human-centred innovations, such as marker-free wound measurement using anatomical references, further enhance usability and scalability in real-world settings.⁶

Clinical Opportunities and Practical Benefits

AI-assisted wound care offers several practical advantages. Automated measurement and documentation can reduce clinician workload and improve consistency, addressing long-standing challenges in wound care practice.^{2,3} Standardized assessments may also improve communication across care teams and settings.

From a systems perspective, predictive analytics may enable a shift from reactive to proactive wound management, optimizing resource allocation and potentially reducing complications and costs.⁵ Importantly, AI systems are best positioned as decision-support tools, augmenting clinical expertise rather than replacing professional judgment.

Barriers to Translation and Real-World Adoption

Despite encouraging progress, significant barriers limit widespread clinical adoption. Many AI models are trained on small, single-center datasets that lack diversity in wound types, imaging conditions, and skin tones, restricting generalizability.^{3,5} Data fragmentation and the absence of standardized wound datasets further impede model validation and comparison.

Algorithm transparency and interpretability remain critical challenges. Black-box models may undermine clinician trust and limit accountability, particularly when AI outputs influence clinical decisions.⁴ These concerns are amplified by unresolved legal and ethical issues surrounding data privacy, liability, and informed consent in AI-driven healthcare.⁷

Ethical, Legal, and Professional Considerations

The ethical deployment of AI in wound

care requires careful governance. AI systems must respect patient autonomy, ensure data protection, and avoid reinforcing existing biases.⁷ Clear regulatory frameworks are needed to define responsibility and accountability when AI tools are used in clinical decision-making.

Equally important is preserving the clinician–patient relationship. Over-reliance on algorithmic outputs risks marginalizing contextual, psychosocial, and patient-specific factors that are central to wound care. AI should therefore support, not supplant, holistic clinical judgment.^{4,7}

Future Directions

Future research should prioritize multicentre, prospective studies evaluating clinically meaningful outcomes, including healing rates, complication reduction, patient-reported outcomes, and cost-effectiveness.^{3,5} The development of standardized datasets and interoperable digital infrastructures will be essential for scaling AI solutions.

Education and training initiatives are also needed to equip wound care professionals with the skills required to critically appraise and responsibly use AI-based tools.⁴ Interdisciplinary collaboration among clinicians, data scientists, engineers, and ethicists will be key to translating innovation into safe and effective clinical practice.

Conclusion

Artificial intelligence has the potential to transform wound care by enhancing assessment, monitoring, and personalized management. However, its true clinical value will depend on robust evidence, ethical governance, and thoughtful integration into existing care pathways. AI should be embraced as a supportive technology that strengthens expert, patient-centred wound care rather than replacing it.

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Clinical Use of Platelet-Rich Plasma in Neonatal and Pediatric Populations: A Scoping Review

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Abstract

Introduction. Platelet-rich plasma (PRP) is a regenerative therapy that delivers concentrated platelets and growth factors to promote angiogenesis, modulate inflammation, and support tissue repair. While its use is well established in adults, evidence on PRP for neonatal and pediatric wound management remains scarce and heterogeneous. This scoping review aimed to map the existing literature on PRP for cutaneous wound healing in patients aged 0-18 years and to assess the presence of standardized preparation or application protocols.

Methods. The review followed Arksey and O'Malley's methodological framework, enhanced by Levac et al., and was reported according to PRISMA-ScR guidelines. Searches were conducted in PubMed, Scopus, and Google Scholar (January 2014-April 2025), complemented by backward/forward reference screening and gray literature searches. Eligible studies included neonates, children, or adolescents receiving PRP for any cutaneous wound etiology. Data were extracted on study design, population characteristics, wound type, PRP preparation/application, and clinical outcomes.

Results. A total of 1,812 records were identified, with 8 sources meeting inclusion criteria: 4 clinical pediatric wound-care studies, 3 randomized surgical trials, and 1 congress-level protocol. Reported outcomes included rapid healing of neonatal and pediatric surgical dehiscence (mean ~12 days), complete resolution of a chronic neuropathic ulcer within 2 weeks, and >50% ulcer reduction in pediatric chronic graft-versus-host disease. Surgical trials showed reduced fistula formation, postoperative edema, and complications. One transient citrate-related reaction was the only adverse event

recorded. Across studies, substantial heterogeneity in PRP preparation techniques and absence of validated pediatric protocols were observed.

Discussion and conclusions. Findings suggest that PRP is safe and potentially effective for complex wounds and postoperative recovery in neonates and children, especially when conventional treatments are insufficient. However, methodological variability, small sample sizes, and the lack of standardized pediatric protocols limit comparability and clinical implementation. Pediatric-specific challenges – such as limited blood volume, venipuncture difficulty, and risks of iatrogenic anemia – further underline the need for tailored approaches. High-quality, prospective pediatric studies and validated clinical protocols are required to support evidence-based adoption.

Keyword: Platelet-Rich Plasma, PRP, Pediatric Neonatal Wound Healing, Regenerative Medicine, Pediatric Surgical Wound Care

Introduction

Regenerative medicine represents one of the fastest-growing fields in the management of acute and chronic skin injuries. Although advances in advanced dressings and wound-care protocols have significantly improved clinical outcomes, a substantial proportion of wounds – particularly those that are surgically complicated, neuropathic, or associated with systemic comorbidities – continues to exhibit delayed healing or lack of closure, especially in complex surgical wounds and postoperative dehiscence.¹⁻³

In this context, platelet-rich plasma (PRP) has emerged as an innovative and biologically supported therapeutic strategy. PRP is a blood component obtained through centrifugation of autologous or heterologous blood, characterized by a high concentration of platelets and bioactive growth factors released following cellular activation.⁴⁻⁶ Molecules such as platelet-derived growth factor (PDGF), vascular endothelial growth factor (VEGF), transforming growth factor- β (TGF- β), and epidermal growth factor (EGF) play a key role in angiogenesis, cell proliferation, inflammatory modulation, and extracellular matrix deposition, thus promoting tissue repair and modulating inflammatory and proliferative processes.⁷⁻¹⁰

In the adult population, PRP has found wide application – particularly in orthopedics, plastic

surgery, and aesthetic medicine – with growing interest in standardizing the preparation and classification of PRP.¹¹⁻¹³ However, pediatric evidence remains limited and fragmented. Recent studies report promising results regarding the use of PRP for the management of complex wounds and postoperative complications in children, showing reduced healing times, improved outcomes, and a favorable safety profile even in neonates.¹⁴⁻¹⁷ In parallel, experiences in pediatric surgical settings indicate a potential role of PRP in preventing postoperative complications.^{5,6,17,18}

Despite these preliminary data, no standardized protocol currently exists for the preparation and application of PRP in neonatal and pediatric populations. This gap is related to the limited availability of controlled clinical studies, the biological specificities of pediatric age – including limited blood volumes, different tissue response, and safety considerations – and to the methodological variability in preparation procedures reported in the literature.¹¹⁻¹³

The aim of this scoping review is to map the scientific evidence regarding the use of PRP for wound treatment in neonatal and pediatric patients, with particular attention to the types of patients and lesions treated, the protocols described, and clinical outcomes, in order to identify knowledge gaps and guide future research toward the development of shared pediatric protocols.

Methods

This scoping review was conducted with the aim of exploring and synthesizing the available literature on the use of platelet-rich plasma (PRP) in the treatment of skin wounds in neonatal and pediatric populations, with particular attention to the existence of standardized protocols for the preparation and clinical application of PRP in this age group. The choice of a scoping review was driven by the need to map an emerging and rapidly evolving field, in which the available evidence remains fragmented and heterogeneous, and an insufficient number of clinical studies exists to support a traditional systematic review.

The review was designed and performed following the methodological framework originally proposed by Arksey and O'Malley (2005)¹⁹ and subsequently enhanced by Levac et al (2010).²⁰ The reporting of results was guided by the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) recommendations.²¹ Literature search and study selection activities were carried out between January and April 2025.

Research question and PCC framework

The research question was structured using the Population-Concept-Context (PCC) framework, which is recommended for scoping reviews, as reported in Table 1.

Table 1. PCC framework for the scoping review.

P	Neonates, children, and adolescents (0-18 years)
C	Use of PRP for promoting tissue healing
C	Hospital, outpatient, and surgical settings

The primary research question was: "What scientific evidence exists regarding the use of PRP for the healing of skin wounds in pediatric patients, and are standardized protocols available for the preparation and administration of PRP in this population?"

Search strategy

The literature search was conducted in PubMed, Scopus and Google Scholar, chosen to ensure broad coverage of clinical studies, case series, and emerging academic contributions. Manual screening of reference lists (snowballing) was performed to identify further relevant records. In addition to database

searching, both ancestry (backward reference screening) and descendant (forward citation tracking) strategies were applied. Gray literature sources, including conference proceedings and non-indexed pediatric PRP protocols, were also screened. Articles published between January 2014 and April 2025 in Italian, English, Spanish, and Portuguese were considered.

Boolean research strings included, among others: (Pediatric OR neonatal OR children) AND ("platelet-rich plasma" OR PRP) AND (wound OR ulcer OR skin); ("platelet-rich plasma") AND pediatric AND (protocol OR guideline); ("wound healing" OR "wound dressing") AND PRP AND (child OR infant).

Search terms were adapted as needed to maximize sensitivity and capture non-indexed evidence, including preliminary studies and conference abstracts.

Eligibility criteria

Studies were included if they involved patients aged 0-18 and reported clinical use of PRP to promote healing of cutaneous wounds of any origin (surgical wounds, dehiscence, chronic ulcers, wounds secondary to systemic conditions). Case reports, case series, clinical trials, and systematic reviews were eligible.

Studies were excluded if they were: conducted exclusively on adults, animal or in vitro studies, focused on orthopedic or aesthetic PRP applications only

Classification of studies

Given the increasing application of PRP in pediatric surgical practice – particularly in urological surgery – studies involving pediatric surgical wounds were included and analyzed separately, distinguishing interventions targeting the management of complex wounds from intraoperative PRP applications as adjuncts to tissue repair.

Protocol evidence

To complement peer-reviewed evidence, a non-peer-reviewed yet clinically relevant source was included: the PRP protocol presented by Hugo Sousa as an e-poster at the EWMA 2024 conference and published in the Journal of Wound Management abstracts supplement, representing one of the few existing pediatric-specific procedural algorithms for PRP preparation and application.²²

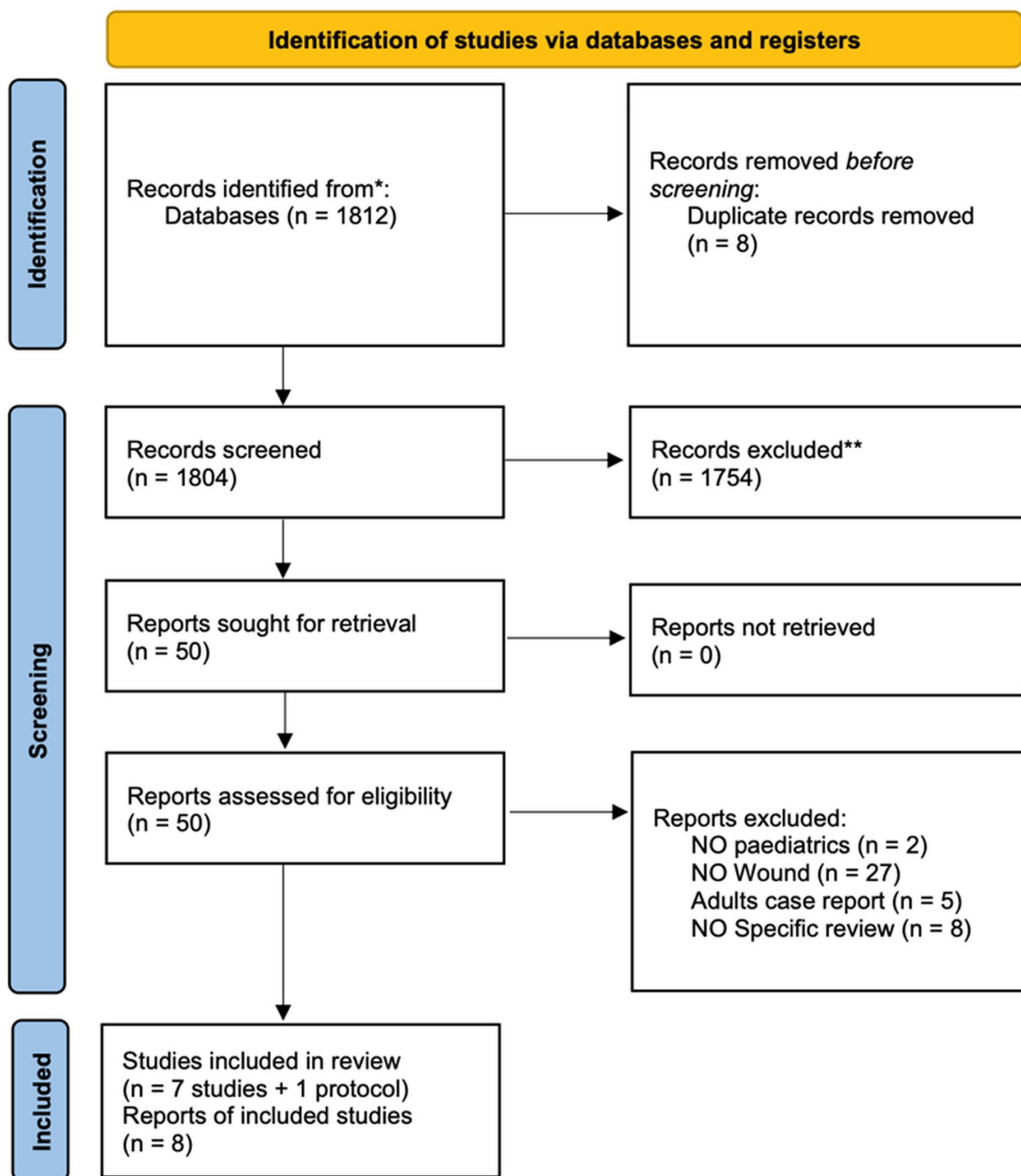


Figure 1. PRISMA flow diagram of study selection. A total of 1.812 records were identified, with 1.804 screened after removing duplicates. Following eligibility assessment, 8 reports (7 studies and 1 protocol) were included in the review on PRP use for wound healing in patients aged 0-18 years.

Data extraction and synthesis

For each study, the following were extracted: author, year, study design, patient characteristics, wound type, PRP preparation/application method (when reported), and clinical outcomes.

Due to the heterogeneity of methodologies, a narrative synthesis was performed, summarized in the PRISMA flow diagram (Figure 1).

Table 2. Characteristics of the included evidence on PRP in neonates, children, and adolescents with acute or chronic wounds, including clinical outcomes and reported application protocols.

Authors, year	Study Design	Population / Setting	Condition	Key Findings	Protocol Reported
Nicolosi B. et al. (2024)	Case series	7 neonates/ children	Surgical wound dehiscence	Complete healing in ~12 days; 1 citrate reaction	Clinical use; no standardized pediatric protocol
Joshi A.D. et al. (2020)	Case report	1 child (11 years)	Chronic neuropathic ulcer	Epithelialization after 3 applications; complete healing in 2 weeks	Weekly PRP; no formal protocol
Mohseni R. et al. (2024)	Randomized Controlled Trial	Pediatric cGVHD patients	Refractory cutaneous ulcers	>50% ulcer reduction in 87.5% vs 6.25% control; no adverse reactions	Umbilical cord PRP protocol; not generalizable
Di Mitri M. et al. (2024)	Systematic review	Pediatric surgical population	Pediatric surgical wounds (e.g., hypospadias)	Reduced postoperative infections and fistulae; promising results	No standardized pediatric protocol identified
RCT Hypospadias Trial A – Full author list not reported (2025)	Randomized Controlled Trial	Children undergoing hypospadias repair	Hypospadias surgical wound	Reduced fistula and complications; improved healing	Intraoperative PRP; not a wound-care protocol
RCT Hypospadias Trial B (African J Urology) – full author list not reported. (2025)	Randomized Controlled Trial	Children undergoing hypospadias repair	Hypospadias surgical wound	Significant fistula reduction vs controls	Intraoperative protocol only
RCT Circumcision Trial (J Clin Med) – full author list not reported (2025)	Randomized Controlled Trial	Children undergoing circumcision	Post-circumcision wound	Reduced edema/ bleeding; faster healing	Intraoperative PRP application
Sousa H.M. and Gonçalves V. (2024)	Conference protocol (EWMA poster)	Pediatric complex wound care	Pediatric complex wounds	Detailed pediatric PRP/PRF procedural algorithm presented	Yes – pediatric PRP protocol (experimental)

Results

The initial search identified 1.812 records. After removal of duplicates and preliminary screening, 50 articles were assessed in full text. In total, 8 sources met the inclusion criteria: 4 studies on PRP in pediatric wound care, 3 randomized trials evaluating PRP in pediatric surgical wounds, and 1 congress protocol (Table 2).

The included studies indicate that PRP may represent a valuable therapeutic option for complex pediatric wounds.

Evidences in Neonates

Nicolosi B. *et al.* (2024) reported complete healing of surgical dehiscence in seven

neonates and children within a mean of 12 days, demonstrating rapid clinical benefit and treatment safety, with only one transient adverse reaction related to the anticoagulant.^{4,14}

Joshi A.D. *et al.* (2020) documented the case of a child with a chronic neuropathic ulcer refractory to conventional treatments, achieving complete epithelialization within two weeks following weekly PRP applications.^{14,15}

Mohseni R. *et al.* (2024), in randomized clinical trial, observed significant improvements in the healing of ulcerative lesions associated with cutaneous graft-versus-host disease (cGVHD), with >50% reduction in ulcer area in the majority of patients treated with cord-blood platelet gel.^{8,10,16}

Di Mitri M. *et al.* (2024), through a systematic review, confirmed that PRP is associated with lower postoperative complication rates in pediatric surgery, although standardization of preparation and application techniques is still lacking.^{12,13,17}

Collectively, these studies suggest good tolerability, absence of major adverse events, and encouraging clinical outcomes in the management of complex pediatric wounds.^{5,18}

Evidence in Children and Adolescents

Three randomized controlled trials in pediatric urological surgery (hypospadias repair and circumcision) consistently reported reduced postoperative fistula formation, edema, and bleeding, and accelerated wound healing.^{1,3}

The randomized trials identified, conducted predominantly in pediatric urological surgery (hypospadias repair and circumcision), showed reduced fistula formation, decreased postoperative edema and bleeding, and improved surgical healing times. However, these studies describe intraoperative procedures rather than structured protocols for complex wound management or postoperative follow-up. Therefore, although confirming the biological effectiveness of PRP in pediatric tissues, they do not provide practical recommendations generalizable to pediatric wound care.^{2,23}

The protocol presented by Sousa & Gonçalves (2024) represents a valuable source, as it outlines an operational algorithm for the preparation, centrifugation, and application of PRP and PRF, which can potentially be adapted to clinical context and pediatric physiological constraints. Although not yet validated through controlled clinical studies, it constitutes the first structured protocol proposed in this field.^{11-13,22}

Overall, available evidence suggests that PRP is a promising and safe treatment in pediatrics, promoting faster healing of complex wounds and demonstrating good tolerability even in neonates. However, no shared and standardized protocol currently exists for this population. The Sousa protocol represents a pioneering contribution but requires scientific validation and multidisciplinary consensus.^{4-6,12,13}

In addition to clinical outcomes, mechanistic studies indicate that PRP supports wound healing by modulating inflammation, enhancing fibroblast recruitment, stimulating angiogenesis, and promoting extracellular matrix remodeling.^{4,7,8,10}

Discussions

This scoping review highlighted a growing interest in the use of PRP for the treatment of neonatal and pediatric wounds, despite the limited number of structured clinical studies and the marked methodological heterogeneity. The findings suggest a relevant potential for this therapy in clinical scenarios where conventional treatments prove insufficient, while simultaneously emphasizing the need for specific protocols and further scientific evidence. This observation is consistent with the broader literature on the role of platelets and growth factors in activating the regenerative cascade and the wound-healing process.

Clinical Evidence and Therapeutic Potential

The included studies reported encouraging results regarding the efficacy and safety of PRP in the management of complex pediatric wounds. In particular, Nicolosi *et al.* described complete healing within a mean of 12 days in seven neonatal and pediatric patients with surgical dehiscence, with no adverse events reported.¹⁴ The only adverse event attributable to PRP use in pediatrics is documented in a case report, described as a transient event related to the citrate anticoagulant.²⁴ Similarly, Joshi *et al.* reported rapid resolution of a neuropathic ulcer refractory to conventional treatments in an 11-year-old child.¹⁵ These findings support the evidence that platelet-derived products can accelerate cellular proliferation, angiogenesis, and tissue remodeling, as previously demonstrated in preclinical and clinical studies in non-pediatric populations.

