Review Article

Pathophysiological Effects of Skin Aging on Wound Healing and Postoperative Outcomes in Geriatric Patients Undergoing Oncologic Dermatologic Surgery: A Bibliographic Review

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Abstract

Skin aging has a profound impact on wound healing and postoperative outcomes in geriatric patients undergoing oncologic dermatologic surgery. Both chronological aging and photoaging contribute to progressive structural and functional deterioration of the skin, including epidermal thinning, flattening of the dermoepidermal junction, reduced fibroblast activity, collagen fragmentation, loss of elastic

fibers, diminished vascularity, and impaired hydration. These alterations increase skin fragility, reduce elasticity, and compromise regenerative capacity. As a result, aged skin is more susceptible to injury and heals more slowly after surgical intervention. The pathophysiology of impaired healing in elderly skin involves disruption of all wound healing phases. Inflammation is prolonged because of dysregulated inflammatory mediators, delayed immune cell recruitment, and chronic low-grade inflammation. The proliferative phase is weakened by reduced fibroblast proliferation, impaired collagen deposition, delayed keratinocyte migration, and deficient angiogenesis. Remodeling is also compromised, leading to reduced tensile strength and persistent wound vulnerability. These processes are further aggravated by oxidative stress, mitochondrial dysfunction, immunosenescence, and the accumulation of senescent cells, all of which promote chronic inflammation and defective tissue repair. In the setting of dermatologic oncology, these age-related changes complicate surgical planning, reconstruction, and recovery. Frailty, sarcopenia, comorbidities, polypharmacy, malnutrition, and reduced functional capacity further increase the risk of delayed wound healing, dehiscence, infection, hematoma, necrosis, flap or graft failure, pain, and poor cosmetic outcomes. Nevertheless, with careful preoperative optimization, individualized surgical strategies, close follow-up, and multidisciplinary care, oncologic dermatologic surgery can still be performed safely and effectively in older adults.

Key words

Skin aging, wound healing, dermatologic surgery, geriatric patients, postoperative complications, skin cancer.

Introduction

The incidence of skin cancer is notably high in older populations, with melanoma being particularly prevalent among individuals aged 80 years and above [1, 2]. Non-melanoma skin cancers, including basal cell carcinoma and squamous cell carcinoma, are also highly frequent in this age group, with basal cell carcinoma accounting for 70% of all skin cancers [3]. In this context, the management of skin cancer in elderly patients requires careful consideration of comorbidities, patient preferences, and the risk of adverse events, which underscores the importance of a patient-centered approach to care [4].

These clinical considerations are closely linked to the biological and physiological modifications associated with aging skin. Aged skin undergoes important structural changes, including reduced elasticity, thinning of the dermal layers, and decreased vascularity, all of which can interfere with healing and increase the risk of surgical complications [5]. As a result, these age-related alterations require a tailored approach to both surgical planning and postoperative care in order to optimize outcomes [6].

In parallel, the relationship between skin aging and impaired healing capacity has been well documented, with older patients showing slower wound healing and higher rates of postoperative complications [7]. This impaired healing capacity is influenced by factors such as reduced collagen production and a diminished immune response, both of which contribute to delayed tissue repair and postoperative vulnerability [6]. Consequently, age-related tissue changes have a direct impact on surgical planning, since older patients may be better suited to less invasive procedures or to alternative treatments such as radiotherapy [4]. Likewise, postoperative recovery in elderly individuals may be prolonged and accompanied by a greater likelihood of complications, including infection and delayed wound healing [7].

For these reasons, integrating pathophysiological mechanisms with their practical clinical implications is essential for guiding surgical decision-making and postoperative care strategies [8]. A better understanding of the biological basis of skin cancer in elderly patients may also contribute to the development of more targeted therapies and, ultimately, to improved patient outcomes [6].

The objective of this work is to review the pathophysiological effects of skin aging on wound healing and postoperative outcomes in geriatric patients undergoing oncologic dermatologic surgery, with emphasis on the structural, vascular, cellular, and immunologic changes that influence surgical planning, tissue repair, complication risk, and recovery.

