Plasma medicine in Indonesian wound care: Clinical potential, implementation barriers, and practice recommendations

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Introduction

Both acute and chronic wounds remain significant challenges in Indonesian healthcare services. Postoperative wounds, diabetic ulcers, traumatic wounds, and infected wounds impose substantial clinical, financial, and psychosocial burdens on patients, families, and the healthcare system. The high incidence of non-communicable diseases, such as diabetes, limited availability of modern wound care facilities in many regions, and risk of nosocomial infections complicate the wound healing process and increase the length of hospital stay.

Plasma medicine, particularly nonthermal plasma (cold atmospheric plasma), has emerged as an innovative approach to wound care. Nonthermal plasma can generate reactive oxygen and nitrogen species, electric fields, and low-dose UV radiation, all of which collectively contribute to antimicrobial effects, modulation of inflammation, and stimulation of tissue regeneration without causing thermal damage to healthy tissue (Kamaruddin et al., 2024). Various studies have shown that plasma-based wound therapy can reduce microbial load, improve granulation, and accelerate wound closure, particularly in chronic, hard-to-heal wounds.

In Indonesia, the discourse on plasma medicine remains limited to physics and engineering research, and its clinical, nursing, and health policy implications have not been widely discussed. This perspective aims to outline the clinical potential of nonthermal plasma for wound therapy, identify implementation challenges in the context of Indonesian healthcare services, and offer practical recommendations for contemporary nursing practice.

Clinical Potential of Non-Thermal Plasma for Wound Therapy

1. Antimicrobial effects and prevention of wound infection

One of the main advantages of non-thermal plasma is its ability to reduce the burden of bacteria, fungi, and even some viruses on the wound surface without causing significant tissue damage. Reactive species produced by plasma damage microbial cell membranes and genetic material, thereby reducing the risk of infection and supporting

a cleaner wound environment (Darmawati, 2022; Syam, 2025). In Indonesia, where hospital patient density is high and adherence to infection prevention practices is uneven, nonthermal plasma has the potential to serve as an additional therapy to reduce colonization by resistant bacteria and the incidence of nosocomial infections in wounds. Standardized use, accompanied by clear nursing protocols, can help minimize reliance on topical and systemic antibiotics, thereby supporting efforts to control antimicrobial resistance.

2. Stimulation of healing and improvement of tissue quality
In addition to its antimicrobial effects, exposure to non-thermal plasma at appropriate parameters has been shown to modulate inflammatory processes, increase fibroblast and keratinocyte proliferation, and support angiogenesis (Utami, 2023). Clinically, this is reflected in accelerated granulation tissue formation, reduced wound size, and improved epithelialization quality. For patients with chronic wounds, such as diabetic ulcers, whose numbers are increasing with the diabetes epidemic in Indonesia, a modality that can accelerate the healing phase without increasing pain and cost burden becomes highly relevant (Siregar, 2022). Nonthermal plasma has the potential to be used as an adjunctive therapy in comprehensive wound care protocols that include debridement, exudate management, infection control, and metabolic status optimization.

3. Pain reduction and improved patient comfort
Several clinical reports indicate that non-thermal plasma application is generally well tolerated and can reduce pain in some patients, possibly by modulating inflammatory mediators and inducing mild local desensitization (Kamaruddin et al., 2024). This relatively short and non-invasive procedure can improve patient comfort and facilitate nurse involvement in non-pharmacological pain management. In nursing practice in Indonesia, where high workloads often limit patient contact time, an effective, fast, and relatively easy-to-use modality can improve wound care quality without significantly increasing the complexity of daily procedures.

Implementation challenges in Indonesia

1. Availability of devices and technical standards
Nonthermal plasma technology requires specialized devices with precise parameter settings (voltage, frequency, working gas, and exposure duration). Currently, the availability of such devices in Indonesian healthcare facilities is very limited, especially outside referral hospitals or educational centers. In addition, not all commercial plasma devices have a clear registration pathway with national health regulatory authorities. The ambiguity of regulatory categories (e.g., high-, medium-, or low-risk medical devices) can hinder adoption and procurement.

2. Local clinical evidence and cost-benefit evaluation
Local Indonesian data on clinical effectiveness, long-term safety, and cost-benefit analyses are still scarce. Without contextual data, it is difficult for hospital management and policymakers to assess the investment priority of this technology compared to other interventions, such as increasing wound care nurse capacity, procuring modern dressings, or strengthening infection prevention programs (Kadar, 2023). Structured clinical research, including controlled trials and cohort studies in teaching hospitals

and referral centers, is an important prerequisite for broader implementation justification.

3. Capacity and competence of the nursing staff
Nurses play a central role in daily wound care, from initial assessment and dressing selection to procedure execution and patient education. The implementation of plasma medicine requires additional competencies, including a basic understanding of the working principles of non-thermal plasma. Clinical indications and contraindications; therapy parameter setting and monitoring; identification and management of side effects; clinical documentation and systematic evaluation of wound response.

4. Ethical aspects, patient safety, and acceptance
As a new technology, nonthermal plasma must undergo rigorous ethical and patient-safety assessments. Clarity is needed regarding potential long-term risks, effects on healthy tissue, and possible interactions with other therapies (e.g., topical or systemic drugs). In the context of Indonesian healthcare culture, clear explanations to patients and families about the purpose, benefits, and risks of plasma therapy are also important for building trust and meaningful informed consent.

Contemporary clinical practice recommendations
Based on the potential and challenges outlined above, several strategic recommendations can be considered to encourage the gradual, responsible implementation of plasma medicine in nursing in Indonesia:

1. Policy implications and future research: policy recommendations, required further research, and cross-sector collaboration.
2. Development of plasma-based wound care protocols and SOPs.
3. Nurse training and competency improvement programs.
4. Pilot projects and collaborative research.
5. Integration into quality and patient safety policies.
6. Cross-disciplinary collaboration and policy advocacy.

Conclusion
Plasma medicine, particularly nonthermal plasma, offers significant potential as an adjuvant therapy for wound care in Indonesia. Its antimicrobial effects, modulation of healing processes, and good patient comfort profile make it relevant to contemporary nursing practice, which is focused on safety, quality of life, and service efficiency. However, implementing this technology faces various challenges, including limitations in devices and technical standards, a lack of local clinical evidence and cost-benefit analyses, competency gaps among nursing staff, and the need for a clear ethical and policy framework to support its use. To address this, a phased approach involving SOP development, nurse training, research-based pilot projects, and integration into quality and patient safety programs is a realistic strategy.

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