The randomized clinical trial by Mohseni *et al.* further demonstrated significant benefit from cord-blood-derived platelet gel in ulcerative lesions associated with cGVHD, with more than 50% reduction in ulcer area in 87.5% of treated patients.¹⁶ These results confirm the biological role of PRP in activating regenerative processes, even in complex clinical conditions.^{4-6,11} The role of platelet-derived growth factors and inflammatory modulation is well documented.⁷⁻⁹

PRP has also been successfully used in pediatric surgical contexts, particularly in hypospadias repair and other urological procedures. Although these studies reported reduced fistula formation, edema, and infectious complications, they primarily describe intraoperative applications and cannot be directly translated into protocols

for postoperative wound care or advanced dressings.²⁵⁻²⁷ This limits the generalizability of those results to the management of chronic or complex wounds.^{2,18}

The use of PRP in surgery aligns with consolidated evidence supporting the intraoperative use of biological materials and sealants.^{1,25,28} However, such applications have limited impact on the nursing-driven postoperative wound-care pathway, as described in studies on surgical wounds healing by secondary intention.^{3,23,29}

Methodological Variability and Lack of Standardized Protocols

A clear finding was the absence of standardized protocols for the preparation and application of PRP in pediatric patients. Several studies highlight that variables such as centrifugation settings, platelet concentration, potential activation, and the purity of the preparation influence clinical outcomes.^{5,11,12} Such methodological variability limits reproducibility and makes it difficult to compare existing studies, as already noted in adult and regenerative-medicine contexts.^{5,6}

This heterogeneity is also reflected in consensus documents aimed at standardizing PRP.¹³ Specific pediatric methodological guidelines are still lacking, as also noted in recent clinical reviews.⁶

The only operational reference identified was the protocol presented by Sousa and Gonçalves at the EWMA 2024 congress, proposing a preliminary algorithm for adults.²² However, this constitutes congress-level evidence not yet clinically validated.^{1,18}

Pediatric Specificities: Practical and Safety Considerations

The management of PRP in pediatric patients poses specific challenges, particularly in neonates, where the available blood volume is limited.^{30,31} Multiple blood draws may alter homeostasis and lead to hemodynamic instability, especially in patients weighing <2,500 g, where guidelines recommend limiting blood sampling volumes to less than 1-2% of total blood volume.^{32,33} This supports the growing interest in alternatives such as heterologous PRP or cord-blood platelet gel, which has demonstrated safety in the included pediatric RCT.¹⁶

Vascular fragility and reduced circulating blood volume in neonates are also critical factors in the pathophysiology of tissue repair.^{8,34}

Further challenges relate to the difficulty of venipuncture in neonates and the need for

atraumatic techniques to minimize pain and stress, in accordance with pediatric and neonatal nursing recommendations.^{32,35,36}

Nursing implications

The introduction of PRP in pediatric care opens new perspectives for advanced nursing practice. Nurses play a crucial role in blood collection, PRP preparation, clinical application, and monitoring for adverse reactions, as well as caregiver education.^{5,37}

The development of a structured and validated protocol would promote standardized management, reduce clinical variability, and ensure an evidence-based approach, while also supporting the advancement of specialized nursing competencies.^{11-13,37}

This direction is consistent with the expanding nursing role in advanced wound-bed management and regenerative therapies.^{1,38,39}

Prospective, multicenter studies with larger cohorts are needed, reporting standardized technical parameters and clinical outcome indicators.^{4,6}

The definition of pediatric-specific guidelines, particularly for neonates and hematologically fragile patients, is a priority to ensure the safe and appropriate adoption of PRP in pediatric wound management.

Limitations

This scoping review is limited by the small number of available studies, heterogeneity of PRP preparation techniques, and the predominance of small case series and surgical trials. The inclusion of one non-peer reviewed protocol further reflects the scarcity of standardized pediatric data. The absence of multicenter prospective studies restricts generalizability and prevents robust comparison across different PRP methodologies.

Conclusions

This scoping review highlights the emerging therapeutic potential of PRP in the management of pediatric and neonatal wounds. Although the current evidence base remains limited and largely heterogeneous, preliminary findings suggest that PRP may promote accelerated wound healing, reduce postoperative complications, and demonstrate an acceptable safety profile even in vulnerable populations such as neonates.

At present, the absence of standardized pediatric preparation and administration

protocols represents a major barrier to widespread clinical adoption. Variability in centrifugation techniques, platelet concentration, activation procedures, and clinical application methods limits comparability across studies and hinders the development of evidence-based clinical pathways. Moreover, unique pediatric physiological characteristics – including restricted blood volumes, vascular fragility, and distinct wound-healing mechanisms – require tailored approaches and careful safety considerations.

Future research should prioritize well-designed, prospective, multicenter trials with defined clinical endpoints and harmonized methodological criteria. The development of pediatric-specific consensus guidelines and standardized protocols is essential to ensure safe, effective, and ethically appropriate implementation of PRP in clinical practice. Collaboration between clinicians, researchers, and nursing professionals is critical to advancing knowledge, refining indications, and optimizing care pathways.

In conclusion, while PRP represents a promising regenerative tool for pediatric wound care, robust clinical validation and standardized frameworks are needed to translate its biological potential into consistent, high-quality clinical outcomes for children and neonates.

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Integration of Artificial Intelligence in Specialist Nursing Education: Experiences of an Innovative Pedagogical Strategy in Tissue Viability

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Abstract

Introduction. Artificial intelligence (AI) has emerged as a transformative tool in health education, with the potential to enhance scientific literacy, critical thinking, and evidence-informed decision-making. In specialist nursing education, particularly within tissue viability, innovative pedagogical strategies are required to strengthen research competencies. This study aimed to analyse and to compare the integration of AI as an educational support tool through two applied case studies.

Methods. Within a specialist/master's nursing curriculum, students formulated structured research questions, performed systematic database searches, and interacted with AI tools using predefined inclusion and exclusion criteria. Two case studies were developed: (i) caregiver burden in diabetic foot ulcers and (ii) coping strategies in ostomy patients. Traditional narrative and integrative literature reviews (PubMed, Scopus, Web of Science, EBSCO, B-On) were compared with AI-assisted searches (ChatGPT-4.0, SciSpace, Consensus). Data were screened, extracted, and analysed through thematic analysis.

Results. In the first case study, both traditional and AI-assisted searches identified the same three eligible studies addressing

version and the Version of Record.

Competing Interests: The author(s) declare(s) no conflict of interest.

caregiver burden. Common factors included female gender, low income, low educational level, high caregiving workload, limited social support, and poor communication with health professionals. AI retrieval was faster but required human critical appraisal. In the second case study, three studies on coping strategies in ostomy patients were identified, highlighting active information-seeking, professional guidance, peer support, cognitive reframing, and religious or social support. AI outputs overlapped with these findings and emphasised emotional and cognitive dimensions such as acceptance and self-efficacy.

Discussion and conclusions. The integration of AI improved the efficiency of evidence retrieval and supported enriched thematic analysis. Although it did not replace methodological rigour or human critical reasoning, AI functioned as a valuable complementary pedagogical resource, enhancing student autonomy, scientific literacy, and reflective practice.

Keyword: Nursing Education, Artificial Intelligence, Wound Care, Caregivers, Ostomy, Coping Strategies

Introduction

Higher education is undergoing constant evolution and is currently facing a profound transformation, driven by the demands of an increasingly digital and interconnected society, which requires the incorporation of emerging technologies aimed at enhancing teaching and learning processes. Teaching methodologies have evolved to foster active, reflective, and student-centred learning, emphasising the learner's active role in the acquisition of knowledge. Within the context of specialist nursing education, it is imperative to adopt innovative pedagogical strategies that promote not only technical competences but also complex cognitive skills such as critical thinking, evidence-based decision-making, autonomy in knowledge construction, and scientific literacy.

Several authors have highlighted the potential of digital technologies to promote more dynamic, reflective, and problem-oriented teaching, supporting the development of transversal competences such as critical thinking, autonomy, and research capacity.^{1,2} These methodologies are aligned with the contemporary need to train healthcare professionals capable of responding to complex and constantly changing scenarios.

Artificial intelligence (AI), in particular, has gained prominence as an emerging and promising

tool in the transformation of education, offering opportunities for personalised learning, support for critical thinking, and the development of students' reflective skills. Recent studies suggest that integrating AI tools into teaching and learning processes, in conjunction with active, student-centred methodologies-especially in higher nursing education can significantly enhance the efficiency and effectiveness of learning by promoting more interactive and personalised educational experiences.^{3,4} In nursing specifically, the adoption of AI-based technologies has shown potential to enrich student training, particularly in the acquisition of clinical competences and evidence-based decision-making.^{5,6}

AI may be particularly useful in conducting literature reviews, a central academic practice in the development of scientific literacy. Literature review, as an essential competence in the academic and professional trajectory of nursing students, requires the ability to locate, select, interpret, and integrate relevant scientific evidence-skills that are vital to evidence-based practice. Traditionally conducted through scientific search engines, this activity has recently been enriched by the emergence of generative AI tools, which can assist in formulating research questions, systematising information, and clarifying complex concepts.^{7,8} When used critically and ethically, these tools hold considerable potential

to foster deep and meaningful learning. The simultaneous integration of scientific databases and AI represents an opportunity to stimulate critical thinking, a core competence in advanced nursing education, particularly in contexts where evidence-based decision-making is required.⁹

Furthermore, this strategy contributes to developing an investigative and collaborative mindset among students, while also raising ethical discussions regarding the reliability, privacy, transparency, integrity, and limitations of AI tools in academic context thereby requiring a careful, critical, reflective, and guided pedagogical approach by educators.^{7,9}

As part of a master's/specialist nursing curriculum, an innovative pedagogical strategy was developed to combine the scientific rigour of literature review with the emerging potential of generative AI. This approach involved challenging students to formulate a relevant nursing research question, conduct a systematic search in recognised scientific databases, and simultaneously interact with an AI tool to explore, validate, and structure the knowledge obtained. Students were asked to query the AI based on their research question and triangulate its responses with the scientific articles identified.

This methodology not only strengthens the ability to identify and interpret scientific literature but also, by critically comparing AI-generated responses with evidence from reliable sources, empowers students to reflect on the validity and trustworthiness of information, fostering a more critical and ethical stance towards new technologies.¹⁰ The strategy was designed to promote scientific information literacy, encourage autonomy in constructing scientific knowledge, develop critical and reflective thinking skills in the analysis of evidence, and explore the potential of AI as a complementary tool for academic reasoning.¹¹

Thus, the articulation between active methodologies, scientific literacy, and emerging technologies such as AI constitutes a valuable pedagogical opportunity in specialist nursing education. This integration can support the development of fundamental competences for contemporary professional practice, namely critical analysis, reflective thinking, and evidence-informed decision-making, placing the student at the centre of the knowledge construction process.

This article aims to describe the integration

of artificial intelligence as an innovative pedagogical strategy in specialist nursing education, through two applied case studies in tissue viability: one addressing the burden of informal caregivers of people with diabetic foot ulcers, and another focusing on the coping strategies employed by individuals with an ostomy. The aim was to compare traditional literature review methods (narrative and integrative reviews) with AI-assisted approaches, exploring their pedagogical potential to foster scientific literacy, critical thinking and evidence-informed decision-making among nursing students, in an exploratory, descriptive educational design rather than a hypothesis-testing study.

The pedagogical activities described in this article were implemented within a master's/specialist nursing programme at a higher education institution in Portugal. Students were enrolled in a curricular unit focused on research methods and evidence-based practice in wound care. A total of 20 students participated and all participants were registered nurses with at least 3 years of clinical practice chronic care. These activities were part of the regular coursework and were supervised by the teaching staff responsible for the curricular unit.

In both case studies, generative AI tools were used as complementary resources to traditional database searches. For each topic, students first formulated a clear research question and completed the database search and preliminary selection of studies. Only afterwards were AI tools queried, using structured prompts that included: (i) the research question, (ii) the target population and context, (iii) the desired time frame, and (iv) a request for recent, peer-reviewed scientific references.

Students were instructed to:

- compare AI-suggested references with those retrieved from databases (title, authors, year and journal);
- check whether AI generated non-existent, inaccurate or irrelevant references (potential “hallucinations”);
- identify overlapping themes between AI-generated summaries and the findings of the selected articles;

AI outputs were not accepted at face value: they were treated as hypotheses to be verified against primary sources.

Methodology

This chapter describes the methodology adopted for this study, outlining a comparative approach between two strategies for retrieving scientific information: a narrative literature review and the use of an AI-based tool. To this end, the same research question was formulated: “What is the burden on the informal caregiver of a person with a diabetic foot ulcer?”, using both methods of inquiry.

The research question was guided by the PCC strategy: Population – informal caregivers of people with diabetic foot ulcers; Context – home setting; Concept – caregiver burden.

Inclusion criteria comprised articles involving informal caregivers who did not receive financial remuneration, describing any form of burden in caring for a person with a diabetic foot ulcer in the home/primary care/community context. Publications had to be from the past five years (January 2020 – March 2025), open access, with full text available in Portuguese and/or English.

Exclusion criteria included all studies involving formal, paid caregivers of people with diabetic foot ulcers.

The search was conducted in March 2025 in the PubMed, Scopus and Web of Science databases using a predefined search strategy based on the PCC framework. The following Boolean search string was applied, with appropriate adaptation to each database syntax: (“informal caregiver” OR “family caregiver”) AND “diabetic foot” AND (burden OR “caregiver burden”) AND (“primary care” OR “home care” OR community). A total of 17 articles were retrieved.

The time frame (January 2020–March 2025) was selected to capture recent evidence reflecting contemporary patterns of caregiving and current models of diabetic foot management. Given the exploratory and pedagogical nature of this work, the two reviews were conducted as narrative/integrative reviews rather than full systematic reviews.

The selection process followed the main steps of PRISMA 2020 statement reporting (identification, screening, eligibility and inclusion) and the diagram (Figure 1) represents an educational adaptation. In this educational context, these

steps were documented narratively and used as a teaching scaffold to guide students through each phase of the review.¹²

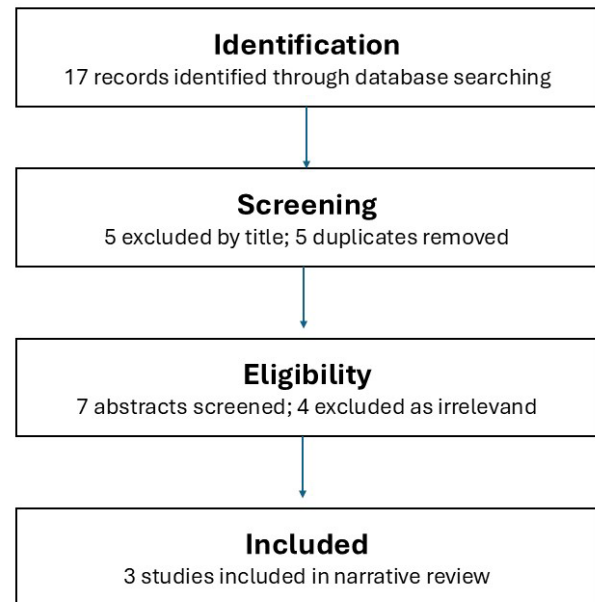


Figure 1. PRISMA-Style flowchart.

Five articles were excluded because their titles did not contain at least two of the predefined keywords/criteria. Following this filter, five duplicates were removed. Seven articles remained, and their abstracts were screened for relevance to the research question, leading to the exclusion of those deemed irrelevant.

Three articles were therefore selected for full reading and further analysis; these are described in Figure 1.

No formal, standardised critical appraisal tool (such as CASP or JBI checklists) was applied in this classroom activity. However, students were guided to assess the relevance, methodological clarity and limitations of each included study (study design, sample, setting and main biases) and to explicitly discuss these aspects in their synthesis. This lack of formal quality appraisal is acknowledged as a limitation of the present educational study.

Subsequently, a prompt was entered into the AI tools ChatGPT-4.0 and SciSpace, using the same research question and previously defined inclusion and exclusion criteria. The aim was to identify whether the results would differ; however, the articles provided by the AI coincided with those retrieved from the scientific databases.

Results

In the narrative literature review, of the 17 articles initially retrieved, 3 met the predefined inclusion and exclusion criteria. Their main characteristics and results are summarised in Table 2.

The study by Costa et al. (2020) aimed to assess the burden and quality of life (QoL) of caregivers of diabetic patients who had undergone amputation one month earlier, using six assessment scales on a sample of 110 caregivers.¹³ Regarding sociodemographic and clinical data, collected through the Sociodemographic and Clinical Questionnaire, it was observed that female caregivers, unemployed or retired, living with chronic conditions, and lacking family and social support reported lower QoL when compared with male caregivers who were married, employed, physically active, and able to take holidays, who showed higher QoL indices.

The Burden Assessment Scale revealed that increased caregiver burden (around 36.5%) was associated with fragile family dynamics, high stress levels, and lack of social support. Assessment of depression and anxiety levels through the Depression Anxiety Stress Scales identified symptoms such as devaluation, inertia, lack of interest, anxiety, difficulty relaxing, restlessness, and irritability among caregivers with dysfunctional family structures and poor social support.

Findings from the Satisfaction with Social Support Scale showed that caregivers who were more dissatisfied with perceived social support experienced higher levels of burden. Similarly, data from the Family Assessment Device indicated that caregivers within functional and supportive family structures had higher QoL and less burden.

Assessment of physical and mental burden using the Short Form Health Survey demonstrated that caregivers with health problems showed greater burden both physically and mentally, negatively impacting their QoL. In summary, the sample was predominantly composed of female caregivers, unemployed, with low educational attainment, lacking regular physical activity and social support. They reported lower QoL and higher incidence of symptoms of depression and anxiety.

The study by Hançerlioğlu et al. found that the burden level among caregivers was moderate

and identified the following influencing factors: being female, aged between 40 and 63 years, being a first-degree relative of the patient, taking on the caregiving role out of obligation, low educational level, low income, the number of weekly hours dedicated to care, and disease progression.¹⁴ The authors recommend that healthcare professionals consider these factors during interviews with informal caregivers to better direct interventions aimed at reducing burden. They also emphasised the importance of further research to identify other influencing elements and develop more effective strategies to mitigate caregiver burden.

The study by Doss et al. mapped and analysed evidence on the impact of family caregiving for individuals with lower limb wounds resulting from diabetes mellitus (DM), focusing on caregiver burden and QoL.¹⁵ Qualitative results showed that informal caregivers of people with DM-related lower limb wounds face significant emotional and socioeconomic challenges. Five thematic axes related to caregiver experience were identified: disruption of routine and activities of daily living (ADLs); anxiety and insecurity; difficulties in communication with healthcare professionals; financial impact; and coping strategies.

Regarding disruption of daily routine, caregivers reported difficulties balancing care demands with personal life, experiencing sleep deprivation, deterioration of their own health, and limitations in their social and professional lives. The caregiving role was often perceived as an unavoidable imposition, with no viable formal support alternatives. Anxiety and insecurity were linked to the absence of clear, structured information on required care, leading to high levels of uncertainty. Caregivers expressed fear of not performing wound care procedures correctly, worrying about prognosis, disease progression, and risk of amputation.

Lack of communication with healthcare professionals was identified as a central source of emotional burden, worsening difficulties in obtaining appropriate clarification and continuous support. Inconsistent guidance and absence of effective support resulted in frustration and feelings of isolation.

On the socioeconomic level, a significant financial impact was noted. Caregivers who had to reduce their working hours or quit their jobs to provide care faced economic hardship,

heightening the sense of burden. Furthermore, uncertainty regarding the patient's disease progression and treatment costs contributed to constant concern.

Finally, some caregivers developed coping strategies to manage care demands, such as structured routine organisation, informal support from family and friends, and increased emotional resilience. These strategies partially mitigated the negative impacts of caregiving and favoured better adaptation to the role.

Across the three studies, common factors contributing to caregiver burden were identified: caregivers are mostly women, direct family

members, with low income and low educational attainment, assuming the role involuntarily and dedicating many hours per week to care. The burden manifests through stress, anxiety, and depression, exacerbated by lack of social support, poor communication with healthcare professionals, and insecurity about correct wound treatment. Additionally, balancing caregiving with professional and social life is challenging, leading to isolation and significant financial impact. Although some caregivers develop adaptive coping strategies, the studies highlight the need for targeted interventions that promote psychological support, empowerment for caregiving, and work–life balance.

Table 1. General analysis of the articles.

Author	Title	Objectives	Study type	Conclusions
Costa, S et al. (2020)	Burden and quality of life in caregivers of patients with amputated diabetic foot	To assess caregiver burden and QoL among informal caregivers of diabetic patients who had undergone amputation or presented with diabetic foot ulcers	Cross-sectional study	Higher burden and lower QoL were observed among older female caregivers, unemployed, and lacking support in caregiving. Highlights the need for greater psychological and social support, stress-reduction interventions, and encouragement of physical activity. The formal recognition of the “informal caregiver” status was also considered a positive aspect.
Haçerlioğlu, S et al. (2023)	Burden of Diabetic Foot – caregivers and affecting factors	To determine the caregiver burden of informal caregivers of patients with diabetic foot and the factors influencing it	Cross-sectional study	Caregiver burden was higher among older caregivers, with low income and low educational attainment, caring for patients with Wagner stage 4–5 diabetic foot ulcers, and dedicating more weekly hours to care. Burden was lower among those caring for patients without a history of amputation. Influencing factors: age, family structure, educational level, income level, and hours of care provided per week.
Doss, E et al. (2023)	Informal Family Caregiving of Patients with Diabetic Extremity Wounds: An Integrative Review	To synthesise the literature on the experiences of informal caregivers of patients with diabetic lower limb wounds	Integrative literature review	Caregiver burden decreased over time but remained higher in cases of major amputation. Anxiety, insecurity, lack of support and communication with healthcare professionals, unemployment, lack of access to holidays, routine disruption, stress, and compromised personal health were linked to higher burden levels.

Discussion

The caregiving process is dynamic and complex, requiring continuous cognitive, emotional, and physical effort, often underestimated and insufficiently recognised. When prolonged, it can generate significant negative impacts, with consequences not only for the caregiver but also for the family.¹⁶ The number of diabetes cases has risen sharply in recent decades, a trend expected to continue. Alongside this increase, the incidence of diabetic foot ulcers and the consequent need

for continuous care has also intensified. In this context, the role of informal caregivers becomes essential in assisting these individuals.¹⁴

Caring for a person with a diabetic foot ulcer imposes a significant burden on informal caregivers, linked to personal characteristics (eg, age, education, income), lack of adequate family and social support, and the severity of the patient's condition—particularly wound extension, pain, and level of amputation.¹³ This situation results in high levels of stress, anxiety, and negative impact on QoL, disrupting daily routines and evidencing the need to improve

social support, communication with healthcare professionals, and the promotion of self-care practices.¹⁵

Analysis of the selected studies shows that informal caregivers perform a wide range of tasks, including meeting the physical and emotional needs of the care recipient. The findings also indicate that caregivers experiencing higher burden and reduced QoL are mainly direct family members, predominantly women, with low literacy, not actively employed, and with weak socioeconomic support.^{13,17} Using the AI tool Consensus, the response to our research question highlighted the same three articles previously identified in the narrative literature review. This reinforces the understanding that caregiving is associated with physical, psychological, emotional, social, and financial challenges for the caregiver, impacting care quality and, ultimately, the health, well-being, and QoL of all those involved: caregiver, patient, and family.¹⁸ Nurses hold the responsibility to support informal caregivers both during the caregiving period and in promoting healthy lifestyle habits, recognising the importance of caring for caregivers' well-being as well.¹⁹

The importance of the Statute of the Informal Caregiver, approved under Law No. 100/2019 of 6 September, also became evident. This statute recognises the fundamental role of informal caregivers in ensuring the well-being of care recipients, while safeguarding their right to receive support and training for skill and competency development in providing adequate healthcare. Its aim is to relieve burden and enhance QoL.²⁰ Furthermore, it is essential that healthcare services provide psychological support whenever necessary, including after the death of the care recipient, and ensure periods of rest that promote well-being, emotional balance, and work-caregiving reconciliation. The statute thus represents a relevant social milestone, highlighting the growing importance of informal caregivers (19). Reflecting more deeply on the implications of the results for nursing practice, we conclude that the findings converge in both approaches (traditional and AI-assisted). However, the AI-based search was faster, though it still required the nurse's critical judgement.