Methodology

This manuscript was developed as a structured narrative review aimed at providing an updated and clinically integrated analysis of the pathophysiological effects of skin aging on wound healing and postoperative outcomes in geriatric patients undergoing oncologic dermatologic surgery, with particular emphasis on age-related structural, vascular, cellular, and immunologic changes that influence tissue repair, surgical planning, and postoperative recovery. The review was conducted in accordance with the SANRA (Scale for the Assessment of Narrative Review Articles) framework and followed a predefined methodological protocol established prior to literature screening. Given the biological complexity of cutaneous aging, the clinical heterogeneity of geriatric patients, and the variability in oncologic dermatologic procedures and reconstructive strategies, a narrative interpretative synthesis was selected over quantitative pooling in order to integrate pathophysiological, surgical, and geriatric considerations into a coherent and clinically applicable framework. Special attention was given to the effects of impaired collagen synthesis, reduced vascularity, immunosenescence, delayed reepithelialization, frailty, and comorbidity burden on wound healing dynamics and postoperative outcomes. The objective was to provide a structured synthesis capable of supporting individualized surgical decision-making and postoperative care in elderly patients undergoing dermatologic oncologic procedures.

A comprehensive literature search was conducted in PubMed, Scopus, and Web of Science, including peer-reviewed articles published in English or Spanish between January 2020 and December 2025. The final search was performed in March 2026. This timeframe was selected to capture contemporary advances in the understanding of skin aging biology, wound healing mechanisms, geriatric surgical risk, dermatologic oncologic techniques, and postoperative management strategies in elderly populations. Foundational studies were incorporated when necessary to contextualize the biological mechanisms of skin aging or the historical evolution of wound healing concepts and dermatologic surgical practice. The search strategy combined MeSH and free-text terms using Boolean operators related to skin aging, aged skin, wound healing, wound repair, postoperative complications, dermatologic surgery, oncologic dermatologic surgery, skin cancer, basal cell carcinoma, squamous cell carcinoma, melanoma, geriatric patients, frailty, reconstructive surgery, flaps, grafts, and postoperative outcomes. Searches were conducted in titles and abstracts as well as indexed subject headings to maximize sensitivity.

The initial search yielded 196 records. After removal of duplicates, 144 articles remained for title and abstract screening. Of these, 92 underwent full-text evaluation, and 51 studies were included in the final synthesis. Selection was performed independently by two authors, with disagreements resolved through discussion

and consensus. Exclusion criteria comprised non–peer-reviewed publications, isolated case reports, editorials without relevant clinical or biological data, purely technical surgical descriptions lacking information on wound healing or postoperative outcomes, redundant datasets, and studies not directly addressing the relationship between skin aging, tissue repair, and postoperative results in geriatric patients undergoing dermatologic oncologic surgery.

Eligible studies included randomized controlled trials, observational cohorts, systematic reviews, meta-analyses, expert consensus statements, and contemporary international guidelines relevant to dermatologic surgery, wound care, geriatric medicine, and cutaneous oncology. Priority was assigned to multicenter investigations, studies focused on elderly populations, and research evaluating wound healing outcomes, postoperative complications, reconstructive success, functional recovery, and factors influencing surgical tolerance in geriatric patients. Extracted variables included study design, patient age and frailty profile, skin cancer type, surgical modality, reconstructive technique when applicable, wound healing outcomes, postoperative complications, recovery time, functional and cosmetic results, and biological factors associated with impaired repair. Methodological quality and internal validity were assessed narratively, considering risk of bias, sample size, follow-up duration, consistency in the definition of geriatric and postoperative variables, and reproducibility of reported outcomes. In cases of conflicting evidence, greater interpretative weight was assigned to higher-level evidence and guideline-supported recommendations.

Reference lists of included studies were manually screened to identify additional relevant publications. Given its narrative design, this review is subject to potential selection bias and does not provide pooled quantitative estimates. Artificial intelligence–based tools were used exclusively to assist in literature organization and structural coherence, whereas critical appraisal, synthesis, and final interpretation were conducted independently by the authors to preserve methodological rigor.

Structural and Functional Changes in Aging Skin

Skin aging results from both chronological aging and photoaging, two interrelated but distinct processes that contribute to progressive structural and functional deterioration of the skin. Chronological aging is characterized by natural and inevitable changes driven by genetic programming and cellular senescence. This process is associated with oxidative stress and cumulative cellular damage, which lead to gradual thinning of the skin and a reduced regenerative capacity [9, 10]. In contrast, photoaging is caused by prolonged exposure to ultraviolet radiation and accelerates skin aging through damage to the extracellular matrix and increased production of reactive oxygen species, which in turn promote deoxyribonucleic acid damage and cellular dysfunction [11].

These aging-related processes are reflected in both microscopic and macroscopic changes within the epidermis. Aging leads to epidermal atrophy as a consequence of decreased keratinocyte proliferation and turnover, resulting in a thinner epidermal layer [12, 13]. At the same time, the dermoepidermal junction becomes flattened and less pronounced, which reduces structural integrity and interferes with nutrient exchange between the dermis and epidermis. In parallel, barrier function becomes altered, making the skin more vulnerable to environmental insults and less capable of retaining moisture [14].