Second experience: Coping with loss and emotions—coping strategies in ostomy patients

Methodology

This study aimed to identify coping strategies used by individuals with an ostomy during the process of adapting to their condition. The research question guiding the study was formulated as follows: "What coping strategies facilitate the adaptive process in individuals with an ostomy?"

To address this question, an integrative literature review was conducted, based on rigorous selection criteria. The descriptors were extracted from the Medical Subject Headings (MeSH) terminology: Ostomy, Coping Skills, Coping Behaviour, and Psychological Adaptation. These terms were combined using the Boolean expression: "Ostomy AND (Coping Skills OR Coping Behaviour OR Psychological Adaptation)".

The bibliographic search was performed in three databases recognised for their relevance in health sciences: EBSCO, B-On, and PubMed. Inclusion criteria were: (i) articles published in the last five years (2019–2024), (ii) in Portuguese or English, (iii) peer-reviewed, (iv) full-text available, and (v) exclusively addressing adult individuals (aged over 18) with an ostomy. Studies conducted in inpatient hospital settings were excluded to ensure the focus on experiences in community or outpatient contexts.

The time window (2019–2024) was chosen to focus on contemporary ostomy care practices and coping models, ensuring that the evidence reflected current psychosocial and clinical approaches. The review was designed as an integrative review, suitable for synthesising heterogeneous qualitative and quantitative evidence within an educational setting.

As with the first experience, no formal critical appraisal tool was systematically applied; instead, students were encouraged to identify methodological strengths and weaknesses (study design, sampling, transferability of results) during guided group discussions. This decision reflects the pedagogical focus of the activity and is considered a limitation of the review's methodological rigour.

A total of 63 articles were initially identified. After screening titles and abstracts according

to the criteria, 14 were selected for full reading. Of these, only 3 were included in the final analysis, as they provided relevant data directly related to the research question. The selection process followed the main steps of PRISMA 2020 statement reporting (identification, screening, eligibility and inclusion) and the diagram (figure 2) represents an educational adaptation.¹²

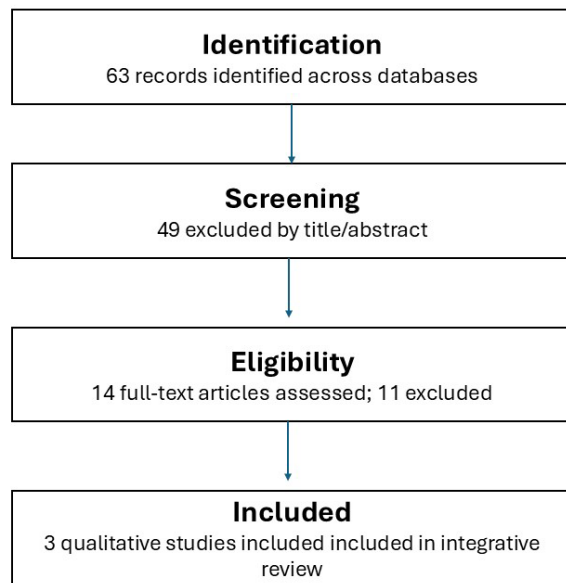


Figure 2. PRISMA-Style flowchart.

The analysis of selected articles was based on critical and interpretive reading, systematising the coping strategies described. Subsequently, the AI platform ChatGPT-4.0 was used as a complementary tool for thematic exploration, enabling comparison with findings from the narrative literature review. A structured prompt was formulated with the research question and inclusion/exclusion criteria.

This methodology sought to ensure rigour and validity in identifying the most effective coping strategies, contributing to a holistic understanding of the adaptation process of ostomised individuals, with practical implications for specialised nursing practice.

Results

The analysis of data obtained from both the literature review and the AI platform (ChatGPT-4.0) identified several coping strategies adopted by ostomised individuals, with direct impact on adaptation to their new life condition.

Both approaches revealed strong convergence in identifying adaptive and maladaptive strategies, reinforcing the consistency of the results.

From the literature review, three qualitative studies were included:

Chen et al. (urostomy patients) highlighted the importance of proactive information-seeking and professional support as key determinants of effective stoma management. Participants adopting a proactive attitude towards knowledge and self-care demonstrated better adaptation and reduced emotional distress. Cognitive strategies, such as reframing negative thoughts, were also emphasised as important in minimising the stigma associated with an ostomy.²¹

Son and Kang (focus groups with ostomised patients) identified a structured adaptive trajectory in three stages: struggling and suffering, learning to live with the ostomy, and living with the ostomy. Family support, religious faith, and peer interaction were key elements fostering confidence, resilience, and self-esteem. Skills developed in ostomy management - such as accident preparedness, adaptation of sexual activity, and dietary reorganisation - were associated with greater sense of control and security.²²

Choudhary and Kaur (meta-synthesis of 13 studies) reinforced the value of peer-to-peer collaborative learning. Sharing experiences not only helped participants solve practical daily challenges but also provided emotional comfort and encouraged effective coping. Problem-solving, creativity in overcoming limitations, and maintaining continuity of daily activities were identified as protective factors for mental health and quality of life.²³

Complementing these findings, the AI platform ChatGPT-4.0 - after structured reformulation of the research question - presented consistent results aligned with existing evidence. It highlighted studies such as Ang et al., Bondarchuk et al., and Hughes and Romo, which emphasised active acceptance of the condition, cognitive restructuring, and promotion of self-efficacy as key strategies for reducing depressive symptoms and enhancing adaptation.²⁴⁻²⁶ The AI also underscored the role of social and emotional support, including healthcare professionals' interventions through tailored educational programmes, directly improving perceived control and self-esteem in ostomised individuals.

While the literature had a stronger emphasis

on practical dimensions of coping (self-care, daily management), the AI added insights on emotional and cognitive aspects, such as belief re-evaluation and integrating the experience into life projects. This complementarity enriched understanding, showing that adaptation to an ostomy depends on interconnected physical, psychological, social, and spiritual factors.

Discussion

The results of this study demonstrate that adaptation to an ostomy is multidimensional, requiring not only physical adjustments but also significant emotional, cognitive, and social transformations. The coping strategies identified in both the literature and AI analysis were essential to mitigate the impact of this chronic condition and to promote quality of life among ostomised individuals.

Scientific evidence indicated that active knowledge-seeking, professional support, self-care skill development, and peer experience-sharing are widely valued adaptive strategies.²⁷ These were reinforced by AI analysis, which also highlighted active acceptance of the condition, cognitive reappraisal, and fostering a positive self-image as central elements of adjustment. Effective coping thus results from a balance between practical actions and cognitive strategies, empowering individuals to face challenges imposed by ostomy.

Social support—from family, support groups, or religious communities—emerged as an essential determinant of emotional stability and ostomy acceptance. This support not only offers psychological relief but also acts as a catalyst for developing positive strategies, reducing risks of isolation and prolonged emotional distress. Literature confirmed that adaptation is more successful when supported by formal and informal networks.^{21,23}

Adaptation to an ostomy is a dynamic, complex, and deeply individual process, requiring effective coping strategies and integration of physical, emotional, social, and cognitive resources.^{28,29} The findings of this study reinforce the importance of self-care competence development, social and emotional support, and cognitive reframing as fundamental pillars of successful adaptation.

The use of AI as a complementary analytical tool proved valuable for content systematisation and for strengthening validity of findings.

Although it initially generated generic responses, once the research question was reformulated, AI provided an analysis consistent with traditional data, including relevant citations from recent literature.^{30,31} The convergence between both methods underscores AI's potential in scientific research, especially as a resource for supporting evidence synthesis. Nevertheless, as noted by various authors, AI cannot replace human critical thinking or the methodological rigour required in scientific practice.³⁰ Its value lies in expanding and complementing analysis, provided it is carefully guided and supervised.

Additionally, this study highlights the importance of healthcare professionals, particularly nurses, in developing personalised interventions that support ostomised individuals in adopting effective coping strategies. Promoting self-care skills, active listening, emotional support, and facilitating access to support groups should be integral to each patient's therapeutic plan. Equally important is incorporating person-centred approaches that respect individual adaptation rhythms and the diversity of sociocultural contexts.

Educational and clinical implications

Integrating artificial intelligence into specialist nursing education may offer a complementary tool to support students in critically appraising evidence and reflecting on clinical decision-making, although this was not formally measured in the present study.

AI tools can accelerate evidence retrieval but require ethical guidance and critical appraisal to evaluate its limitations, ensuring safe and responsible adoption.

Across both experiences, students also became aware of the risks of AI-generated “hallucinations” and implicit biases, as some initial AI outputs were overly generic or omitted relevant contextual details. This was explicitly addressed in class discussions, reinforcing that AI must be used as a support tool whose outputs always require verification against primary scientific sources.

Combining conventional database searches with AI-assisted approaches appears to be a potentially valuable pedagogical strategy, which may help prepare nurses to navigate complex clinical scenarios with technological competence and evidence-informed reasoning; this

hypothesis should be tested in future research using well-defined educational outcomes.

Conclusion

Through the analysis of this pedagogical practice within the scope of tissue viability, this study seeks to contribute to the contemporary debate on the role of artificial intelligence (AI) in health education, while offering concrete insights for curricular innovation aimed at preparing critical, reflective professionals equipped to address future challenges.

In the first case study, the use of AI as an auxiliary tool for literature search proved to be a valuable ally by facilitating quicker access to information with fewer steps and filters. However, the articles retrieved by the AI overlapped with those obtained through traditional scientific databases. In the second case study, although the AI initially produced generic responses, once the research question was reformulated, it presented an analysis consistent with findings derived from conventional methods, including relevant citations from recent literature. The convergence between results obtained through both approaches highlights the potential of AI in scientific research, particularly as a support resource for evidence synthesis.

This experience suggests that AI may act as a mediator of knowledge and a potentially useful resource to support nurses' autonomy and critical capacity in constructing scientific knowledge, when embedded within structured, supervised pedagogical activities. While AI cannot replace the researcher's critical and analytical reasoning, it emerges as a valuable complementary tool, capable of strengthening analytical robustness and providing a more integrated perspective of the phenomenon under study.

Furthermore, Within the limits of this descriptive educational experience, AI appeared to be a promising supplementary tool, particularly for identifying patterns and synthesising relevant evidence, provided it is applied with methodological rigour, appropriate guidance and ethical responsibility. However, no formal learning outcomes were measured, and future studies are needed to evaluate the impact of AI-assisted approaches on educational results quantitatively and qualitatively.

In the current context of rapidly evolving technologies, nurses are called upon to seek the

best available evidence by employing research tools that facilitate the mobilisation of knowledge in the domain of new technologies. This includes the management, intervention, and evaluation of complex therapeutic processes, optimising both time and effort, while ensuring that professional practice remains anchored in scientific evidence.

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SONO APERTE LE ISCRIZIONI ALLE CANDIDATURE VOLONTARIE



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ASSOCIAZIONE INFERMIERISTICA
PER LO STUDIO DELLE LESIONI CUTANEE
Società scientifica italiana a carattere interdisciplinare

ADDENDUM REGOLAMENTO DELEGATI REGIONALI AISLeC

REGOLAMENTO DELEGATI REGIONALI AISLeC
Approvato dal Consiglio Direttivo in data 01 dicembre 2025

In un contesto nazionale ove è imprescindibile un confronto costante e continuo fra il Consiglio Direttivo, i Soci e le figure/collaboratori esterni, diventa indispensabile mantenere un flusso informativo continuo, fluido e immediato. A questo scopo AISLeC ha istituito la figura del Delegato Regionale, che riveste il ruolo di Coordinatore all'interno della regione di appartenenza e che grazie alla conoscenza capillare del territorio e delle necessità locali può fornire un fondamentale apporto per le scelte strategiche e formative del Consiglio Direttivo.

1. SCOPO E CAMPO DI APPLICAZIONE

Questo Regolamento è stato redatto allo scopo di fornire ai Delegati Regionali indicazioni pratiche e coerenti con il mandato assunto e in linea con la Vision di AISLeC, oltre ad essere al contempo un quadro di riferimento per migliorare le attività e la comunicazione tra il Consiglio Direttivo e i Delegati Regionali.

2. LA FIGURA DEL DELEGATO REGIONALE

Il Delegato Regionale:

- è Socio AISLeC
- è in regola col pagamento della quota associativa annuale per tutta la durata del mandato triennale
- è un professionista sanitario esperto/specialista in wound care
- è il referente del Consiglio Direttivo per la regione di appartenenza
- condivide la Mission e Vision AISLeC e agisce in coerenza alle attività e finalità dell'Associazione applicando le norme ed i contenuti di:
 - a. Statuto AISLeC
 - b. Regolamento Delegati Regionali
 - c. Carta Etica
- è il tramite tra il Consiglio Direttivo e i Soci, agisce da collegamento tra AISLeC e le varie Istituzioni, Amministrazioni pubbliche, Ordini, Regione, ecc. su mandato del Consiglio Direttivo
- si impegna a realizzare attività divulgativa e formativa in tema di Wound Care con l'egida di AISLeC nella propria Regione
- si impegna ad aumentare la fidelizzazione dei Professionisti, la visibilità e il coinvolgimento delle attività dell'Associazione nel mondo del Wound Care nella propria Regione
- ha il compito di creare e mantenere il flusso informativo, di monitorare criticità e punti di forza delle attività relative al Wound Care nelle rispettive regioni

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Nurses' Knowledge and Practice Gaps in Incontinence-Associated Dermatitis: Findings from a Cross-Sectional Survey

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Abstract

Introduction. Incontinence-Associated Dermatitis (IAD) is an inflammatory condition of the perineal and perianal skin caused by prolonged contact with urine and feces. Despite its clinical impact, recognition and documentation remain inconsistent, with wide variability in diagnosis, prevalence, and treatment across care settings. This study aimed to provide a narrative overview of current evidence on IAD and to assess nurses' knowledge of its diagnosis, staging, and management across healthcare settings.

Methods. A descriptive cross-sectional observational study was conducted using an anonymous online questionnaire (Google Forms) developed from a literature review. The survey included 11 items on demographics, self-assessed competence, and objective knowledge. Data were collected from March to June 2025 via snowball sampling, with 186 nurses completing the questionnaire. Descriptive and comparative analyses were performed across care settings.

Results. Participants' ages ranged from 22 to 62 years (mean 41.7 ± 10.2), with an average of 15.4 ± 8.6 years of professional experience. About half felt inadequately prepared to manage IAD, while only 18% rated themselves as highly competent. Only 44% correctly distinguished IAD from pressure injuries. Barrier products, gentle hygiene, staff training, and proactive incontinence management were the most cited preventive strategies. Knowledge and tool use were higher in surgical and medical/oncology settings, while community, home care, and rehabilitation showed critical gaps. Adoption of standardized tools such as GLOBIAD was limited.

Discussion. IAD remains underrecognized and inconsistently managed across care settings. The mismatch between perceived and actual competence, together with low use of standardized assessment tools, may contribute to misdiagnosis, delayed treatment, and suboptimal prevention. Structured, context-specific educational programs and wider implementation of tools such as GLOBIAD are essential to enhance prevention, support accurate documentation, and ultimately improve patient outcomes.

Keyword: Incontinence-associated Dermatitis, Urinary Incontinence, Fecal Incontinence, Moisture-Associated Skin Damage, Skin Integrity

Introduction

Incontinence-Associated Dermatitis (IAD) is an inflammatory condition of the perineal and perianal regions caused by prolonged skin contact with urine and feces, and is classified as a form of Moisture-Associated Skin Damage (MASD).¹ It causes pain, discomfort, and has a considerable impact on care, being both difficult to treat and resource-intensive.^{1,2} However, IAD is often underestimated in clinical practice: documentation is frequently incomplete or inconsistent across care settings, and injuries may remain untreated or recorded as secondary diagnoses. This variability hampers accurate diagnosis, prevalence estimates, and effective management.²

Recent studies and consensus papers have emphasized that the implementation of evidence-based practice is hindered by the absence of standardized definitions and terminology, the limited availability of high-quality studies, and the lack of national or international guidelines.¹⁻³

The World Health Organization (WHO) included specific codes for MASD, including IAD, in the ICD-11 (effective January 2022). Yet this regulatory progress has had limited impact in practice: awareness remains low, and clinicians still face challenges in recognition, differential diagnosis, and consistent documentation.⁴

This gap between regulation and practice contributes to underestimation of IAD, heterogeneity in epidemiological data, and incomplete documentation. Although standardized tools such as GLOBIAD (2017) are available, their limited adoption underscores the need for targeted nursing education to promote their use and establish a shared diagnostic

language.⁵

Despite its clinical relevance, no study to date has systematically documented IAD in care contexts. Reported incidence varies widely, ranging up to 25% among incontinent patients in acute hospital settings and between 3.4% and 25% in nursing homes and long-term care.⁴ These data further confirm the heterogeneity in approaches to the phenomenon, in terms of diagnosis, classification, and monitoring.

Skin aging represents an important risk factor for IAD development in older adults, a population that is rapidly growing worldwide. This trend reinforces the need for standardized strategies across care settings, given that IAD, despite its clinical significance, continues to be underestimated and inadequately addressed in daily practice.⁶

The objectives of this study were to (1) briefly review the current evidence on IAD and (2) conduct a cross-sectional survey assessing nurses' knowledge of IAD diagnosis, staging, and management across healthcare settings to identify educational gaps and inconsistencies in clinical practice.

The pathophysiology of IAD is driven by recurrent chemical and physical irritation of the skin barrier, leading to inflammation and subsequent skin damage.^{1,2} Fletcher J. et al. (2020) describe the condition as the result of combined chemical, physical, and microbial factors that compromise skin integrity. Prolonged exposure to urine and/or feces causes maceration of the stratum corneum and overhydration of the cutaneous environment, with water migrating into keratinocytes.¹ These cells swell, undergo lysis, and eventually rupture their membranes, causing direct structural damage to the skin.

Altered pH levels, particularly in the presence of fecal matter, activate proteolytic and lipolytic enzymes that degrade structural proteins and lipids. Additional irritants, such as ammonia produced by urea damage, further compromise the skin, while friction and shear forces exacerbate injury. The warm, humid environment promotes microbial proliferation, raising the risk of superinfection. Together, these mechanisms result in inflammation characterized by erythema, pain, and eventual erosion of the skin.¹⁻⁴

The clinical presentation of IAD is mainly characterized by erythema and maceration, which in more advanced cases may be associated with loss of skin integrity, edema, and blister formation.³ Initially, the epidermis retains its structure, but as the condition progresses, epidermal flattening and partial or complete destruction occur, manifesting as eczema, exudative or bleeding injuries, and extensive

erosions. Symptoms include discomfort, pain, burning, and itching, often worsened by handling or postural changes.^{3,7} Persistent itching may lead to scratching, excoriations, and worsening of skin damage.³ Severe cases of IAD predispose patients to recurrent urinary tract infections and pressure injuries, with the latter occurring at rates up to six times higher than in unaffected individuals.

IAD and Pressure Injuries

Accurate recognition of IAD is essential not only for guiding appropriate treatment but also for avoiding misdiagnosis with other skin conditions. Pressure Injuries (PIs) represent the primary differential diagnosis. Differentiating IAD from PIs is crucial, as both may coexist and interact in the same patient, yet they differ in etiology, location, clinical features, and management strategies (Table 1).

Table 1. Comparison between IAD and PIs in terms of etiology, location, clinical characteristics, and preventive strategies.⁸⁻¹¹

Parameter	IAD	PI
Main etiology	Prolonged exposure to urine and/or feces (chemical, physical, and microbial factors)	Pressure and/or shear forces on bony prominences or under medical devices
Pathogenetic mechanism	“Top-down” lesion injury – damage originating from the skin surface	“Bottom-up” lesion injury – damage originating in underlying soft tissues
Typical location	Perineal, perigenital, gluteal, skin folds, inner thighs, lumbar region (may extend beyond bony prominences)	Primarily on bony prominences (sacrum, heels, trochanters, malleoli) or under medical devices
Clinical appearance	Diffuse erythema with irregular, poorly defined edges; possible maceration, edema, superficial erosions, blisters	Lesion Injuries with well-defined edges; ranges from non-blanchable erythema to partial/full-thickness tissue loss with possible necrosis
Depth	Superficial or partial-thickness; rarely full-thickness	May involve all layers down to muscle and bone
Associated symptoms	Pain, burning, itching; possible signs of superficial infection (e.g., candidiasis)	Localized pain; possible signs of soft tissue infection
Infectious involvement	Common superficial fungal or bacterial superinfection	Possible deep tissue infection
Classification	GLOBIAD – 4 categories	NPIAP – EPUAP – PPPI – 6 categories
Prevention	Incontinence management, skin protection (barriers, polymers), reduction of friction and moisture	Reduction of pressure and shear forces, use of support surfaces, mobilization

Materials and Methods

Narrative review to inform questionnaire development

A narrative review was conducted to summarize current evidence on the definition, risk factors, differential diagnosis, and prevention and management of incontinence-associated dermatitis and to inform questionnaire development. The review focused on the

PubMed database and was carried out between 3 and 12 February 2025. We combined free-text terms and Medical Subject Headings (MeSH) related to incontinence-associated dermatitis and moisture-associated skin damage (e.g., “incontinence-associated dermatitis,” “IAD,” “moisture-associated skin damage,” “diaper dermatitis,” “urinary incontinence,” “fecal incontinence,” “skin integrity,” “older adults”). Boolean operators (AND/OR) were used to link

concepts, and searches were limited to articles involving human participants and adult or older adult populations, without language restrictions.

Titles and abstracts were screened for relevance to IAD pathophysiology, epidemiology, risk factors, differential diagnosis with pressure injuries, and prevention and treatment strategies. Full texts were retrieved when at least one of these areas was addressed. Reference lists of key papers and consensus documents were also examined to identify additional relevant publications. The evidence collected through this process was used to map the main conceptual domains – definition and classification of IAD, risk factors, staging tools (e.g., GLOBIAD), differential diagnosis with pressure injuries, and preventive and treatment measures – which directly informed the generation of questionnaire items.

Study Design

A descriptive, cross-sectional observational study was conducted to evaluate nursing knowledge on the diagnosis, prevention, and management of IAD across different care settings, with the aim of identifying training gaps and areas for improvement. Data were collected using an anonymous online questionnaire (Google Forms®).

Questionnaire Development

The questionnaire items were developed based on a narrative review conducted on PubMed (03-12 February 2025).

The questionnaire comprised 11 mandatory items, divided into three sections: (1) sociodemographic data; (2) self-assessment of training and competence; and (3) specific knowledge of definition, risk factors, staging tools, differential diagnosis, and preventive/treatment measures. The questionnaire included multiple-choice items and Likert-scale questions rated on four levels. Prior to administration, the instrument underwent peer review (n = 3 wound care nurses) to ensure clarity and relevance.

Instrument development

The initial pool of items was generated by mapping the key domains emerging from the narrative review, namely: conceptual definition and classification of IAD, risk factors and predisposing conditions, differential diagnosis with pressure injuries, use of staging tools (in particular GLOBIAD), and preventive and

treatment strategies. For each domain, we drafted items aiming to capture both self-perceived competence (via Likert-scale questions) and objective knowledge (via multiple-choice questions).

Content validity and clarity were assessed through a peer-review process involving three wound care nurses with expertise in IAD management, who independently evaluated each item for relevance, wording, and comprehensiveness. Their feedback was discussed and used to refine item phrasing, response options, and the overall structure of the questionnaire. No formal pilot study was conducted; however, the instrument was iteratively revised until all reviewers agreed on its face and content validity. The final version of the questionnaire is reported in Appendix 1.

Sampling

Anon-probabilistic snowball sampling approach was adopted to reach nurses working across a variety of care settings (medical/oncology, surgical, critical care, rehabilitation, and home care) throughout the country. Data collection was conducted between March and June 2025 via a Google Forms® link distributed through email and professional group chats. Inclusion criteria required participants to be employed in Italy, working in one of the specified settings, and voluntarily completing the questionnaire. Ensuring anonymity and requiring mandatory responses helped minimize social desirability bias and missing data. However, given the non-probabilistic snowball sampling approach and the use of snowball dissemination strategies, it was not possible to reliably estimate how many nurses actually received the survey link; therefore, response rates could not be calculated. To further minimize selection bias, coordinators distributed the questionnaire widely across diverse clinical settings.

Data collected through Google Forms® were exported into Microsoft Excel® and cleaned to verify completeness and consistency of responses. Descriptive analyses were performed to summarize the characteristics of the sample and the distribution of responses to each questionnaire item.

Categorical variables (e.g., care setting, multiple-choice responses, Likert scale options) were reported as absolute frequencies and percentages. Continuous variables (e.g., age, years of work experience) were described using

mean, standard deviation, minimum, and maximum values.

Results were presented overall and, where relevant to the discussion, stratified by care setting to highlight potential exploratory differences. Data processing and graphical representation were carried out using Microsoft Excel®.

Semi-quantitative scoring for the heatmap

To facilitate visual comparison of competence levels across care settings, we derived a semi-quantitative score for five key indicators: subjective knowledge, objective knowledge, use of clinical tools, misclassification rate, and perceived need for training. For each domain and setting, we transformed the underlying percentages into a three-level ordinal scale, where 1 indicated a low level, 2 a moderate level, and 3 a high level. As a general rule, values below approximately 40% were assigned a score of 1, values between 40% and 69% a score of 2, and values of 70% or higher a score of 3. Higher scores reflect more favourable conditions for knowledge, tool use, and perceived training needs, while a higher score for misclassification indicates a greater proportion of incorrect answers and therefore a more critical area.

Ethical Considerations

Participation was voluntary and anonymous; no sensitive data were collected. Data were treated in aggregate form in compliance with EU Regulation 2016/679 (GDPR). Ethical committee approval was not required as the study did not involve clinical interventions or personally identifiable data. The study was conducted in accordance with the institutional policy on survey-based research involving healthcare professionals, and the Scientific Directorate was informed of the project and its objectives.

Results

Questionnaire Findings

The analysis of the results follows the structure of the administered questionnaire, which comprised three main sections. The first section collected participants' sociodemographic and professional data (age and years of work experience), providing a profile of the sample. The second section explored nurses' self-perceived preparation, competence, and perceived usefulness of clinical tools for

managing Incontinence-Associated Dermatitis (IAD). Finally, the third section assessed objective knowledge through multiple-choice questions on the definition of IAD, risk factors, differential diagnosis, staging tools, and prevention and treatment strategies.

Results are presented descriptively, with graphical illustrations and tables for each section, and exploratory comparisons across different care settings. A total of 186 questionnaires were completed by nurses working in different care settings (Table 2). Because of the snowball sampling strategy, the number of nurses who received the survey link could not be determined, and response rates by setting could not be estimated.

Table 2. Distribution of respondents by care setting (n = 186).

Setting	Responses (n)	Response Rate (%)
Rehabilitation	37	56.9
Critical care	45	40.2
Medical/Oncology	33	82.5
Surgical	26	86.7
Home and community care	45	75.0

The data were analyzed using descriptive statistics (absolute frequencies, percentages, means, and standard deviations), with stratification by care setting. An exploratory comparative analysis was also conducted to highlight potential differences across clinical areas (Figure 1).

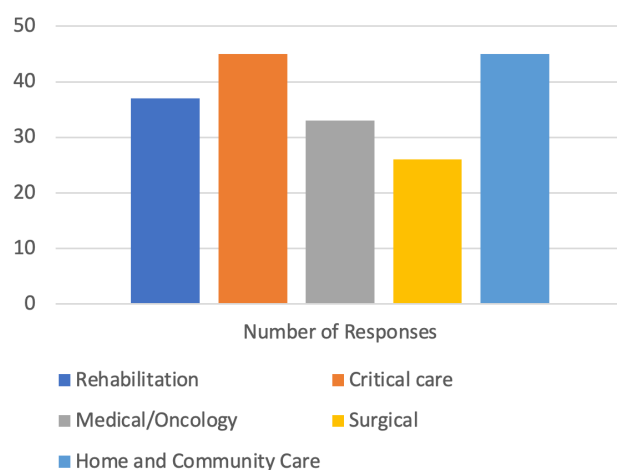


Figure 1. Distribution of Survey Responses by Care Setting.

The following presents the results organized by each section of the questionnaire. The first section included two open-ended questions on age and years of work experience. Participants' ages ranged from 22 to 62 years (mean 41.7 ± 10.2), while the average length of professional experience was 15.4 ± 8.6 years (range 1–38) (Table 3).

Table 3. Demographic and Professional Characteristics of the Sample (n = 186)

Variable	Value
Mean age (years)	$41,7 \pm 10,2$
Age range	22 – 62
Mean years of work experience (years)	$15,4 \pm 8,6$
Range of years of work experience	1 – 38

The second section, consisting of three closed-ended questions with a four-point Likert scale (“Not at all,” “Slightly,” “Moderately,” “Very”), explored nurses’ self-perceived preparation, competence, and perceived usefulness of clinical tools for managing IAD. Across all care settings, approximately half of the nurses felt poorly prepared on the topic (Figure 2) and lacking competence in injury management. Specifically, 52% of nurses reported feeling minimally competent in the clinical management of IAD, while only 18% considered themselves highly competent. These results were relatively consistent across the different settings.

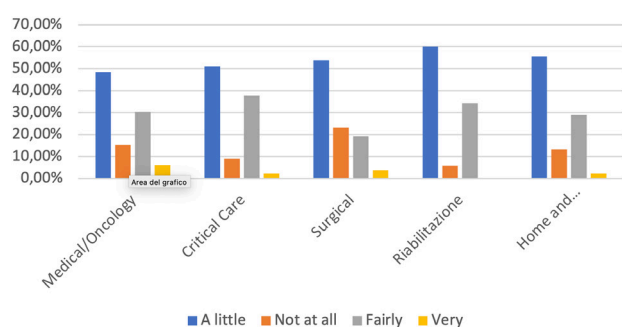


Figure 2. Responses to the question “How knowledgeable do you consider yourself to be on this topic?”.

After exploring participants’ subjective perception of preparation and competence, the third section assessed objective knowledge through multiple-choice questions. This section, comprising five multiple-choice items, showed that, at the aggregate level, 66–73% of participants correctly identified the definition

of IAD, while 54% selected at least one incorrect response regarding risk factors (Figure 3). These aggregated results are presented for the entire sample, without stratification by clinical setting.

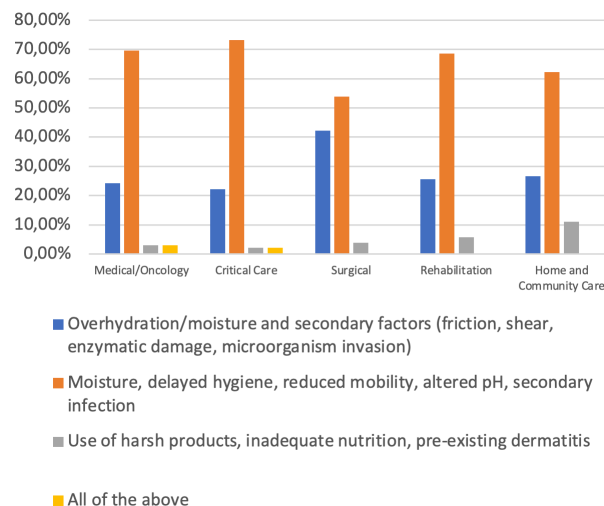


Figure 3. Responses to the question “What are the risk factors that increase the likelihood of IAD?”.

Furthermore, the EPUAP staging system emerged as the second most frequently selected option, despite not being appropriate for IAD staging. (Figure 4).

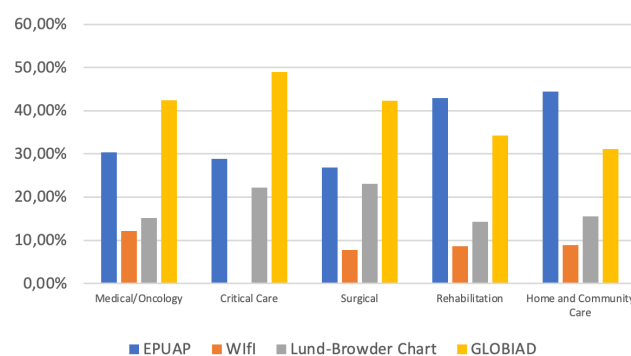


Figure 4. Responses to the question “Which scale is appropriate for staging IAD?”.

The correct definition of IAD was recognized by 70% of participants, with similar rates in the surgical (73%) and medical/oncology (71%) settings, and slightly lower in the community setting (65%).

Similar challenges were observed in the differential diagnosis between IAD and PIs: only 44% of the sample correctly identified the distinctive symptoms of IAD compared to PIs. The most common errors involved interpreting

localized redness and well-defined edges as characteristic of IAD.

The strategies considered most effective for prevention and treatment, listed in order of frequency, included: use of barrier products (82%), gentle hygiene without friction (76%), staff training (65%), and proactive incontinence management (63%). Less frequently cited but still relevant interventions were the use of collection devices (28%) and periodic review of care protocols (25%).

Comparative Analysis Across Care Settings

Exploratory analysis of responses stratified by care setting revealed notable differences in knowledge levels, competence, and use of tools for IAD management (Table 7).

The surgical and medical/oncology settings showed the highest scores in objective knowledge, particularly regarding the correct definition of IAD and the identification of the most effective preventive measures. Both settings also demonstrated greater familiarity with the use of barrier products and specific devices for incontinence management.

The community/home care setting exhibited

Table 4. Comparison of Care Settings Based on Survey Results. No critical issues identified according to the survey responses.

Setting	Strengths	Identified Weaknesses
Surgical	High objective knowledge on IAD definition and prevention; familiar use of barrier products	NI*
Medical/ Oncological	Familiarity with tools and preventive strategies	NI*
Territorial/ Home Care	Interest in the topic, but fragmented training	Confusion between IAD and pressure injuries; limited use of standardized assessment tools
Critical Care	High awareness of the importance of support tools (e.g., GLOBIAD)	Marked heterogeneity in perceived competence; internal knowledge gaps within the team
Rehabilitation	Good baseline knowledge; interest in the topic	Limited practical use of standardized tools and protocols

*NI: Non Identified.

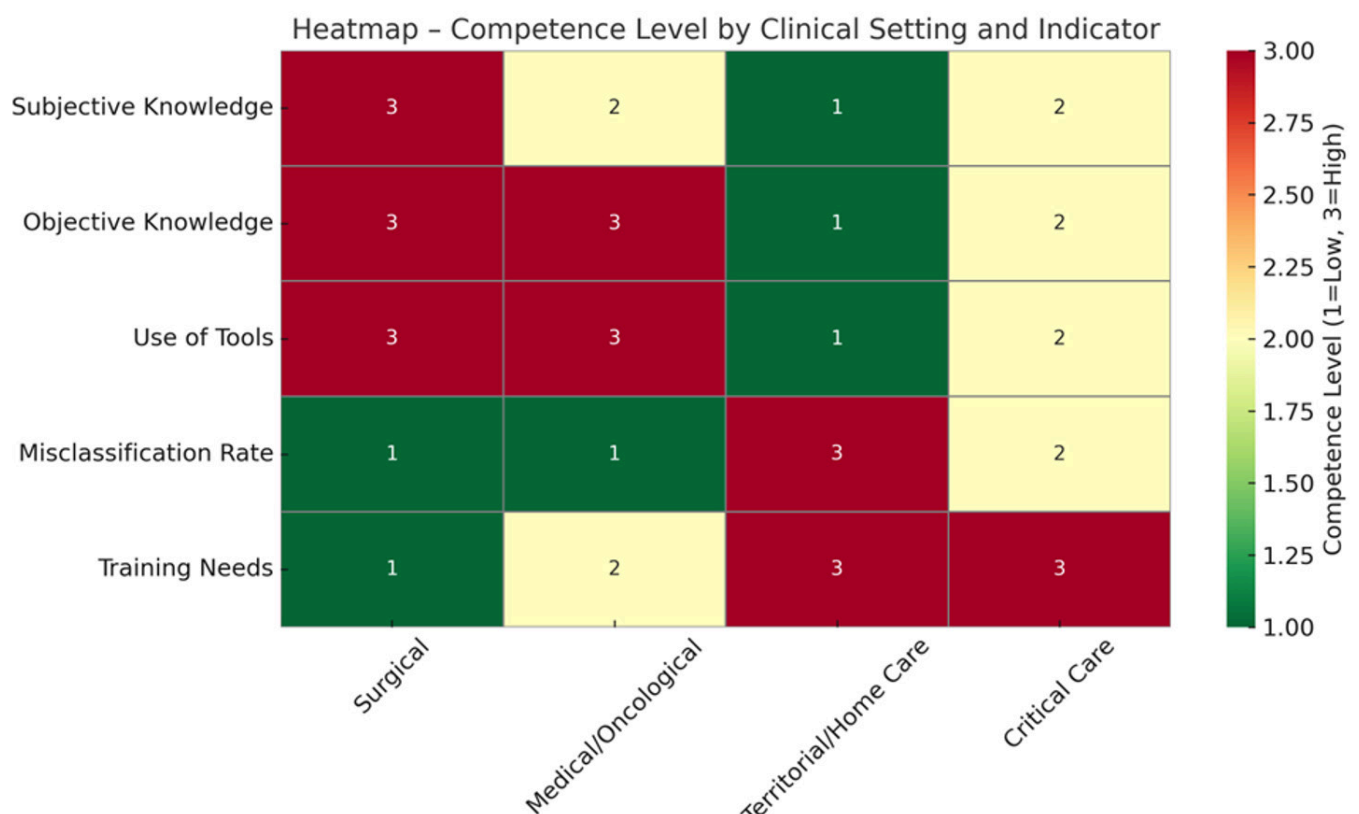


Figure 5. Comparative heatmap of competence levels by setting and domain. The scale ranges from 1 (low) to 3 (high). Indicators include subjective knowledge, objective knowledge, use of tools, misclassification rate, and perceived training needs.

more critical gaps, especially in recognizing risk factors and differentiating IAD from pressure injuries. These difficulties appear linked to lower exposure to standardized assessment tools and structured training programs.

The critical care area showed a high perceived usefulness of support tools such as the GLOBIAD; however, perceived competence levels were highly heterogeneous, with some professionals reporting being very well-prepared while others felt completely unprepared, indicating internal training disparities.

The rehabilitation setting displayed consistent interest in the topic and solid basic knowledge, but there is room for improvement in the practical application of assessment tools and shared protocols.

These differences underscore the need to develop targeted, context-specific training interventions, with particular attention to community-based settings and areas with internal heterogeneity, which are often less supported by common protocols and validated tools.

To complement the table, the data were further summarized using a semi-quantitative heatmap (Figure 5), which compares perceived and actual competence across care settings. The heatmap evaluates five key indicators: subjective knowledge, objective knowledge, use of clinical tools, misclassification rate, and perceived need for training. Scores were derived using predefined thresholds, as detailed in the Methods section. Scores are presented on a 1-3 scale, where higher scores reflect more pronounced levels of the indicator under consideration.

Discussion

The findings of this study confirm the fragmentation of nursing knowledge related to Incontinence-Associated Dermatitis (IAD), aligning with existing international literature, which highlights significant variability in both diagnostic accuracy and the implementation of evidence-based preventive strategies.^{8,9} Although a portion of the sample demonstrated solid knowledge in specific areas, particularly regarding the definition of the condition and certain preventive measures, the heterogeneity observed across clinical settings and levels of experience suggests the absence of a systematic and standardized national training pathway.

A particularly critical issue is the discrepancy

between nurses' self-perceived competence and their actual knowledge, as measured by the multiple-choice questions. This gap, also described in studies conducted in both hospital and community settings^{12,14,21,22} may represent a significant clinical risk: a healthcare professional who perceives themselves as competent but lacks up-to-date and consolidated knowledge may fail to recognize IAD in its early stages or may confuse it with a pressure injury, thereby delaying the initiation of effective interventions. This gap increases the likelihood of underdiagnosis, inappropriate treatment, and incomplete or inaccurate collection of epidemiological data, ultimately affecting the quality of care and hindering the implementation of targeted prevention strategies.⁸

Beyond documentation and process measures, these gaps in knowledge and diagnostic accuracy are likely to translate into poorer patient outcomes. Inadequate recognition and staging of IAD may lead to delayed initiation of appropriate skin care regimens, prolonged exposure to irritants, and progression from mild erythema to more extensive erosions and secondary infections.^{1,4,8} Misclassification between IAD and PIs can result in the use of suboptimal preventive strategies and support surfaces, potentially increasing the incidence and severity of both conditions.^{3,8} Previous studies have shown that patients with IAD are at higher risk of developing pressure injuries and experience significant pain, discomfort, and reduced quality of life, underscoring the importance of timely and accurate identification.^{3,8,9,11} Strengthening nurses' knowledge, training, and use of standardized tools such as GLOBIAD is therefore essential not only for improving documentation, but also for reducing IAD incidence, mitigating severity, and preventing avoidable complications.^{5,8,23}

The adoption of standardized tools such as GLOBIAD represents a concrete opportunity to standardize terminology, enhance interdisciplinary communication, and ensure accurate and consistent classification of moisture-associated skin damage.⁵ However, the limited use of such tools observed in our sample reflects both poor integration into operational protocols and insufficient institutional promotion. Their adoption could be encouraged through ongoing professional development programs, supported by periodic clinical audits to monitor adherence to best practice recommendations.

The comparative analysis across clinical settings showed that surgical and medical-oncology areas benefit from greater exposure to structured training pathways and dedicated skin assessment tools, probably due to well-established local protocols and a higher level of specialized care. In contrast, community, home care, and rehabilitation settings demonstrated more difficulty in accurately identifying risk factors and distinguishing IAD from pressure injuries. This scenario suggests that training initiatives should be targeted and context-specific, integrating theoretical and practical modules, clinical simulations, and field-based education to strengthen both foundational knowledge and applied skills.²³

The lack of consolidated and shared knowledge emerges as one of the main barriers to effective management of IAD. This gap contributes to underdiagnosis, inappropriate treatment, and poor epidemiological data, ultimately compromising care quality and hindering prevention strategies.²⁴ It also reflects a broader knowledge-to-practice gap frequently described in nursing education – where theoretical awareness fails to translate consistently into clinical competence and standardized practice – as conceptualized in the seminal framework by Kitson et al. (1998) on enabling the implementation of evidence-based practice.^{25,26}

Finally, the results of this study can serve as a foundation for the development of educational and organizational interventions aimed at addressing the identified gaps. Standardizing procedures and adopting shared assessment tools, combined with continuous training, could substantially contribute to improving care quality and reducing the incidence of IAD across different healthcare settings.

Limitations of the study

This study has several limitations that should be acknowledged. First, the cross-sectional design precludes any causal inference between nurses' knowledge, training, and clinical practices, and actual patient outcomes related to IAD. Second, the use of a non-probabilistic snowball sampling strategy limits the generalizability of the findings and prevents the calculation of response rates, as it was not possible to determine how many nurses were exposed to the survey invitation.

Third, data were self-reported and may be subject to recall and social desirability bias, particularly regarding perceived competence and

reported clinical practices. Although mandatory responses and anonymity may have mitigated these effects, they cannot be fully excluded. Fourth, while the questionnaire was grounded in a narrative review and underwent expert content review, no formal psychometric validation was conducted, and the scoring approach used to generate the heatmap represents a semi-quantitative synthesis rather than a validated measurement scale.

Finally, despite efforts to include nurses from diverse care settings, the uneven distribution of respondents across settings may have influenced comparative analyses. Nevertheless, the study provides valuable insights into knowledge gaps and educational needs related to IAD across multiple healthcare contexts.

Recommendations for future research

Future research should move beyond cross-sectional assessments of knowledge and self-reported practices to evaluate how educational interventions and the use of standardized tools translate into clinical outcomes. Prospective cohort studies and quasi-experimental designs could examine whether variables such as participation in structured training programs, higher knowledge scores, or routine use of GLOBIAD and other assessment instruments predict lower incidence and severity of IAD, reduced misclassification with pressure injuries, and improved pain control. Longitudinal studies may also explore the sustainability of educational effects over time and identify organizational factors that facilitate or hinder the integration of IAD-related best practices into routine clinical care.