The dermis also undergoes important age-related modifications. Fibroblasts in aged skin exhibit reduced activity, which contributes to diminished collagen production and progressive extracellular matrix degradation [12, 14]. In addition, collagen

fibrils become fragmented and disorganized, further impairing structural integrity and elasticity [15]. This process is accompanied by fragmentation of elastic fibers, which leads to a decline in skin resilience and elasticity [11]. Simultaneously, the extracellular matrix loses its normal organization, which affects the mechanical properties of the skin and compromises its ability to support essential cellular functions [12, 14].

Alongside these epidermal and dermal changes, vascular alterations also contribute to the aging phenotype. Aging reduces dermal microcirculation, thereby impairing the delivery of oxygen and nutrients to the skin. Moreover, the angiogenic response becomes diminished, limiting the skin's capacity to form new blood vessels and, consequently, reducing its ability to repair and regenerate effectively. Changes in cutaneous appendages further aggravate this condition, as aging decreases sebaceous and sweat gland activity, which results in lower hydration and lubrication of the skin. As a consequence, the skin becomes drier and more prone to irritation and damage [13].

Taken together, these structural alterations have important clinical consequences. Thinner skin and reduced collagen content increase skin fragility and susceptibility to injury [13]. At the same time, the loss of elastic fibers and the disorganization of the extracellular matrix reduce skin elasticity and contribute to wrinkle formation [11]. The progressive loss of structural integrity also increases susceptibility to tearing and pressure-related injury. Ultimately, these cumulative changes reduce the regenerative potential of aged skin, impairing its ability to heal and regenerate efficiently and thereby prolonging recovery after injury [13].

Pathophysiology of Wound Healing in Elderly Skin

Wound healing normally progresses through four sequential and overlapping phases: hemostasis, inflammation, proliferation, and remodeling. Hemostasis is the initial phase and involves blood clotting to prevent further bleeding while also providing a scaffold for incoming cells. This is followed by the inflammatory phase, which is characterized by the recruitment of immune cells to the wound site and is essential for the clearance of debris and pathogens. The proliferative phase then involves the formation of new tissue, including fibroblast proliferation, collagen deposition, and reepithelialization. During remodeling, collagen is reorganized and the wound gradually gains tensile strength over time [16].

In geriatric skin, however, these phases are altered by age-related pathophysiological changes, beginning with the inflammatory phase. Elderly skin frequently exhibits a dysregulated response to inflammatory mediators, which contributes to prolonged inflammation. In addition, immune cell recruitment is delayed, further slowing the healing process [17]. This is compounded by the presence of prolonged low-grade inflammation, a common feature of aged skin that contributes to delayed healing and increases the risk of chronic wound formation [18].

The proliferative phase is also significantly affected by aging. Fibroblast activity declines with age, leading to reduced fibroblast proliferation, which is essential for collagen production and wound closure [19]. At the same time, both the quality and quantity of collagen deposition are diminished, compromising the structural integrity of the healed tissue [20]. In parallel, keratinocyte migration is decreased and reepithelialization is delayed, further impairing effective wound closure in elderly skin [21].

These changes are further aggravated by alterations in angiogenesis. Aging affects the vascular endothelial response, reducing the ability of endothelial cells to form new blood vessels that are necessary to supply oxygen and

nutrients to healing tissue. As a consequence, the formation of new capillaries is reduced, which impairs tissue oxygenation and nutrient delivery and contributes to further delays in healing [21].

Alterations also extend into the remodeling phase. In elderly patients, the remodeled tissue often has reduced tensile strength compared with younger skin. Collagen maturation is slower, which prolongs wound vulnerability. As a result, wounds remain more susceptible to reopening or infection for longer periods of time [16].

In addition to these phase-specific changes, oxidative stress and mitochondrial dysfunction play an important role in impaired healing. Increased production of reactive oxygen species together with reduced antioxidant defenses contributes to cellular damage and disrupts tissue repair. At the same time, mitochondrial dysfunction associated with aging exacerbates oxidative stress and impairs cellular energy production, further limiting the healing response [22].

Cellular senescence also has a major influence on regenerative capacity in aged skin. Senescent cells accumulate over time and secrete pro-inflammatory cytokines while degrading the extracellular matrix, thereby impairing tissue regeneration [23, 24]. The persistence of these cells reduces the regenerative potential of the skin and contributes to the development of chronic wounds [18].