Conclusion

This study reveals significant gaps in nursing knowledge regarding incontinence-associated dermatitis (IAD), highlighting how insufficient training contributes to missed diagnoses, clinical underestimation, and inconsistency in data collection. To address these shortcomings, it is essential to implement structured, continuous, and context-specific educational programs that not only provide updated theoretical content but also encourage critical reflection on nursing practices and the appropriate use of assessment tools. In this regard, the systematic adoption of GLOBIAD across care settings could foster a meaningful cultural and organizational shift.

Integrating targeted education, validated assessment tools, and updated care protocols is essential to enhance care quality, reduce IAD incidence, and mitigate severity in at-risk patients. The findings of this study may serve as a foundation for local policies and coordinated initiatives aimed at strengthening the diagnosis, treatment, and documentation of IAD, with the active involvement of nursing leadership, training units, and professional networks.

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Physiotherapy Management in Pediatric Burns: A Five-Year Experience Comparing Children and Adolescents at a Tertiary Burn Center

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Abstract

Introduction. Physiotherapy plays a crucial role in the management of pediatric burn patients, requiring early intervention and long-term follow-up to prevent functional limitations and manage scar-related complications. Adolescents represent a particularly challenging group, as developmental, psychological, and social factors may negatively influence engagement and adherence to rehabilitation programs. This study aimed to describe the physiotherapy tools used in pediatric burn patients and to compare physiotherapy modalities and treatment adherence between children and adolescents treated at a tertiary pediatric burn center.

Methods. A retrospective observational, monocentric chart review was conducted in accordance with STROBE guidelines. Medical records of pediatric burn patients (≤ 18 years) admitted to the Burns Center of Meyer Children's Hospital IRCCS, Florence, between 2017 and 2022 and managed by the Rehabilitation Unit were reviewed. Patients were divided into two groups based on age at admission: children (< 11 years) and adolescents (11-18 years). Data collected included demographic characteristics, burn features, physiotherapy modalities used during the acute and scarring phases, and adherence to the prescribed physiotherapy program. Adherence was assessed subjectively by treating physiotherapists during routine clinical practice. Categorical variables were analyzed using Chi-square or Fisher's exact tests.

Results. Thirty-five patients were included: 20 children and 15 adolescents. The adolescent group more frequently presented with burns involving a larger total body surface area. Most physiotherapy tools were used similarly in both groups;

however, gait training during the acute phase was more frequently applied in adolescents ($p = 0.046$), while contact media during the scarring phase were more commonly used in children ($p < 0.05$). Adherence to physiotherapy during hospitalization was generally good in both groups. During the scarring phase, children showed significantly higher adherence to splints, massage combined with skin hydration, elastic-compressive garments, and contact media (all $p < 0.05$).

Discussion. Physiotherapy management in pediatric burn patients relies on similar tools across age groups; however, adherence appears to be lower in adolescents, particularly during long-term scar management. Developmental factors and family involvement likely play a key role in treatment engagement. These findings highlight the need for age-tailored, patient-centered rehabilitation strategies to improve adherence among adolescents with burn injuries.

Keywords: Pediatric Burns, Adolescents, Physiotherapy, Rehabilitation, Treatment Adherence

Introduction

Burns remain a major public health issue in industrialized countries, particularly among children, where they are among the top five causes of accidental mortality in the European Union and account for 1% of all pediatric deaths.¹ In Italy, approximately 440 deaths due to burns are recorded annually, over 70% of which occur in the home. Among pediatric fatalities, 16% are burn-related, with the majority affecting children under the age of four.^{1,2}

Thanks to medical and surgical advances, the last three decades have seen a marked decline in burn-related mortality in children.^{3,4,5} Improved outcomes have shifted focus toward the long-term consequences of burns and the growing need for extended rehabilitation.^{6,7} These patients—many of whom are now adolescents or adults—often face complex physical, functional, and psychosocial challenges that require sustained, multidisciplinary care well beyond the acute phase.⁶ Severe burns can result in functional impairment, aesthetic disfigurement, and psychological trauma, with consequences on independence, pain perception, and mobility. The literature emphasizes the essential role of a coordinated multidisciplinary team in managing pediatric burns, both during hospitalization and in the long-term recovery process.^{3,8,9,10} Physiotherapists are key members of this team, contributing from the early stages of care

through individualized interventions to preserve range of motion (ROM), prevent contractures, and promote functional independence.¹¹

Physiotherapy intervention typically begins within 48 hours of admission and continues for months or years post-discharge, depending on the severity of the injury.^{6,12}

In the acute phase, physiotherapy tools include splinting, kinesitherapy (active and passive), therapeutic positioning, and stretching.^{13,14} These tools aim to reduce pain, prevent joint stiffness, and maintain mobility. Once wounds are healed and scar formation begins (non-acute phase), rehabilitation shifts toward scar management with techniques such as elastic-compression garments, manual or mechanical massage therapy, kinesitherapy, and silicone-based applications (contact media).^{9,13,15,16} This phase, which can last years in growing children, is crucial to improving functional outcomes and quality of life.

Within this framework, the role of the child's family is crucial. From the first days of hospitalization, family involvement is actively encouraged. This long-term engagement is essential for treatment adherence and successful rehabilitation outcomes.^{6,16}

Despite growing awareness of rehabilitation's importance, there remains significant heterogeneity among burn centers in the evaluation and treatment of pediatric patients.^{9,16} A lack of validated tools impairs

outcome measurement and limits opportunities for clinical research.¹⁶ The need for shared, evidence-based rehabilitation protocols is widely acknowledged¹⁷, and international collaborations—particularly multicenter studies—are considered essential to advancing practice.⁷

The European Club for Pediatric Burns (ECPB), founded in 1991, plays a key role in promoting standardization and cooperation across Pediatric Burn Centers.¹⁸ However, data from Italian centers remain limited.

Working in a pediatric context poses unique challenges. The care team must manage patients ranging from infancy to adolescence, each with specific developmental needs. Adolescents, in particular, experience physical, emotional, and social changes that can be exacerbated by a disfiguring and painful injury such as a burn.^{19,20,21,22} They may feel isolated or misunderstood, and the burden of ongoing treatment can further strain their mental well-being.²¹ Therapeutic approaches must therefore be tailored to this age group, balancing clinical objectives with the adolescent's individual preferences and psychological state.^{12,23}

The World Health Organization defines therapeutic adherence as “the degree to which a person's behavior corresponds to the recommendations agreed with the health professional”.²³ This concept implies an active partnership between patient and provider and is especially important during adolescence, when autonomy and self-image become more salient. Poor adherence can reduce treatment effectiveness and lead to long-term disability, while also increasing healthcare costs.^{24,25}

Despite recognition of the value of adolescent participation in treatment planning, current practice often overlooks their voices.^{26,27} Studies show that adolescents are rarely asked about their preferences or priorities^{27,28}, which can result in reduced engagement and lower adherence to physiotherapy regimens.^{29,30,31}

To explore this issue, a retrospective review of cases at the Meyer Burns Center was conducted to answer the following questions: What physiotherapy tools are most commonly used in the treatment of pediatric versus adolescent burn patients? What differences in adherence to physiotherapy treatment emerge between these two groups?

Methods

Study design and setting

This study was a retrospective observational, monocentric chart review, conducted in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational studies.

The study was carried out at the Burns Center of Meyer Children's Hospital IRCCS, Florence, a tertiary referral center for pediatric burns, in collaboration with the Rehabilitation Unit.

Study population

Medical records of pediatric patients admitted for burn injuries between January 2017 and December 2022 were retrospectively reviewed. Patients were eligible for inclusion if they met the following criteria: age ≤ 18 years at the time of injury; admission to the Burns Center during the acute phase of burn injury; documented involvement of the Rehabilitation Unit with structured physiotherapy intervention; availability of complete clinical and rehabilitation records. Patients were excluded if: they were transferred to another facility before initiation of physiotherapy; physiotherapy documentation was incomplete or unavailable; severe pre-existing neurological or musculoskeletal conditions interfered with rehabilitation assessment. Baseline demographic and clinical characteristics of the study population are reported in Table 1.

Table 1. Baseline demographic and clinical characteristics of pediatric burn patients included in the study, stratified by age group. Abbreviations: TBSA, Total Body Surface Area; n, number of patients; %, percentage; years, age expressed in years.

Variable	Children (<11 years)	Adolescents (11–18 years)
Number of patients, n	20	15
Age, mean (range), years	3.7	12.5
Sex, male, n(%)	13 (65%)	9 (60%)
TBSA category	<15% prevalent	>25% prevalent
Main burn location	Hands / Upper limbs	Lower limbs / Trunk

Based on age at admission, patients were divided into two groups: Children group, patients younger than 11 years; Adolescent group, patients aged 11–18 years.

Physiotherapy management protocol

According to the institutional physiotherapy protocol for pediatric burn patients, physiotherapy intervention was initiated during the acute phase of hospitalization and tailored to the patient's clinical condition, burn extent, and tolerance.

During hospitalization, patients received daily physiotherapy sessions, usually conducted in their rooms and in the presence of parents or caregivers. Interventions included active and passive kinesitherapy, stretching, therapeutic positioning, gait training when clinically appropriate, splinting, and caregiver education.

A personalized physiotherapy plan was developed for each patient through multidisciplinary collaboration involving the physiotherapist, attending physician, nursing staff, and family. This plan included recommended activities, positioning strategies, and preventive measures to be maintained throughout the day.

At discharge, families were provided with a home-based physiotherapy program, consisting of daily activities, postural recommendations, and – when indicated – specific exercises to be performed independently. Patients discharged home were scheduled for monthly follow-up visits during the first six months after the burn injury.

Data collection and variables

Data were extracted from electronic medical records using a standardized data extraction protocol by two independent reviewers. Discrepancies were resolved through discussion.

The following variables were collected: demographic data (age, sex); burn characteristics (anatomical location, Total Body Surface Area – TBSA – involved); phase of treatment (acute phase vs scarring phase); physiotherapy modalities used during treatment, including kinesitherapy, stretching, gait training, activities of daily living (ADL) training, splints, elastic-compressive therapy, compression garments, contact media, massage therapy (manual or mechanical), and caregiver education; adherence to the prescribed physiotherapy program.

Physiotherapy tools were considered “used”

if documented at least once during the relevant phase of care.

Assessment of adherence

Adherence to physiotherapy treatment was assessed subjectively by the treating physiotherapist during routine clinical practice. Evaluation was based on direct questioning of parents or caregivers and, when appropriate, consultation with ward staff.

Adherence assessment included: patient engagement and participation during physiotherapy sessions; overall cooperation throughout hospitalization or follow-up; reported compliance with prescribed home-based interventions; observable clinical improvement related to the physiotherapy program.

No validated adherence scale was available or routinely used during the study period. Adherence was therefore documented as a clinical judgment, reflecting real-world practice. This limitation was acknowledged in the interpretation of results.

Statistical analysis

Data were entered into a dedicated database and analyzed using descriptive and inferential statistics. Categorical variables were expressed as frequencies and percentages.

Comparisons between the children and adolescent groups were performed using the Chi-square test or Fisher's exact test, as appropriate based on sample size and expected cell counts.

A two-sided p value < 0.05 was considered statistically significant. Missing data were handled by case-wise exclusion.

Given the exploratory nature of the study and the limited sample size, no adjustment for multiple comparisons was performed.

Ethical considerations

This study was approved by the Regional Pediatric Ethics Committee. Ethical approval was granted under protocol number 21-05-2025 126/2025. The study was conducted in accordance with the principles of the Declaration of Helsinki. Given the retrospective design of the study and the use of anonymized clinical data, the requirement for informed consent was waived.

Results

During the study period, 35 patients with burns

were managed by the Rehabilitation Unit. Two age-based cohorts were identified: the children group (patients under 11 years), which included 20 patients, and the adolescent group (patients aged 11–18 years), which included 15 patients. The mean age in the adolescent group was 12.5 years, while in the children group it was 3.7 years. There was a predominance of males in both groups: 9 out of 15 (60%) in the adolescent group and 13 out of 20 (65%) in the children group. The two groups were comparable in terms of sex distribution and burn location. Burns involving a larger total body surface area were more frequently observed in adolescents, whereas children more commonly presented with burns involving less than 15% TBSA. Formal statistical comparison was limited by sample size. Both groups received standard physiotherapy interventions commonly used in pediatric burn care, as detailed in Table 2.

During the acute phase, gait training was more frequently applied in adolescents than in children ($p = 0.046$). During the scarring phase, contact media were used more often in children compared to adolescents ($p < 0.05$). No other statistically significant differences were observed between groups.

Adherence to physiotherapy treatment

Adherence to physiotherapy treatment during the acute hospital phase was generally good in both groups, with slightly higher adherence observed in the children group, although the difference was not statistically significant. In contrast, during the scarring phase, which typically involved outpatient or home-based

care, adherence was significantly higher in the children group. In particular, greater compliance was noted with the use of splints ($p = 0.023$), massage combined with skin hydration ($p < 0.01$), elastic-compressive garments ($p = 0.004$), and contact media ($p < 0.01$) (Figure 1).

Table 2. Frequency of physiotherapy modalities applied in children and adolescents during the acute and non-acute (scarring) phases of burn rehabilitation.

Physiotherapy tool	Children n/N (%)	Adolescents n/N (%)	Phase
Kinesitherapy	20/20 (100)	15/15 (100)	Acute
Stretching	20/20 (100)	5/15 (33.4)	Acute
Gait training	9/20 (45)	12/15 (80)	Acute
ADL training	9/20 (45)	6/15 (40)	Acute
Splint (hospital)	12/20 (60)	6/15 (40)	Acute
Contact media	18/20 (90)	5/15 (33.4)	Scarring
Compression garment	12/20 (60)	7/15 (46.6)	Scarring
Massage (manual/mechanical)	19/20 (95)	15/15 (100)	Scarring
Splint (home)	13/20 (65)	8/15 (53.4)	Scarring

Legend: **ADL:** activities of daily living; **TBSA:** total body surface area involved; **LPG:** LipoMassage by Endermologie®; **n:** number of patients presenting the characteristic; **N:** total number of patients in each group.

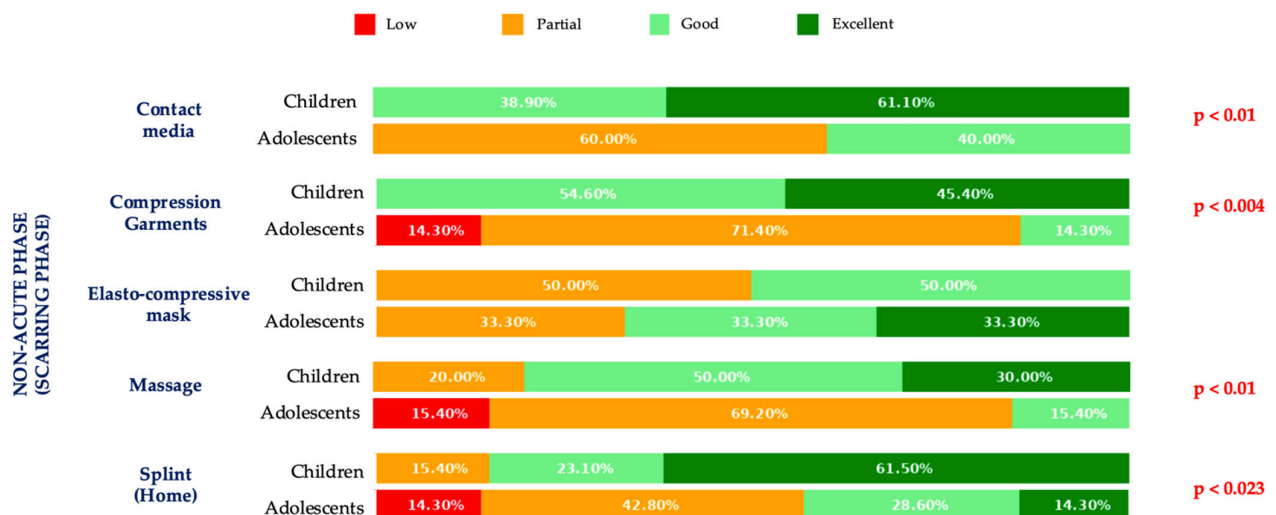


Figure 1. Adherence to physiotherapy treatment in the adolescent group and in the children group, divided according to the physiotherapy tools used, in the scarring phase

Discussion

From the available data, burns involving a higher TBSA were more frequently observed in adolescents, whereas children more commonly presented with less extensive burn injuries. This finding may be related to differences in the mechanisms of injury across age groups. In younger children, burns are more often caused by domestic accidents involving limited body areas, such as contact with hot household surfaces or scalds from boiling liquids during early feeding activities.³²⁻³⁴ In contrast, adolescents more frequently experience burn events with greater dynamics, including flame-related injuries or explosions, which may result in larger TBSA involvement.^{35,36}

Across both the acute and scarring phases, physiotherapy management strategies appeared largely overlapping between children and adolescents, in line with current recommendations for pediatric burn rehabilitation.^{11,13,32,33} Nevertheless, some age-related differences were observed. Gait training was more frequently implemented during the acute phase in adolescents, likely reflecting the higher prevalence of lower limb involvement and more extensive burns in this group. Similarly, contact media were more commonly used during the scarring phase in children, possibly due to the involvement of anatomically delicate areas prone to hypertrophic scarring and contracture development, such as the hands and fingers.^{36,37}

With regard to adherence, higher levels were observed in the children group, particularly for interventions such as splints, massage combined with skin hydration, and elastic-compressive therapy. These findings should be interpreted not only in relation to burn severity but also considering developmental stage and family involvement. In younger children, adherence to rehabilitation programs largely depends on parental or caregiver supervision, whereas adolescents may experience greater challenges related to autonomy, self-image, and resistance to externally imposed treatment regimens.^{38,39}

Previous studies suggest that involving adolescents more actively in treatment planning and periodically renegotiating rehabilitation goals may help improve engagement and adherence over time.^{39,49} Although these strategies were not formally evaluated in the present study, they represent important considerations for future research and clinical practice.

Limitations of the study

This study has several limitations that should be acknowledged. Its retrospective and monocentric design limits causal inference and reduces the generalizability of the findings to other pediatric burn centers. The relatively small sample size may have limited the statistical power to detect differences between groups and precluded multivariable analyses. The adherence to physiotherapy was assessed subjectively by the treating physiotherapists as part of routine clinical practice, in the absence of validated adherence measurement tools. Although this approach reflects real-world clinical conditions, it may have introduced observer bias and variability in assessment. In addition, potential confounding factors such as socioeconomic status, family structure, psychological distress, and pain perception were not systematically collected and could have influenced adherence, particularly in adolescents.

Finally, long-term functional and quality-of-life outcomes were not evaluated, limiting conclusions regarding the clinical impact of differing adherence patterns over time.

Conclusions

Promoting adherence to physiotherapy in pediatric burn patients, particularly adolescents, remains a complex and underexplored challenge. Although physiotherapy tools are largely shared across age groups, developmental stage and family involvement appear to play a relevant role in treatment engagement.

This study highlights age-related differences in adherence during the scarring phase, suggesting that adolescents may require more tailored and participatory rehabilitation approaches. Further research, particularly prospective and multicenter studies, is needed to better define strategies that support sustained adherence and optimize long-term outcomes in this population.

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Abstract

Introduction. Neonatal and pediatric patients present an increased risk of skin injuries due to their immature skin barrier and frequent exposure to medical devices. To improve prevention, monitoring, and standardization of care, the Azienda USL Toscana Centro (AUTC), one of the largest healthcare organizations in Italy, implemented a corporate pediatric wound care model supported by a multidisciplinary working group.

Methods. This descriptive retrospective observational study was conducted within an institutional Quality Improvement framework. Aggregated anonymized data were collected annually from 2021 to 2024 across Neonatal Intensive Care Units (NICUs), Neonatology units, and Pediatric wards. Nurse representatives, coordinated by a pediatric wound care specialist from the corporate Wound Care Team, reviewed medical records to identify pressure injuries (PIs), medical device-related pressure injuries (MDRPIs), and incontinence-associated dermatitis (IAD). Total admissions and injury frequencies were reported for each setting.

Results. Over the four-year period, 12,818 admissions were recorded (mean 3,204.5 per year). The mean incidence of PIs was 0.47%, while IAD incidence averaged 5.13%, with higher rates observed in NICUs. Between 2021 and 2024, 149 healthcare professionals (nurses, physicians, and midwives) completed seven editions of a dedicated pediatric wound care

training program. The pediatric wound care working group expanded from 6 to 9 nurses and 1 physician, meeting quarterly to review surveillance data, discuss clinical challenges, and update procedures. In 2024, the corporate procedure for the prevention and treatment of neonatal and pediatric skin injuries was revised, and an inter-organizational pathway for the management of minor pediatric burns was jointly developed with Meyer IRCCS Children's Hospital.

Discussion and conclusions. The corporate wound care model supported consistent monitoring, widespread training, and standardized preventive practices across AUTC. The very low incidence of PIs and the stable burden of IAD indicate positive organizational impact, highlighting the value of sustained multidisciplinary engagement in pediatric skin injury prevention.

Keyword: Pediatric Skin Injuries, Quality Improvement, Pressure Injuries, Incontinence-Associated Dermatitis, Neonatal Intensive Care Units

Introduction

Skin injuries in neonatal and pediatric care represent a significant clinical challenge, as the skin of patients in developmental age exhibits anatomical and physiological characteristics that increase its vulnerability. In newborns, the stratum corneum is thinner and composed of fewer cellular layers, resulting in greater permeability and a higher risk of infection. The neutral pH, weak dermo-epidermal junctions, and reduced cellular cohesion further predispose infants to friction injuries and skin stripping. Additionally, conditions such as hypoalbuminemia and immature vascular structures significantly increase the risk of developing pressure injuries.^{1,2}

International literature confirms that the prevalence of pressure injuries (PIs), incontinence-associated dermatitis (IAD), and medical device-related pressure injuries (MDRPIs) in the pediatric population is substantial and displays epidemiological characteristics that differ from those of adults. A recent systematic review and meta-analysis reported an overall PIs prevalence of 7.8% and a cumulative incidence of 3.9%, corresponding to an incidence rate of 8.2 per 1000 patient-days. For MDRPIs, the reported prevalence was 7% and the cumulative incidence 5%, with an incidence rate of 6.7 per 1000 patient-days. The most commonly affected anatomical sites included the face (29.1%), ankle/

foot (20.1%), and head (15.7%), while the devices most frequently associated with these injuries were external monitoring devices, respiratory devices, and fixation/support systems.³

In light of this evidence, the management of skin injuries in patients of developmental age requires dedicated approaches focused not only on treatment, but also on prevention. Such approaches must account for increased skin fragility, limited tissue reserves, and the need to ensure the highest possible safety for this vulnerable population.^{4,5}

The Azienda USL Toscana Centro (AUTC), one of the largest and most complex healthcare organizations in Italy, offers an ideal context for implementing a structured model for prevention and monitoring of pediatric skin injuries. The organization includes 13 hospitals, 6 maternity wards, 2 level II Neonatal Intensive Care Units (NICUs), 6 Neonatal Pathology Units, and 5 pediatric wards, for a total of over 2,900 annual admissions.⁶

In 2017, AUTC introduced a corporate procedure for the prevention and treatment of pediatric and neonatal skin injuries, developed according to the best available evidence and regional recommendations. The implementation of this procedure requires adequately trained professionals, consistent monitoring, and regularly updated operational tools. For this reason, a corporate working group was established, composed of nurses representing all neonatal and pediatric units and coordinated by

a member of the Wound Care Team with specific expertise in pediatric wound care.⁷

Over the years, this group has strengthened an organizational network aimed at standardizing care pathways, promoting continuous staff education, monitoring the incidence of PIs, MDRPIs, and IAD, and updating corporate procedures in line with emerging evidence. The group's activities have also fostered increasing synergy with Meyer Children's Hospital IRCCS, resulting in the development of a shared care pathway for the management of minor pediatric burns.⁸

Within this context, the present study aims to describe the incidence and temporal trends of PIs, MDRPIs, and IAD in the pediatric and neonatal units of AUTC from 2021 to 2024, through the analysis of aggregated data derived from routine corporate monitoring. Secondary objectives include assessing adherence to the corporate procedure, evaluating the impact of ongoing staff training, and describing the organizational development of the pediatric wound care working group.

Methods

Study Design

This study adopts a descriptive retrospective observational design embedded within a broader Quality Improvement (QI) initiative aimed at enhancing the prevention, monitoring, and management of skin injuries in neonatal and pediatric patients across the AUTC. The methodological framework is aligned with the SQUIRE 2.0 guidelines¹⁰ for reporting quality improvement initiatives and integrates relevant elements from the RECORD extension of the STROBE statement¹¹, which is specifically tailored for research based on routinely collected data.

The study relies exclusively on aggregated, anonymized information derived from institutional monitoring processes. No individual-level clinical or demographic variables were collected, and no tracing of patient identities was possible.

Setting

The project was conducted across the neonatal and pediatric care settings within AUTC, a large and complex regional healthcare organization that includes multiple hospitals and services. These comprise NICUs, Neonatal Pathology Units, and Pediatric Wards distributed

throughout the territory.

To support the implementation of wound care procedures and the monitoring system, a Pediatric Wound Care Working Group was established in 2020. This group includes at least one trained representative nurse from each pediatric and neonatal unit, coordinated by a member of the corporate Wound Care Team (WCT) with specific expertise in pediatric wound care. The working group is responsible for supervising surveillance processes, promoting adherence to the corporate procedure, and facilitating continuous education among healthcare professionals involved in pediatric and neonatal wound care.

Data Sources and Collection Procedures

Data used in this study originated from routine institutional monitoring. Every six months, the designated nurse representative of each unit reviewed the medical records of all discharged patients to identify newly developed skin injuries, including PIs, MDRPIs, IAD.

These events were documented using a standardized reporting form that also included the total number of admissions for each unit during the same period. All data were aggregated at the unit level, ensuring complete anonymization. No patient-level variables – such as gestational age, comorbidities, or length of stay – were collected.

The six-monthly reports were submitted to the WCT coordinator, who compiled them into an annual dataset and subsequently into a consolidated dataset for the four-year study period (2021–2024). This dataset included aggregated numbers of admissions and the corresponding number of PIs, MDRPIs, and IAD cases across NICU, Neonatology, and Pediatric units. The structure of the dataset allowed for the comparison of trends across different care settings with varying patient acuity and clinical characteristics.

Period of Analysis

The analysis covered the period from January 1, 2021, to December 31, 2024. During these four years, the monitoring system registered a total of 12,818 admissions across the neonatal and pediatric settings included in this study. All data produced during this period were incorporated into the final analysis.

Outcome Measures

The primary outcomes of interest consisted of the frequency and proportion of PIs, MDRPIs, and IAD observed within each neonatal and pediatric care setting, as well as the overall and setting-specific temporal trends across the four-year observation period.

Secondary outcomes included the evaluation of Quality Improvement indicators, such as the expansion and evolution of the Pediatric Wound Care Working Group, participation in corporate training activities, and the updates implemented in clinical procedures and care pathways during the study period.

Data Analysis

Data analysis was entirely descriptive, reflecting the aggregated nature of the dataset and the QI-oriented purpose of the monitoring activity. Annual frequencies and percentages were calculated for each type of injury, and temporal trends were examined by comparing data across the four years of observation. Tables and graphical representations were generated using Microsoft Excel®, which provided an adequate platform for organizing and visualizing the aggregated data.

No inferential statistical tests or multivariate analyses were performed, as the study design and the nature of the available data did not allow for hypothesis testing or analytical modeling.

Data Quality and Limitations

Several limitations are intrinsic to institutional monitoring systems based on routinely collected data. Differences in documentation practices across hospitals, inconsistencies in form completion, and variability in medical record archiving may introduce discrepancies or missing data. These issues may influence the completeness or precision of the aggregated dataset. Nevertheless, these limitations do not compromise the descriptive intent of the study, which is primarily focused on identifying organizational trends and monitoring the evolution of wound care practices over time.

Ethical Considerations

Ethical approval was not required for this study. The project was conducted as part of an institutional Quality Improvement (QI) initiative aimed at monitoring and enhancing the prevention and management of pediatric and neonatal skin injuries within the AUTC. The data analyzed were fully anonymized and aggregated

at the unit level, without any direct or indirect identifiers that could allow the identification of individual patients.

The use of routinely collected, non-identifiable data for organizational monitoring was authorized by the AUTC Health Directorate and is in accordance with national regulations on QI activities. Since no identifiable information was processed, individual informed consent was not required.

According to the European General Data Protection Regulation (EU GDPR 2016/679), anonymized data fall outside the scope of data protection legislation, as specified in Recital 26, which states that the regulation does not apply to information that does not relate to an identified or identifiable natural person.¹²

Results

PIs incidence and prevalence

Between 2021 and 2024, a total of 12,818 neonatal and pediatric patients were hospitalized across AUTC facilities. During this period, the routine monitoring system identified 53 cases of pressure injuries (including both PIs and MDRPIs) and 575 cases of incontinence-associated dermatitis (IAD).

When examined by care setting, skin injuries were markedly more frequent in the NICU compared with Neonatology and Pediatrics. This pattern is clinically coherent, as NICU patients are predominantly premature or medically complex infants with immature skin barrier function, higher exposure to medical devices, and typically longer hospital stays – all factors that increase the risk of both device-related and moisture-associated skin damage.

A comprehensive summary of the distribution of injuries across the different care settings is presented in Figure 1, which reports, year by year, the number of PIs, MDRPIs, and IAD cases, together with their proportional incidence within NICU, Neonatology, and Pediatric wards.

When these data are considered in aggregate over the four-year period, as shown in Figure 2, a clear pattern emerges, with the NICU consistently displaying the highest prevalence for all categories of skin injuries.

The temporal behavior of these conditions is illustrated in Figure 3, which traces the percentage trends of PIs, MDRPIs, and IAD between 2021 and 2024, allowing for a visual comparison of how their incidence has evolved across settings over time.

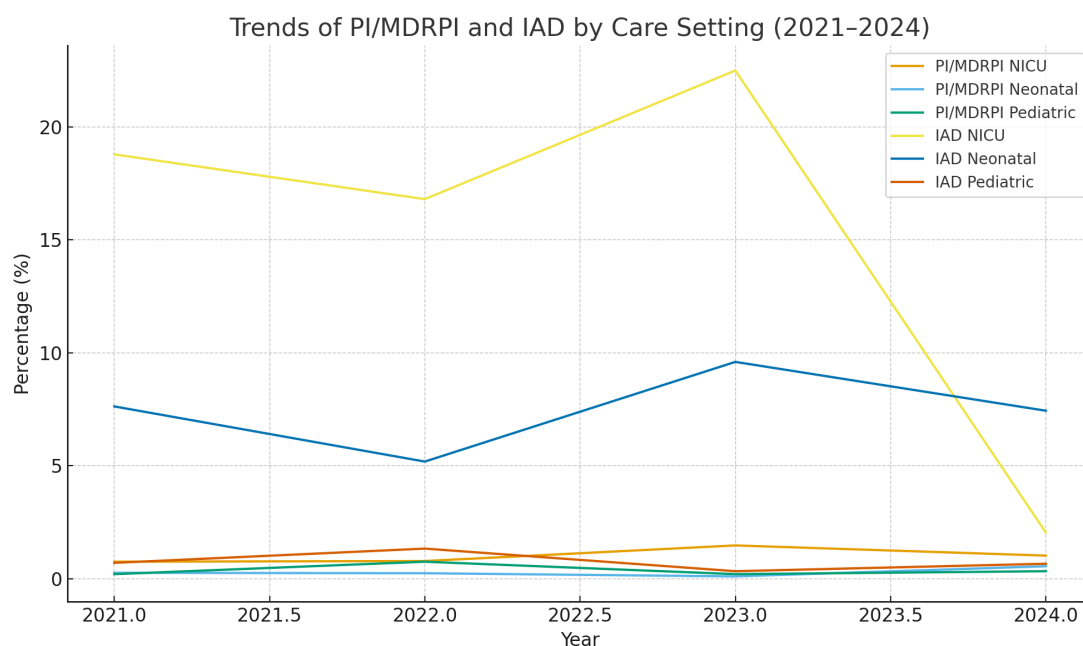


Figure 1. Trends in the percentage of pressure injuries (PIs), medical device–related pressure injuries (MDRPIs), and incontinence-associated dermatitis (IAD) across NICU, Neonatology, and Pediatric units from 2021 to 2024. The figure shows the four-year evolution of skin injury rates in the Azienda USL Toscana Centro (AUTC). PI/MDRPI rates remained consistently low (<0.6%) in all settings, with minimal annual variation, indicating stable and effective preventive measures. In contrast, IAD prevalence was substantially higher—especially in the NICU, where it ranged from ~16% to 22% before declining in 2024. Neonatology showed intermediate IAD values, while Pediatric units maintained low rates. The graph underscores distinct epidemiological patterns across settings and highlights the greater vulnerability of NICU patients due to clinical complexity, device exposure, and longer hospitalization.

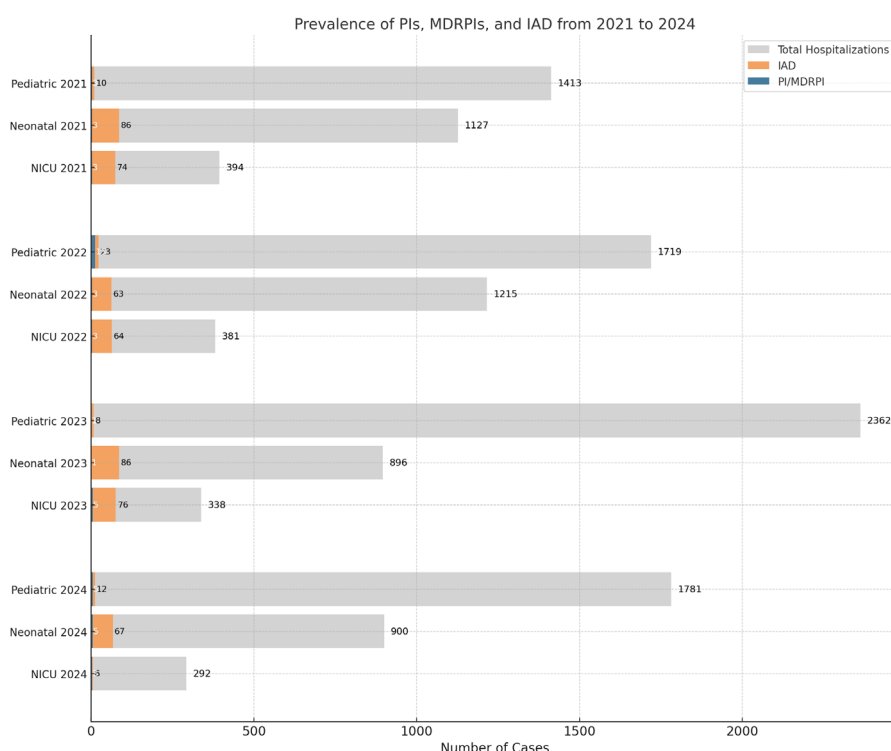


Figure 2. Prevalence of pressure injuries (PIs), medical device–related pressure injuries (MDRPIs), and incontinence-associated dermatitis (IAD) across NICU, Neonatal, and Pediatric units from 2021 to 2024. The figure displays, for each year and setting, total hospitalizations and the corresponding number and percentage of PIs/MDRPIs and IAD. PI/MDRPI prevalence remained below 0.6% across all settings and years, indicating stable and effective prevention. IAD prevalence was consistently higher, particularly in NICUs, with peak rates in 2021–2023, reflecting the vulnerability of premature and critically ill neonates. The visualization underscores inter-setting differences and temporal patterns of skin injury within the Azienda USL Toscana Centro (AUTC).

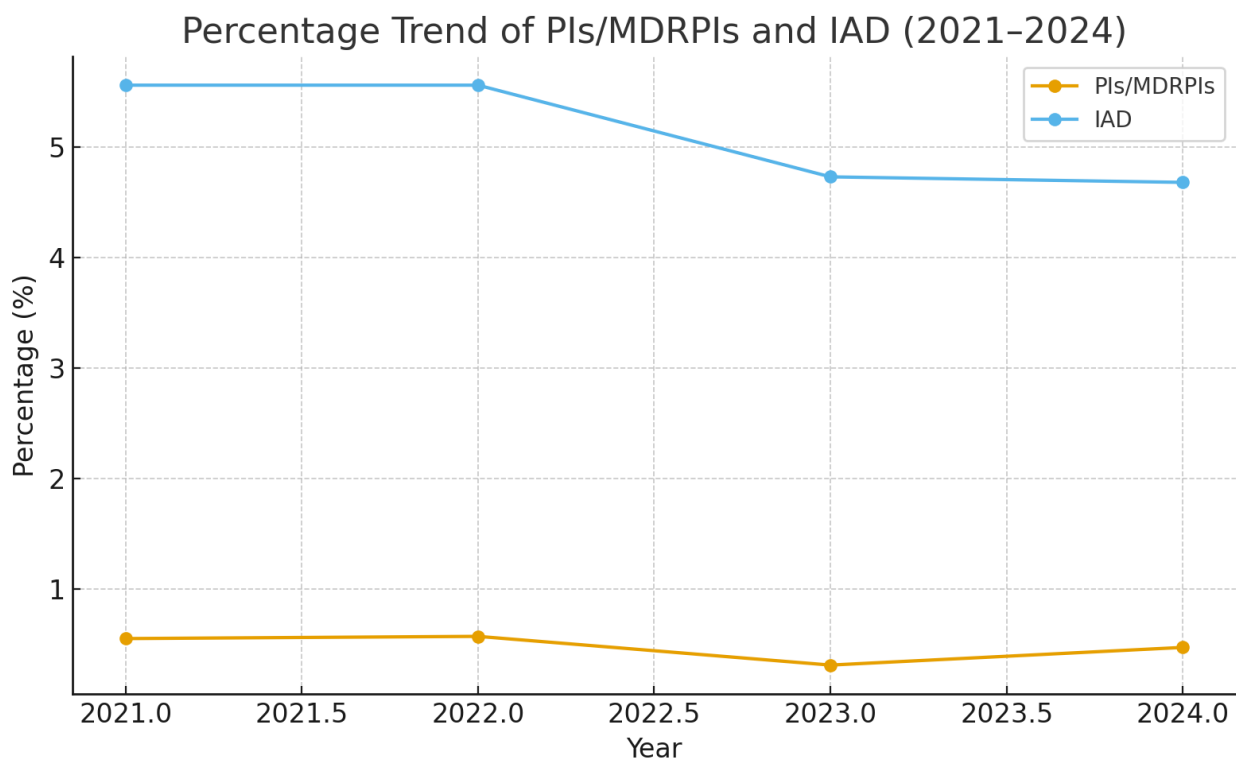


Figure 3. Percentage trend of pressure injuries (PIs), medical device–related pressure injuries (MDRPIs), and incontinence-associated dermatitis (IAD) from 2021 to 2024. The figure shows the annual percentages of PIs/MDRPIs and IAD across all neonatal and pediatric settings of the AUTC. Pressure injuries remained consistently below 1% with minimal year-to-year variation, while IAD percentages were higher but fluctuated modestly between ~4.6% and 5.6%. Overall, the trends indicate a stable burden of device- and moisture-associated skin injuries, with persistently low PI rates and limited variability in IAD.

Staff training

From 2021 to 2024, 149 healthcare professionals—including nurses, physicians, and midwives—participated in seven editions of the corporate training program on pediatric and neonatal wound care. The curriculum included pediatric risk assessment and related scales, characteristics of developing skin, principles of wound bed preparation, and the prevention and management of PIs, MDRPIs, IAD, burns, and traumatic injuries.

This training initiative contributed to strengthening the clinical competencies of staff members and supported the implementation of standardized preventive measures across all units.

Evolution of the Pediatric wound care working group

During the study period, the Pediatric Wound Care Working Group expanded from six nurses to nine nurses and one physician, reflecting an increasing institutional commitment to pediatric

wound care. The group met quarterly to conduct training activities, analyze monitoring data, discuss challenges, and propose updates to clinical pathways and procedures.

One of the key outcomes of this collaborative work was the revision of the corporate procedure for the prevention and treatment of pediatric and neonatal skin injuries, finalized in 2024 and aligned with the most recent scientific evidence.

Additionally, a shared care pathway for the management of minor pediatric burns was jointly developed between AUTC and Meyer Children's Hospital IRCCS. This inter-organizational protocol ensures uniform management across emergency departments and continuity of care between hospital and community services.

Another important initiative was the creation of an informational guide on neonatal and pediatric skin injuries, distributed to healthcare professionals across all units. After an initial implementation phase, a staff feedback survey was conducted, and the guide was revised

accordingly. The updated version is currently in use.

Discussion

This four-year descriptive quality improvement project, conducted across neonatal and pediatric settings within the AUTC, shows consistently low rates of PIs, MDRPIs, and a moderate but stable burden of IAD. Overall, PI/MDRPI incidence remained below 1% in all years and care settings, with mean values around 0.5%, whereas IAD incidence averaged just above 5%, with higher figures observed in NICU and lower in pediatric wards.

These findings suggest that a structured organizational model, based on a corporate pediatric wound care working group, routine surveillance of skin injuries, and standardized procedures, can support effective prevention of device- and pressure-related lesions, while highlighting IAD as a persistent challenge requiring ongoing attention, especially in highly complex neonatal patients.

Our results are best interpreted in the context of current epidemiological evidence. The prevalence and incidence of pediatric hospital-acquired pressure injuries reported in the literature are substantially higher than those observed in AUTC. The systematic review and meta-analysis by Şimşek et al. found a pooled prevalence of HAPIs of 7.8%, a cumulative incidence of 3.9%, and an incidence rate of 8.2 per 1000 patient-days, with MDRPIs showing similarly relevant rates (prevalence 7%, incidence 5%, incidence rate 6.7 per 1000 patient-days).³

Similarly, recent pediatric studies focusing on MDRPIs in tertiary children's hospitals and pediatric intensive care units report non-negligible rates of medical device-related damage, often ranging from 6-27% of children exposed to devices, underscoring the magnitude of the problem and its close link to complex care, prolonged device use, and critical illness.¹³⁻¹⁶

When compared with these data, the PI/MDRPI rates observed in our setting appear distinctly lower. Several factors may contribute to this difference: 1) Case-mix and organizational characteristics, because the AUTC network includes multiple neonatal and pediatric wards but not all highly specialized units (for example, long-term pediatric rehabilitation), potentially resulting in a lower baseline risk profile than

in some meta-analyzed cohorts;³ 2) Preventive focus and early device management, in which the corporate procedure emphasizes systematic risk assessment, proactive use of protective dressings, and regular device repositioning, which are known to reduce HAPIs and MDRPIs in pediatric populations;^{16,17} 3) Measurement approach: our surveillance is based on aggregated, routinely collected data rather than prospective daily skin assessments, which may under-detect very early or minimal lesions.^{13,18} This methodological aspect may partly contribute to lower observed rates.¹⁹

In contrast, IAD emerged as a more frequent condition, especially in NICU, aligning with recent evidence that moisture-associated skin damage and diaper dermatitis are highly prevalent in hospitalized neonates. Balaguer-López et al. reported a cumulative incidence of IAD of around 30-35% and an incidence rate of roughly 2-3 cases per 100 neonatal patient-days in Spanish neonatal units. Similar work in pediatric settings confirms that IAD represents the most common subtype of MASD, often exceeding other forms such as peristomal or periwound MASD.^{20,21}

Although our IAD incidence appears lower than the highest rates reported internationally, particularly in high-risk neonatal cohorts, the consistent presence of IAD across years and settings confirms that moisture-related damage remains a critical area for prevention. This is especially relevant in premature and medically complex infants, in whom immature skin barrier function, frequent stooling, and the use of diapers and perianal devices combine to increase MASD risk.^{20,21}

Overall, the comparison with the literature suggests that the organizational model implemented in AUTC may be particularly effective in controlling PIs and MDRPIs, while IAD continues to represent a more pervasive and multifactorial challenge that is less amenable to complete elimination, even in the presence of robust preventive policies.^{3,19,22}

A key feature of this project is the corporate Pediatric Wound Care Working Group, which connects all neonatal and pediatric units and is coordinated by a member of the Wound Care Team with specific pediatric expertise. Over the study period, this group expanded from six to nine nurse representatives and one physician, and it oversaw the implementation of surveillance, the interpretation of data, and the

iterative updating of procedures.²³

In parallel, 149 healthcare professionals (nurses, physicians, and midwives) attended seven editions of a dedicated training program on neonatal and pediatric wound care. The curriculum covered risk assessment, skin development, wound bed preparation, and the prevention and management of PIs, MDRPIs, IAD, burns, and traumatic injuries. This widespread educational effort likely contributed to the uniform adoption of preventive measures and consistent documentation practices across the different hospitals.²⁴

The project also had important inter-organizational implications, fostering synergy between AUTC and Meyer Children's Hospital IRCCS. The development of a shared care pathway for the management of minor pediatric burns, and the dissemination of an informational guide on neonatal and pediatric skin injuries, further highlight how corporate-level initiatives can translate monitoring data into concrete changes in clinical pathways and tools.