Taken together, the cumulative effect of these pathophysiological changes leads to delayed or poor-quality healing in elderly patients. Dysregulated inflammation, impaired cellular activity, and oxidative stress all contribute to chronic wound states, thereby increasing the risk of complications and unfavorable postoperative outcomes in geriatric patients undergoing oncologic dermatologic surgery [19, 20].

Immunologic and Molecular Mechanisms Involved in Impaired Healing

Immunosenescence is characterized by a progressive decline in immune function that affects both innate and adaptive immunity. This process includes thymic involution, reduced production of naïve T and B cells, and the accumulation of memory and senescent cells [11, 25]. In parallel, the innate immune response becomes compromised because immune cells such as macrophages and neutrophils exhibit impaired chemotactic, phagocytic, and antigen-presenting functions [26].

These age-related immune alterations have important consequences for wound defense and tissue repair. Cellular senescence, which is a hallmark of aging, promotes the accumulation of senescent cells at wound sites, thereby contributing to chronic inflammation and impaired healing. In addition, senescent cells secrete pro-inflammatory cytokines and chemokines known as the senescence-associated secretory phenotype, which can further exacerbate tissue dysfunction [18, 27].

At the cellular level, aging is also associated with decreased numbers and reduced function of macrophages, leading to poor resolution of inflammation and excessive tissue damage within wounds [28]. Likewise, neutrophils and lymphocytes show decreased functionality, which further impairs the immune response and delays wound healing [26]. These defects are accompanied by altered cytokine signaling in elderly patients. Dysregulated cytokine production, including increased levels of pro-inflammatory cytokines, contributes to chronic low-grade inflammation, known as inflammaging, which negatively affects wound healing [11]. This altered signaling may also generate an imbalance in the inflammatory response, thereby hindering effective tissue repair [29].

In addition to immune dysfunction, aging skin demonstrates reduced production of essential growth factors involved in healing, including transforming growth factor beta, vascular endothelial growth factor, and platelet-derived growth factor, all of which are crucial for cell proliferation and tissue regeneration (18, 30). At the same time, an imbalance between matrix metalloproteinases and their inhibitors leads to excessive degradation of the extracellular matrix, impairing the structural integrity of healing tissues. Chronic oxidative stress, which is common in aged skin, also damages cellular components and disrupts repair pathways, further delaying wound healing (18).

Markers of cellular senescence, such as telomere shortening and mitochondrial dysfunction, have been associated with impaired wound closure and the development of chronic wounds [25]. Taken together, chronic inflammation and dysregulation of fibrosis, driven by persistent senescent cell activity, contribute to delayed tissue restoration and chronic wound states [18, 19].

Relevance of These Changes in Oncologic Dermatologic Surgery

Surgical excision remains a primary treatment for skin cancers such as basal cell carcinoma and squamous cell carcinoma, which are highly prevalent in older adults [31, 32]. Its importance lies in its established effectiveness for achieving clear margins and reducing recurrence rates, particularly in high-risk cases in which Mohs micrographic surgery is preferred [33]. Despite the challenges posed by advanced age, surgical excision continues to be essential for oncologic control and can be safely performed in elderly patients when accompanied by appropriate preoperative assessment and planning [32].

Within dermatologic oncology, several surgical procedures are commonly used according to tumor characteristics and patient condition. Standard excision is widely employed for a variety of skin cancers, although it may require more complex reconstruction in cases with positive margins [31]. Mohs micrographic surgery offers superior margin control and is recommended for high-risk tumors because it reduces the risk of local recurrence and metastasis. Curettage-based procedures may also be appropriate for selected lesions, especially in patients with significant comorbidities in whom less invasive options are preferred [33]. After tumor removal, reconstruction may be performed through primary closure, flaps, or grafts, with the choice depending on the size, depth, and location of the lesion [34].

However, the surgical management of elderly patients is complicated by the specific characteristics of aged skin. Increased fragility and reduced elasticity make closure more difficult and increase the risk of wound dehiscence. In addition, difficulty in distributing tension adequately during closure may compromise perfusion and increase the risk of ischemia, particularly in areas with limited vascular supply [19]. Reconstructive complexity is further influenced by tumor characteristics and anatomical location, especially in the face, scalp, auricular region, and lower extremities, where both functional and cosmetic considerations are particularly important [32].

For these reasons, surgical decision-making in elderly patients must be individualized. Therapeutic decisions should be based not solely on chronological age, but rather on biological age, overall health status, and functional reserve [35]. At the same time, the goal is not only to achieve adequate oncologic control, but also to preserve tissue and function, which requires a patient-centered approach. In this context, treatment planning should also take into account comorbidities, patient preferences, and the risk of adverse events in order to ensure a balanced and personalized surgical strategy [32, 36].