These elements are fully consistent with current recommendations for quality improvement activities, which emphasize the integration of data monitoring, interprofessional collaboration, and continuous education as essential drivers of sustained improvement in patient safety and skin integrity.

Study limitations

This study has several limitations that should be considered when interpreting the findings. First, it relies on aggregated, routinely collected data, without access to patient-level variables such as gestational age, comorbidities, nutritional status, ventilation type, or length of stay. This prevents adjustment for case-mix and does not allow for an analysis of risk factors or confounding variables.

Second, documentation practices and medical record archiving differ among hospitals within the AUTC network. Despite the use of standardized reporting forms, variability in completeness and accuracy of records may have led to underreporting or misclassification of certain events. This is an intrinsic limitation of institutional monitoring systems that do not rely on prospective, continuous bedside assessments.

Third, the absence of detailed information on patient-days of exposure for each setting precluded the calculation of incidence density rates (for example, per 1000 patient-days), which

are commonly used in epidemiological studies and meta-analyses of pediatric pressure injuries and MASD.

Finally, given the focus on hospitalized patients in NICU, Neonatology, and Pediatrics, the study does not capture injuries that may occur in short-stay observation units, emergency departments, or community settings, potentially underestimating the full burden of skin injuries across the continuum of care.

Future perspectives

Building on the experience gained during this four-year period, several avenues for further development can be identified. At the organizational level, the consolidation of a multidisciplinary corporate team involving nurses, physicians, and midwives may strengthen leadership, facilitate clinical decision-making, and promote shared accountability for outcomes related to skin integrity.

From a monitoring perspective, extending the surveillance system to short-stay units, emergency departments, and community settings would provide a more comprehensive view of the epidemiology of pediatric skin injuries and allow early identification of high-risk pathways, such as the transition from hospital to home care.

Future initiatives could also include: the development and validation of setting-specific risk assessment tools for neonatal and pediatric populations, particularly in NICU; the integration of more granular data (for example, device types, duration of exposure, diapering practices, skin care products) to better understand determinants of IAD and MASD; the design of intervention studies evaluating the impact of specific preventive strategies (for example, barrier products, advanced dressings, care bundles) on PI, MDRPI, and IAD rates in this population.

Conclusions

In summary, this quality improvement initiative demonstrates that a corporate pediatric wound care model, grounded in routine monitoring, standardized procedures, and ongoing staff education, can maintain very low rates of pressure injuries and MDRPIs while managing a persistent but stable burden of IAD, particularly in high-risk neonatal settings.

The establishment and progressive

strengthening of a pediatric wound care network across AUTC – and its collaboration with a specialized children's hospital – illustrate how organizational strategies can translate evidence into practice and foster a culture of prevention. Future work should focus on refining surveillance systems, expanding multidisciplinary engagement, and testing targeted interventions to further reduce the burden of pediatric skin injuries and ensure safe, equitable care for all neonatal and pediatric patients within the network.

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Hyaluronic Acid in Wound Management: An Update on Formulations, Mechanisms, and Clinical Applications

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Abstract

Introduction. HA underpins hydration, immune modulation, and matrix remodeling in wound healing. Its effects vary by molecular weight and formulation, with direct implications for clinical use. This update aims to analyze and discuss the current knowledge on HA, with the objective of outlining its mechanisms of action and exploring the clinical implications of the various formulations used in wound care.

Methods. This update integrates key contributions (2000–2024) from PubMed, Scopus, and authoritative wound-care texts on the cutaneous use of HA in adult and pediatric patients. Evidence was organized to describe mechanisms, formulation characteristics (HA-only, HA+Ag, HA+AA, HYAFF scaffolds, injectable HA+6AA), and practice integration across acute and chronic wounds. No systematic review procedures were applied.

Results. High-molecular-weight HA shows protective and anti-inflammatory actions; low-molecular-weight HA promotes angiogenesis and immune activation. Clinically, HA-only topicals aid hydration and epithelialization; HA+Ag addresses bioburden; HA+AA supports stalled/ischemic beds; scaffolded HYAFF provides structure and sustained release for deep/exuding wounds; injectable HA+6AA augments remodeling in complex cases. A TIMERS-aligned framework supports step-up/step-down use and escalation when progression thresholds are unmet.

Discussion. HA is a formulation-dependent therapeutic that benefits wound outcomes when matched to phenotype and phase. Heterogeneity of products and outcomes limits cross-study comparability; head-to-head trials and standardized endpoints are priorities to refine indications across hospital and community pathways.

Keywords: Hyaluronic Acid, Skin Regeneration, Wound Healing, Molecular Weight, Topical Formulations, Chronic Wounds

Introduction

Hyaluronic acid (HA) is one of the main components of the extracellular matrix (ECM) and plays a central role in tissue regeneration processes. Thanks to its marked hydrophilicity, HA is capable of retaining large amounts of water, thereby creating a moist environment that supports the migration and proliferation of fibroblasts and keratinocytes-key cells in wound repair.¹ This hydrated microenvironment not only sustains cellular viability but also facilitates the diffusion of nutrients and biochemical signals essential for skin regeneration.¹

In the field of wound care, interest in HA has grown significantly in recent years due to its involvement in all key phases of the wound healing cascade. During the inflammatory phase, HA contributes to modulating the immune response, helping to control inflammatory infiltrates and limit tissue damage.² In the proliferative phase, it stimulates granulation tissue formation, collagen synthesis and neovascularization. During the remodelling phase, it supports the reorganization of the ECM and the re-epithelialization of the wound. These properties have justified its extensive clinical use in both acute and chronic wound settings, with documented benefits in terms of reduced healing time and improved scar quality.³

However, not all HA-based formulations share the same characteristics or exert equivalent biological effects. The properties of HA are strongly influenced by several variables, including molecular weight (MW), concentration, chemical structure (linear or cross-linked), source of origin (biotechnological or animal-derived) and the pharmaceutical vehicle used. Among these, MW is a key determinant of biological activity: high molecular weight HA (HMW-HA) is generally associated with barrier, anti-inflammatory, and protective effects, while low molecular weight HA (LMW-HA), which tends to accumulate under stress or injury, is more actively involved in immune activation, cell proliferation, and angiogenesis.^{4,5}

The formulation type also plays a crucial role in clinical effectiveness. Gels, creams, sprays, powders, films or membranes differ in their ability to retain moisture, conform to the wound

bed and deliver active ingredients. Therefore, the selection of a specific HA-based medical device must be guided by the wound's characteristics-such as size, depth and exudate level-as well as by the stage of healing and the clinical context.⁶

From an anatomical and physiological perspective, the skin represents the body's main reservoir of HA. Although it constitutes approximately 15% of total body weight, it contains over 50% of the total HA. In the dermis, HA contributes to elasticity and skin turgor, while in the epidermis, it plays a key role in maintaining the lipid barrier and ensuring cell cohesion (Table 1).^{7,8}

Table 1. Physiological functions of HA in the Dermis and Epidermis. Adapted from Ciprandi G, Nicolosi B (2025).

DERMIS	EPIDERMIDIS
Hydration: Exceptional water retention ability, acting as a Natural Moisture Factor (NMF).	Barrier Function: Essential for maintaining the structure of the stratum corneum.
Elasticity: Connects collagen and elastin in the extracellular matrix.	Interstitial Space: Located in the 15-20 nm thick space between keratinocytes.
Intercellular Environment: Facilitates diffusion of nutrients, growth factors, and cytokines.	Interaction with HA Receptors: Maintains lipid barrier integrity.
Inflammatory Regulation: Helps control hydration during inflammation and embryonic development.	Role in Keratinocyte Differentiation: HA and CD44 contribute to lamellar body formation and lipid secretion (sphingomyelin, glycosphingolipids, phospholipids, cholesterol).
Elastic Structures: High-molecular-weight HA can form elastic structures.	Antioxidant Protection: Acts as a free radical scavenger, creating a viscous pericellular mesh around cells.

Today, HA is considered a cornerstone of advanced wound management, thanks to its multifunctionality, biocompatibility, and adaptability to diverse clinical needs. However, its effectiveness cannot be uniformly assessed: careful consideration of each formulation's characteristics is essential, integrating its use into a personalized therapeutic approach based on clinical evaluation and a thorough understanding of tissue repair biology.⁹

Given the numerous biological functions of HA and the growing availability of formulations for

cutaneous applications, a critical synthesis of the scientific evidence supporting its therapeutic use is timely. In particular, the structural and functional variability of HA requires an in-depth reflection on its actual impact on tissue healing processes.¹⁰

This update aims to analyze and discuss the current body of knowledge on HA, with the objective of outlining its mechanisms of action and exploring the clinical implications of the various formulations used in wound care.

Narrative Framework for the Update

This article adopts a narrative and integrative approach, aimed at summarizing the most relevant biological and clinical insights concerning the use of HA in wound care. Rather than assessing the quality of individual studies, the focus was placed on identifying key mechanisms, formulation strategies, and practical implications that have shaped the current understanding and application of HA in clinical practice.

The literature overview was based on a selective exploration of scientific sources published between 2000 and 2024, retrieved from PubMed, Scopus, and authoritative textbooks in dermatology and wound healing. The search included combinations of terms such as “hyaluronic acid”, “skin regeneration”, “wound healing”, “formulation”, and “molecular weight”. Additional references were identified through manual screening of citations within key articles and reviews. Only studies focusing on the cutaneous application of HA in experimental, preclinical, or clinical contexts were considered, while non-dermatologic uses were excluded.

Findings from both basic and applied research were synthesized narratively, with the intent to bridge experimental knowledge and practical wound care applications. The synthesis integrates molecular and physiological mechanisms with clinical and procedural evidence, highlighting how the structural and formulation diversity of HA translates into distinct therapeutic functions.

The following sections reflect this conceptual framework: Section 3 summarizes the biological rationale and mechanisms of action of HA in the three phases of wound repair; Section 4 discusses current formulations, clinical evidence, and procedural updates, integrating information from both commercial products and emerging

technologies.

This structure aims to provide a clinically oriented overview, emphasizing translational insights and practical guidance rather than a quantitative evaluation of study quality.

Biological Rationale and Mechanisms of Action

HA was first discovered in 1934 by Meyer and Palmer in the vitreous humor of bovine eyes. The term “hyaluronic” combines “hyaloid” (vitreous) and “uronic acid,” referring to its chemical nature. Initial studies in the 1950s by Karl Meyer elucidated the chemical structure of HA, and subsequent research through the 1960s and 1970s revealed its localization in tissues and complex conformational structure using X-ray crystallography and nuclear magnetic resonance experiments. For a long time, HA was thought to be an inert ECM component, until pivotal studies by Hardingham and Muir demonstrated its biological functions through specific receptor interactions, fundamentally shifting its role from structural filler to dynamic signalling molecule in tissue repair and inflammation.¹¹

HA is a key component of the extracellular matrix (ECM), acting as a regulator of cellular behavior during tissue injury and repair. Its biological activity depends primarily on its molecular weight (MW), which determines its structural conformation, receptor affinity, and downstream signaling.¹²⁻¹⁵

The molecule consists of repeating disaccharide units of N-acetylglucosamine and glucuronic acid linked by β -1,4 and β -1,3 glycosidic bonds, forming a highly hydrophilic, viscoelastic polymer capable of retaining up to 1,000 times its weight in water (Figure 1).¹⁶⁻¹⁸

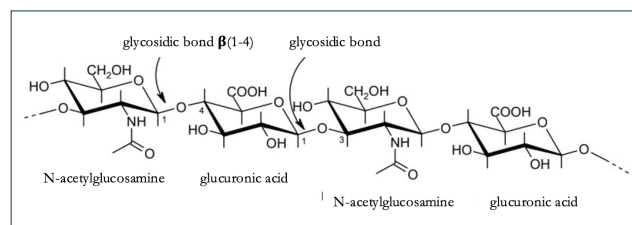


Figure 1. Chemical structure of HA, a linear glycosaminoglycan composed of repeating disaccharide units of N-acetylglucosamine and glucuronic acid. The units are linked via β (1 $\rightarrow$ 4) and β (1 $\rightarrow$ 3) glycosidic bonds, which confer the molecule its viscoelastic and hydrophilic properties essential for biological function in connective tissues.

This unique structure contributes to a hydrated and oxygen-permeable microenvironment essential for cell migration, proliferation, and differentiation within the wound bed.¹⁹⁻²¹

HA interacts with a group of specific cell-surface receptors – CD44, RHAMM, TLR2/4, LYVE-1, and HARE – which regulate processes such as inflammation, angiogenesis, and extracellular remodeling.²²⁻²⁴ Among the three hyaluronan synthase isoforms (HAS1-3), HAS2 predominantly generates high molecular weight HA (HMW-HA), typically around 2000 kDa,

responsible for protective and anti-inflammatory actions.^{25,26} Conversely, low molecular weight HA (LMW-HA), formed by enzymatic degradation through hyaluronidases (HAase) or oxidative stress, behaves as a danger-associated molecular pattern (DAMP) that promotes immune activation, fibroblast proliferation, and angiogenesis.^{27,28}

The dynamic equilibrium between these forms underlies the triphasic role of HA in wound healing (Figure 2).

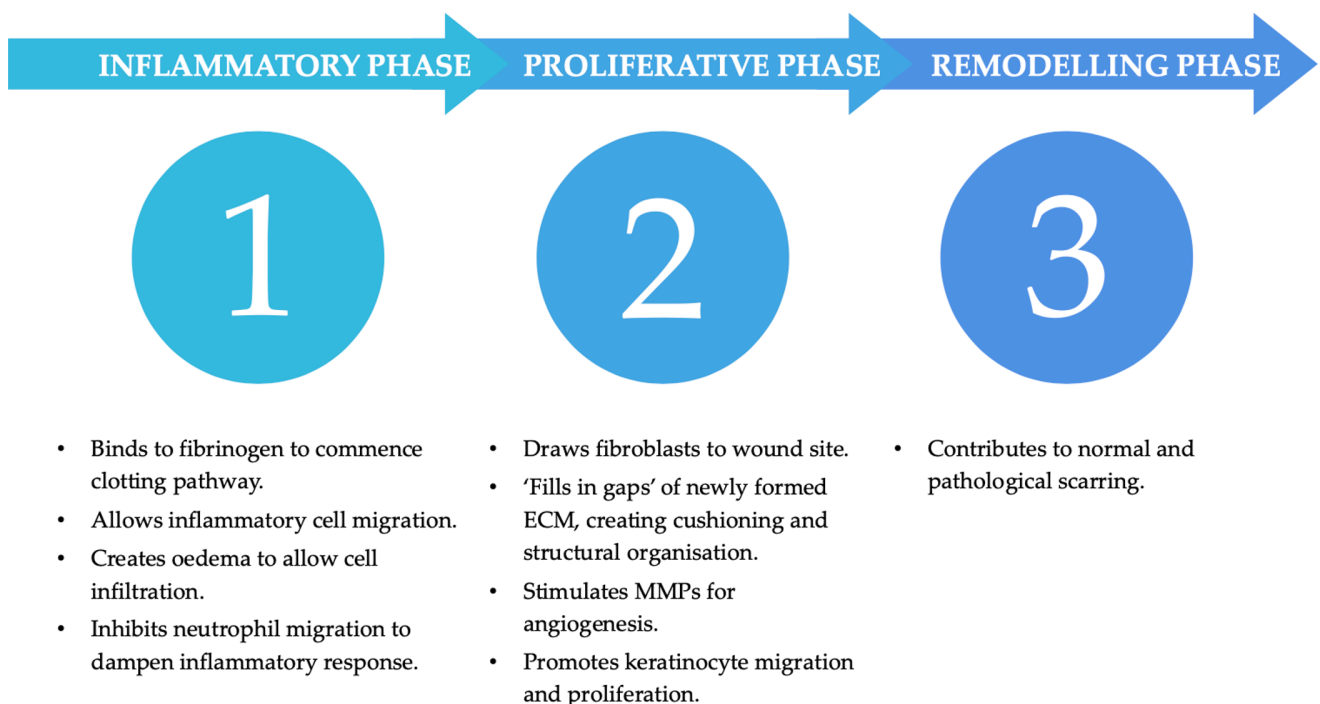


Figure 2. Role of HA during the three main phases of wound healing. In the inflammatory phase (1) initiates the immune response and prepares the wound site; the proliferative phase (2) supports tissue regeneration through the recruitment of fibroblasts and keratinocytes; the remodelling phase (3) leads to wound maturation and the formation of either normal or pathological scarring. Adapted from Ciprandi G, Nicolosi B (2025).⁹

HA and the Inflammatory phase

In the early inflammatory phase, HA synthesis increases rapidly.²⁹ Upon skin injury, HMW-HA fragments are released into the wound environment, including platelet-derived and circulating HA fractions.³⁰ These fragments bind fibrinogen, initiating the extrinsic clotting cascade.³⁰ The massive release of HA saturates the wound site with fluid, causing oedema and tissue swelling and creating a porous matrix that promotes immune cell migration.^{31,32}

This phase is driven by cytokines such as TNF- α , IL-1 β , and IL-8, whose activity is facilitated by HA.³¹ However, HA also modulates inflammation

via the hyaladherin TSG-6, whose expression is upregulated by IL-1 and TNF- α in fibroblasts and immune cells.³³ TSG-6 binds HMW-HA, forming heavy-chain complexes that suppress neutrophil migration and inhibit plasmin activation through feedback mechanisms, thereby tempering the inflammatory response.^{34,35}

HA and the Proliferative phase

As inflammation subsides, fibroblasts migrate to the wound, attracted by small HA fragments (6-20 saccharides) and growth factors.³⁶ These cells synthesize collagen and glycosaminoglycans (including HA), contributing

to ECM reconstruction.^{37,38} The length of HA chains influences collagen subtype expression, affecting scar quality. Collagen provides tensile strength to the healing wound and is synthesized in multiple isoforms by fibroblasts.³⁶⁻³⁸

Granulation tissue forms as collagen and elastin build the fibrous scaffold, and HA fills intercellular spaces with a hydrated gel.³¹ HMW-HA, due to its hydrophilicity, provides elasticity comparable to cartilage, which is crucial in areas subjected to mechanical stress (for example, joints and plantar surfaces).³³ Without HA's porous, hydrated matrix, granulation tissue would lack architectural stability.

Oligomeric HA also promotes angiogenesis by binding CD44 and stimulating matrix metalloproteinases (MMPs), enabling basement membrane remodeling and capillary sprouting.^{39,40}

HA and the Remodelling phase

This final phase involves progressive tissue maturation and scar formation.¹⁸ Fibroblast activity and ECM remodeling continue, with collagen synthesis and degradation reaching physiological equilibrium after approximately three weeks.^{37,44} Although tensile strength increases gradually, it never matches that of uninjured skin.^{37,45} Ultimately, HA and provisional matrix structures are resorbed and replaced by a dense, avascular collagen matrix. This disorganized collagen architecture results in lower mechanical performance compared with native dermis.⁴²

Clinical correlation

The anti-inflammatory, viscoelastic, and angiogenic properties of HA make it a versatile biopolymer adaptable to specific stages of wound healing. High-molecular-weight HA (HMW-HA) formulations are suited for early, inflamed wounds due to their protective and immunomodulatory effects, whereas low-molecular-weight HA (LMW-HA) species promote cellular proliferation, angiogenesis, and wound closure. Cross-linked or esterified HA scaffolds extend residence time and provide structural support for chronic or deep wounds (Table 2).^{46,47}

Table 2. Classification of HA based on molecular weight. The biological activity of HA varies significantly according to its MW (in kilodaltons-kDa), influencing its role in inflammation modulation, cell proliferation, angiogenesis, and tissue regeneration.

Type of HA	MW Range
Oligomeric HA (o-HA)	< 10 kDa
Low Molecular Weight HA (LMW-HA)	10–250 kDa
Medium Molecular Weight HA (MMW-HA)	250–1000 kDa
High Molecular Weight HA (HMW-HA)	> 1000 kDa
Very High Molecular Weight HA (vHMW-HA)	> 6000 kDa

Beyond molecular-weight classification, the Visual and Structural Classification of Natural and Variably Stabilized Hyaluronic Acids (ViSCNOVAS) provides a complementary framework to describe the morphological and functional variability of HA formulations. This system considers key parameters such as molecular-weight distribution, polymer chain architecture (linear versus cross-linked), degree of modification or esterification, and the resulting rheological behavior.⁴⁸

According to the ViSCNOVAS model, HA formulations can be conceptually grouped into four progressive structural categories. The first category includes native, linear, non-stabilized HA, characterized by high purity and minimal chemical modification, primarily intended to enhance hydration and epithelial regeneration. The second category consists of hybrid or partially stabilized HA, in which chains of different molecular weights are combined to optimize viscoelasticity and persistence. A third category comprises cross-linked HA, designed to increase viscosity and resistance to enzymatic degradation, thereby prolonging its residence time and providing structural support in deeper or more complex wound environments. Lastly, chemically modified or esterified HA represents the fourth category, developed for sustained release, three-dimensional integration, and regenerative matrix support, particularly in situations requiring prolonged biomechanical stability and tissue integration.⁴⁸

This classification underscores how HA's structural conformation directly influences its clinical performance, helping clinicians match molecular characteristics with therapeutic goals in wound management.

The distribution of HA molecular weights

also changes significantly under pathological conditions. Under physiological circumstances, tissues primarily contain high-molecular-weight HA; however, following injury or during inflammation, low-molecular-weight HA fragments accumulate and act as molecular

danger signals, activating immune responses and stimulating fibroblast and endothelial activity. In contrast, high-molecular-weight forms exert epithelial protective functions, support tissue stability, and demonstrate anti-inflammatory and analgesic effects (Table 3).^{49,50}

Table 3. Classification of HA based on its molecular weight, highlighting the typical molecular weight range, presence under physiological or pathological conditions, and biological roles. Each HA subtype – from oligomeric to very high molecular weight – exhibits distinct effects on tissue homeostasis, inflammation, and wound healing, reflecting its structural and functional diversity.

Type of HA	MW	Presence	Role
o-HA	< 10 kDa	Rarely detected in vivo, produced by intense degradation	May exert marked pro-inflammatory and pro-angiogenic effects but is not well characterized.
LMW-HA	10–250 kDa	Rarely present under pathological conditions	Enhances immune response, promotes cell proliferation, inflammation, collagen synthesis, and angiogenesis. Acts as a DAMP and may contribute to chronic inflammation.
MMW-HA	250–1000 kDa	In intermediate quantities, produced both by direct synthesis and partial degradation of HMW HA	May have mixed properties, balancing stimulation and modulation of inflammation.
HMW-HA	> 1000 kDa	2000 kDa is the most abundant	Counteracts LMW HA effects, promotes wound healing, maintains tissue stability, protects epithelial tissues, and exerts anti-inflammatory, antinociceptive, immunosuppressive, and anti-angiogenic effects. Interacts with receptors such as CD44 and TLR4, inhibits neutrophil migration via TSG-6.
vHMW-HA	> 6000 kDa	Present in smaller amounts; selectively produced by HAS2 in specific tissues	Amplified protective and anti-inflammatory effects, greater ECM stability and viscosity.

Such differentiation forms the biological foundation for the wide range of HA-based medical devices currently available for wound care, designed to leverage specific molecular and structural properties for targeted clinical outcomes.⁵¹

Practical implications and integration into clinical practice

The clinical translation of HA research requires a formulation-driven and context-specific approach. The biological versatility of HA – determined by its molecular weight, degree of stabilization, and pharmaceutical form – governs its therapeutic behavior and defines its optimal clinical application.⁵² Consequently, integrating HA into wound-care pathways demands careful alignment between its structural and functional properties and the wound's pathophysiological stage, exudate level, and risk of infection.⁵³

Decision-making framework for HA formulation selection

Building on the biological and clinical evidence summarized above, the practical use of HA in wound management should follow a formulation-specific and phase-oriented strategy. Selection must be guided by wound type, moisture balance needs, bioburden status, and predominant healing phase, ensuring that the chosen HA form supports physiological tissue repair while addressing local clinical priorities.⁵³

The following framework provides a concise guide to help clinicians match each HA formulation to the most appropriate wound condition, enabling individualized, mechanism-based, and evidence-driven treatment planning.⁵⁴ Table 4 summarizes the recommended HA formulations according to wound characteristics, exudate level, and therapeutic objectives, offering a practical tool to facilitate structured integration of HA into modern wound-care protocols.

Table 4. Summarizes the recommended HA formulations according to wound characteristics and clinical rationale.

Wound type	Recommended HA formulation	Rationale clinical
Acute clean superficial (abrasions, surgical incisions)	LMW-HA cream or gel (0.2-0.25%)	Promotes hydration, epithelialization, and pain relief.
Exudative or infected wounds	HA+Ag (Connettivina Plus®, Hyalosilver®)	Provides antimicrobial and anti-inflammatory action; controls bioburden.
Chronic dry or necrotic wounds	HA+4AA gel or powder (Vulnamin®)	Supports collagen synthesis, maintains moisture, reactivates chronic wounds.
Deep or full-thickness wounds	Cross-linked or esterified HA scaffold (HYAFF®-based, Hyalomatrix®, Hyalosafe®)	Provides 3D structural matrix for dermal regeneration and sustained HA release.
Mixed or delayed healing lesions	Injectable HA+6AA (Vulnamin® Inj)	Enhances tissue remodeling and localized repair in chronic or complex wounds.
Mucosal or oral lesions	HA+4AA spray or mouthwash (Mucosamin®)	Facilitates rapid mucosal repair and pain reduction; suitable for pediatric and oncologic care.

This framework underscores the importance of integrating HA formulations into standardized wound-care pathways, aligning their application with the Tissue, Inflammation/Infection, Moisture balance, Edge advancement, Regeneration, and Social factors (TIMERS) model and adapting their use to the clinical setting.⁵⁵

Integration of HA into Wound Care Protocols

HA-based dressings can be integrated into standard wound-care algorithms, particularly after wound bed preparation according to the TIMERS framework. Within a TIMERS-oriented workflow, HA selection should correspond to the predominant barrier to healing in each phase.⁵⁶

T (Tissue): after wound bed preparation, sodium hyaluronate combined with collagenase may be used when selective enzymatic debridement is required; once slough and necrosis are reduced, transition to LMW-HA gel or cream (≈0.2-0.25%) to maintain moisture and support keratinocyte migration.⁵⁹

I (Inflammation/Infection): in contaminated or at-risk wounds, prefer HA+Ag (cream, spray, gauze) to couple moisture balance with bioburden control; in overt infection, HA+Ag can support local management while systemic therapy is optimized and reassessed every 48-72h.²⁶⁻²⁷

M (Moisture): for dry or stalled wounds, escalate to HA+AA (gel, cream, or powder depending on exudate) to rehydrate the wound bed and support collagen synthesis; for highly exudative wounds, pair HA powder or HYAFF® scaffolds with absorptive secondary dressings.^{24,46,47}

E (Edge): when epithelial advancement

is limited, use cross-linked or esterified HA scaffolds (for example, HYAFF® films, membranes, sponges) to provide a 3D matrix and support cell migration at wound edges.²¹⁻²³

R (Regeneration): in chronic, deep, or metabolically stagnant wounds, injectable HA+AA may be added peri- or intralesionally to stimulate dermal remodeling in synergy with topical HA.²⁴

Introducing HA across care pathways: hospital, community, and telemonitoring settings

In peri-operative and post-surgical contexts, start LMW-HA immediately after cleansing or closure on clean incisions to reduce pain and support re-epithelialization; upgrade to HA+Ag if device-related risk or early signs of critical colonization emerge.^{26,27,52} In acute burns and superficial trauma, transparent HYAFF® films (for example, Hyalosafe®) help maintain a moist, semi-occlusive environment with easy inspection, then transition to LMW-HA as exudate subsides.^{21-23,46,47}

For chronic-wound clinics or home care, embed HA in the standard visit: a) after debridement, initiate HA+AA for dry/ischemic beds or HA+Ag for bioburden; b) reassess weekly with objective criteria (area reduction, pain, exudate class) and step-down to HA-only when stable.^{26,27,54} In pediatric care, prioritize non-stinging, easy-to-apply formats (sprays, films, soft gels) and minimize dressing changes; telemonitoring (photo audits, exudate scoring) can support titration between HA+Ag and HA+AA, documenting decisions against TIMERS checkpoints.⁵⁸

When wound improvement is insufficient – for

example, when < 30% reduction in wound area is observed after 4 weeks of appropriate therapy – escalation should be initiated. This may include transitioning to scaffolded HA dressings and/or adding peri- or intralesional HA combined with AA or referring the patient for adjunctive or multidisciplinary interventions.^{27,54}

Integrating HA with complementary wound-care strategies

Always prepare the wound bed first: mechanical/sharp or autolytic debridement; if dense fibrin persists or pain limits sharp debridement, use sodium hyaluronate + collagenase short-term, then switch to regenerative HA once clean.⁵⁹ Apply an antibiofilm routine (cyclical cleansing and contact-layer renewal) and, where risk is high, deploy HA+Ag for 7-14 days before de-escalating to HA-only or HA+AA.^{26,27}

With Negative Pressure Wound Therapy (NPWT), place a non-adherent HA interface (LMW-HA gel/sheet or HYAFF® veil) or HA+AA over fragile structures to reduce adherence and support granulation; in deep cavities, HA+AA or HYAFF® sponges/membranes can act as a scaffold under NPWT.⁵⁷ Align dressing choice with the evolution of exudate: HA powder for heavy exudate, then gels/creams/films as moisture normalizes, and edge-focused HA scaffolds in the epithelialization phase.^{21-23,46,47,54}

Follow a step-up/step-down approach: start with an HA formulation matched to the predominant TIMERS barrier; if bioburden or poor edge progression persists, escalate to HA+Ag or to scaffolded/injectable HA. Once the wound bed is clean, pain is reduced, and edges advance, de-escalate to HA-only formulations. Non-progression ($\geq 70\%$ residual area at 4 weeks) or red flags (ischemia, osteomyelitis, uncontrolled edema) should trigger multidisciplinary review.^{27,54}

HA, being a natural (bio)polymer, is widely employed as a biomaterial in the development of wound dressings. Its non-toxicity, biodegradability, biocompatibility, gas permeability, and ease of application support safe use even in pediatric and chronic-care settings.⁵⁸ Despite these advantages, clinical and commercial use still presents limitations – potential impurities from extraction, higher production costs, limited mechanical stability in some vehicles, and variable bioactivity without adjuncts – driving the development of a broad

range of solid and semi-solid HA dressings tailored to specific healing stages.⁵²⁻⁵⁴

Product-based recommendations and clinical scenarios

The growing variety of HA-based medical devices available for wound management necessitates formulation-specific decision-making based on wound characteristics and treatment goals.⁶⁰ Tables 5 and 6 summarize the principal commercially available HA products, classified according to formulation type (solid scaffolds vs topical preparations), concentration, and clinical indications.⁵²⁻⁵⁴

The choice of a specific product should be guided by key wound parameters – including depth, exudate level, infection risk, and healing phase – as well as by the clinician's therapeutic objectives. Each formulation offers distinct handling properties and biological effects, enabling personalized treatment strategies aligned with the TIMERS framework and tailored to the clinical scenario.²⁶⁻⁵⁵

Solid and scaffolded HA formulations such as sponges, films, and membranes are particularly indicated for deep or exuding wounds where structural support and prolonged HA release are required. Hyalomatrix® and Hyalofill-F® are suitable for chronic ulcers, full-thickness lesions, and second-degree burns, providing a three-dimensional matrix that sustains granulation and dermal regeneration.^{21-23,46,47} Hyalosafe®, a transparent HA film, is especially valuable for superficial or surgical wounds and partial-thickness burns, allowing continuous inspection and maintaining an optimal moisture environment.²¹⁻²³ HylaSponge® offers substantial absorbency and is indicated for bleeding or heavily exuding chronic wounds, combining exudate control with hydration of the wound bed.^{21-23,46,47,61,62} These products are summarized in Table 5.

In addition to scaffolded formulations, numerous topical HA-based products are available in gels, creams, sprays, and powders, allowing treatment to be tailored according to wound type and exudate level (Table 6). Topical HA preparations are particularly suitable for acute, superficial, or post-surgical wounds, as well as for maintenance phases following advanced therapies.⁶⁰

Pure HA creams and gels (for example, Connettivina®, Cicatridina®, Ialuset®) promote

Table 5. Solid scaffold HA-based wound dressings. Comparative table of main products by type, HA characteristics, concentration, and clinical indications. *NR: non reported.

Commercially Available HA-Based Wound Dressings	HA dressing type		HA characteristic	HA concentration	Indications for use	References
Hyalofill-F®	HYAFF® hyaluronan-based biodegradable polymers	Fleece wound dressing composed of HYAFF®	Partial benzyl ester derivative of hyaluronan	NR*	Treatment of chronic wounds, including diabetic foot ulcers	56, 57
Hyalomatrix®	HYAFF® hyaluronan-based biodegradable polymers	HA-based membrane	HYAFF® 11 is an HA-derivative, which is acquired via the esterification reaction of the free HA carboxylic group and benzyl alcohol	NR*	Treatment of full-thickness wounds, second-degree burns, venous ulcers, pressure ulcers, and chronic vascular ulcers	58
Laserskin®	HYAFF® hyaluronan-based biodegradable polymers	HYAFF® biopolymer-sheet	HYAFF®-based material that has a microperforated HA sheet, with diameter of 40 mm and 500 mm, made with a laser-drill	NR*	Treatment of acute and chronic wounds	59
Hyalosafe®	HA-based films		HYAFF®, a total benzyl ester of HA, which creates a transparent film that is impermeable to microorganisms, but permeable to water vapor	NR*	Treatment of moderate exuding wounds, surgery wounds and second-degree burns	58
HylaSponge®	HA-based sponges	Network system of huge group of HA molecular chains	Network structure of long molecular chains of HA, capable of absorbing and releasing large volumes of water	2,50%	Treatment of acute and chronic wounds (diabetic, leg, and pressure ulcers and bleeding wounds)	60

hydration and pain reduction in clean, non-infected wounds, supporting epithelial migration and maintaining an optimal moisture environment.⁶⁰

For wounds at risk of infection or showing early signs of critical colonization, HA combined with silver (Connettivina Plus®, Hyalosilver Plus®, Ialuset Plus®) provides local antimicrobial action while preserving moisture balance and tissue protection.⁶¹

Formulations combining HA with AA (Vulnamin® line) enhance collagen synthesis, extracellular-matrix remodeling, and angiogenesis, making them suitable for chronic, dry, or ischemic wounds. They are available

as gel, cream, powder, spray, and injectable preparations, enabling precise adjustment to wound depth and exudate level.⁶²

Other specialized options include sodium hyaluronate combined with collagenase (Bionect® Start), which supports selective enzymatic debridement in fibrinous wounds, and HA combined with polynucleotides (Nucliaskin S®), which aims to enhance dermal regeneration by synergizing HA hydration with nucleic-acid-mediated trophic activity.⁶³

These products and their indications are summarized in Table 6.

Table 6. Topical liquid or semi-liquid HA-based wound dressings. Overview of the main commercially available products, including pharmaceutical form, HA characteristics, concentration, and principal clinical indications.
*NR: non reported; **Percentage calculated from the concentration described in package leaflet.

Commercially Available HA-Based Wound Dressings	Dressing Type	HA characteristic	HA concentration	Indications for use
HA-only component				
Connettivina®	Gel	Sodium hyaluronate	2 mg/g (0.2%)**	Abrasions, grazes, superficial wounds, sunburns, minor burns and small cuts
	Cream	Sodium hyaluronate	2 mg/g (0.2%)**	Superficial skin injuries, such as abrasions, grazes, small cuts, minor burns and friction wounds
Hylase Wound Gel®	Gel	Sodium hyaluronate	2.5%	Acute and chronic wounds, including pressure injuries, 2 nd and 3 rd burns, and diabetic ulcers
Ialuset®	Cream	Sodium hyaluronate	0,2%	Non-infected wounds and burns, with or without exudate, leg ulcers, including those of venous origin, fissures, fistulas, bedsores, post-operative wounds, abrasive skin diseases and abrasions of chemical-physical origin
	Gauze	Sodium hyaluronate	0,05%	
HA-Based combination formulations				
Connettivina plus®	Cream	Sodium hyaluronate + Argentic sulfadiazine	10 mg/mL (1%)**	2 nd and 3 rd degree pressure injuries
Cicatridina®	Cream	Sodium hyaluronate + Almond oil	0.2%	Irritations and redness, superficial lesions (cracks, scratches, abrasions, erythema, superficial cuts), deep lesions (surgical wounds, 1 st and 2 nd degree burns, bedsores, ulcers)
	Spray	Sodium hyaluronate +Aluminum octenyl succinate + Almond oil	0.2%	Abrasions, lacerations, 1st and 2nd degree burns, surgical wounds, bedsores and ulcers
Vulnamin®	Cream	Sodium hyaluronate + 4AA (Gly, L-Pro, L- Leu, L-Lys)	1.33%	Chronic ulcers or damaged dermal areas
	Gel		2%	Necrotic or dry wounds
	PWD (Powder)		20%	Skin injuries of various origins with moderate to heavy exudate, even when colonized.
	Spray (Fluid gel)		1.33%	To prevent and treat early-stage or initial skin lesions
	INJ (Injectable liquid)		1%	Direct applications in chronic wound environments and in the presence of delayed healing
Ialuset® Plus	Cream	Sodium hyaluronate+ Argentic sulfadiazine 1%	0.2%	Infected wounds and burns, dermatological conditions of bacterial origin or predisposed to the development of secondary infections
	Gauze	Sodium hyaluronate+ Argentic sulfadiazine 1%	0,05%	
Bionect® Start	Fluid ointment	Sodium hyaluronate + Collagenase (≥ 2.0 nkat/g)	0.2%	Used to remove harmful agents, abrasions, and restore skin integrity
Nucliaskin S®	Gel	Sodium hyaluronate + Polynucleotides HPT® +Vit E	NR*	Ulcers of lower limbs
Hyalosilver Plus®	Spray	Sodium hyaluronate + Metallic silver + Vit E	0.25%	Acute and chronic wounds at risk of infection or already contaminated, especially in the presence of exudate.

The diversity of HA-based products reflects the multifunctional nature of this biopolymer, with roles ranging from structural support and hydration to modulation of inflammation and tissue repair.⁶⁰ The clinical application of HA in wound management is closely linked to its physicochemical profile, as differences in molecular weight, degree of stabilization, and formulation design not only dictate biological activity but also influence handling properties and appropriate clinical setting.⁶¹

LMW-HA, characterized by high solubility and rapid diffusion, is ideally suited for superficial or early-stage wounds where hydration and epithelial stimulation are priorities. Its rapid absorption and ease of application make it advantageous in outpatient and home-care pathways requiring frequent dressing changes.^{60,61}

Conversely, HMW-HA and vHMW-HA formulations provide greater viscosity, persistence, and mechanical protection, making them particularly useful in inflamed or exudative wounds and in post-surgical settings where prolonged moisture balance and reduced dressing frequency are required.^{4,5,61}

Cross-linked and esterified HA derivatives offer prolonged residence time and enhanced structural integrity, which favors their use in deep or full-thickness wounds and in combination with advanced therapies such as NPWT, where they act as three-dimensional scaffolds promoting dermal regeneration and controlled exudate management.^{21-23,57,62}

Formulations combined with bioactive components further refine clinical use: HA+Ag preparations are indicated for contaminated or high-risk wounds due to their ability to modulate bioburden while maintaining moisture balance,^{26,27} whereas HA+AA formulations support metabolic activity, collagen synthesis, and re-epithelialization in chronic or ischemic wounds.^{24,63,64} Injectable HA blends, such as HA combined with six AA (HA+6AA), expand the therapeutic potential by offering peri- or intralesional stimulation of remodeling pathways in complex or non-healing wounds.^{63,64}

In this context, HA structure and composition should not be considered mere chemical variations, but determinants of therapeutic context, frequency of application, and integration into multidisciplinary care pathways.⁵⁴ A rational selection of HA formulations requires alignment

between physicochemical features, wound pathophysiology, clinical setting, and patient-specific factors, such as pain tolerance, exudate level, and capacity for follow-up care.⁵⁵

Accordingly, different formulations serve distinct therapeutic functions: scaffolded HA for structure and regeneration, HA+Ag for infection risk, HA+AA for chronic or stalled wounds, and HA-only formulations for hydration and maintenance.^{26,27,54} This framework supports the integration of HA-based products into wound care protocols according to healing stage and care environment, from acute hospital settings to community-based and pediatric pathways.⁵⁸

Despite these advances, ongoing research continues to explore new HA-based scaffolds and hybrid systems incorporating antimicrobials, anti-inflammatory agents, or growth factors to enhance epithelialization, angiogenesis, and remodeling.⁶⁵⁻⁶⁷ As topical HA formulations evolve – differing in concentration, pharmaceutical form, and co-components – clinical outcomes may vary substantially, even when HA represents the primary active ingredient. Therefore, appropriate product selection requires consideration of multiple formulation-related variables already discussed, including molecular weight, concentration, delivery system, and adjunctive ingredients.⁶⁰⁻⁶⁴

Limitations and future directions

The present update has several methodological and translational limitations that must be acknowledged. First, the heterogeneity of the available evidence represents a major constraint. Studies on HA in wound care encompass a wide variety of formulations differing in molecular weight, concentration, degree of cross-linking, and combination with other bioactive compounds. This variability complicates the comparison of outcomes and makes it challenging to attribute clinical effects to specific HA characteristics.

Second, few head-to-head comparative studies exist to directly evaluate the relative effectiveness of different HA-based products or formulations. The absence of standardized protocols for application, dosing, and follow-up further limits reproducibility and cross-study comparability. Outcome measures are also inconsistently reported, often mixing subjective clinical impressions with heterogeneous healing endpoints, which weakens the strength of

evidence and impedes meta-analytic synthesis.

Moreover, most studies are single-center and exploratory, with small sample sizes and limited external validity. There is a general lack of data on cost-effectiveness, long-term outcomes, and real-world performance of HA dressings in diverse clinical settings, including community and home care.

Finally, transparency regarding the exact composition and rheological properties of commercial formulations remains limited, hindering the interpretation of product-specific results and the translation of findings into practice.

Future research should therefore focus on well-designed, adequately powered randomized controlled trials comparing standardized HA formulations; on the development of shared outcome measures aligned with international wound-healing frameworks; and on the integration of real-world data and economic analyses to better define the value and sustainability of HA-based wound management strategies.

Conclusions

HA is a fundamental component of the ECM and exerts pivotal functions throughout all stages of wound healing – from inflammation modulation to cellular proliferation and tissue remodelling. Its biological performance is determined by molecular weight, structural configuration, and formulation design, which together shape its interaction with the wound microenvironment.

Topical and scaffold-based HA formulations have consistently demonstrated the ability to maintain hydration, promote granulation and epithelialization, and accelerate wound closure in both acute and chronic lesions. Nevertheless, therapeutic outcomes vary considerably depending on HA concentration, pharmaceutical form, co-formulants, and wound-specific variables such as depth, exudate level, and infection status.

Given this heterogeneity, the clinical use of HA should rely on an individualized, evidence-informed selection process that aligns formulation characteristics with the wound's pathophysiological phase. The current lack of standardized comparative studies and shared outcome measures, however, limits the ability

to establish formulation superiority or develop universal treatment algorithms.

Future investigations should therefore prioritize head-to-head clinical trials, cost-effectiveness analyses, and real-world evaluations integrating molecular, clinical, and patient-reported outcomes.

In summary, HA represents a versatile and biocompatible biomaterial that – when rationally selected and applied within structured wound-care pathways – can substantially enhance healing quality and patient comfort across diverse clinical settings.

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