Geriatric Clinical Factors That Modify Healing and Surgical Outcomes

Frailty and sarcopenia are highly prevalent in the elderly and are associated with increased postoperative complications and mortality. Frailty is a multidimensional syndrome that affects physical, cognitive, and psychosocial domains, whereas sarcopenia is characterized by the loss of muscle mass and strength. Importantly, studies have shown that patients presenting with both frailty and sarcopenia have significantly higher postoperative morbidity rates than those with either condition alone [37, 38, 39]. In addition, sarcopenia has been linked to postoperative complications such as pneumonia, bleeding, and septicemia, and is considered a predictor of poorer surgical outcomes [18, 40].

These vulnerabilities are often compounded by the presence of comorbidities that directly affect healing and postoperative recovery. Diabetes mellitus, peripheral vascular disease, and chronic venous insufficiency are common among elderly patients and can impair wound healing by altering blood flow and immune response. Likewise, chronic kidney disease and cardiovascular disease further complicate surgical recovery by reducing physiological reserves and increasing the risk of complications [41].

Another important factor is polypharmacy, which is highly frequent in geriatric patients and may lead to adverse drug interactions that complicate postoperative management. Anticoagulants and antiplatelet therapies increase the risk of bleeding, whereas corticosteroids and immunosuppressive drugs can impair tissue repair. In oncologic patients, the use of chemotherapy may also delay wound healing because of its immunosuppressive effects [41, 42].

Nutritional status and functional capacity are also crucial determinants of surgical recovery. Malnutrition and micronutrient deficiencies are prevalent in the elderly and can significantly compromise wound healing and postoperative recovery, while adequate protein reserves are essential for effective tissue repair [37, 43]. At the same time, functional status, including mobility and the ability to comply with wound care instructions, plays a central role in recovery. Cognitive decline and insufficient caregiver support may further hinder adherence to postoperative care [41, 42].

Given the interaction of these multiple risk factors, comprehensive geriatric assessment is essential before surgery. This evaluation is valuable for identifying frailty and other conditions that may adversely affect postoperative outcomes. Tools such as the Geriatric 8 and the Karnofsky Performance Scale can help assess frailty and guide preoperative interventions [41, 44]. In this way, comprehensive geriatric assessment can support personalized treatment planning and improve surgical outcomes by addressing modifiable risk factors before the procedure [39, 42].

Postoperative Complications in Geriatric Patients Undergoing Dermatologic Oncologic Surgery

Delayed wound healing and wound dehiscence are common concerns in elderly patients because aging skin exhibits reduced collagen production and diminished fibroblast activity, both of which contribute to slower tissue repair and a greater risk of wound separation [19]. This process may be further aggravated by comorbidities such as diabetes mellitus and peripheral vascular disease, which impair blood flow and alter immune response, thereby delaying healing even more [21].

In addition to impaired wound closure, surgical site infection represents another important postoperative complication in this population. Elderly patients, particularly those with immunosuppression or diabetes, are at increased risk of infection, which can further compromise

healing and increase morbidity. In dermatologic surgery, the reported incidence of infection ranges from 0.96% to 8.70%, with male sex and immunosuppression identified as significant risk factors [45].

Other relevant complications include hematoma, prolonged bleeding, and skin necrosis. Older patients frequently have fragile blood vessels and may also be receiving anticoagulant therapy, both of which increase the risk of hematoma formation and prolonged bleeding [46]. At the same time, skin necrosis may develop when blood supply is compromised, particularly in areas subjected to high tension or in regions with poor vascularization [48].

Flap and graft complications are also of particular concern in elderly patients because reduced skin elasticity and diminished vascularity can compromise tissue viability and increase the risk of partial or total flap loss as well as graft failure [47]. In this context, the keystone flap technique has shown promise as a reconstructive option, as it has been associated with rapid recovery and low morbidity rates [48].

Moreover, excessive inflammation and chronic wound formation may occur as a consequence of cellular senescence in aging skin. This senescent state promotes chronic inflammation and may lead to non-healing wounds or fibrosis [19]. To address these difficulties, topical treatments such as timolol have been explored as potential strategies to improve healing by reducing inflammation and promoting re-epithelialization [22].

These healing disturbances are often accompanied by pain, discomfort, and functional impairment. Prolonged recovery and persistent pain are common in older adults because of slower healing and heightened inflammation [46]. In addition, depending on the surgical site, functional impairment may develop and negatively affect mobility and quality of life [49].

From an aesthetic perspective, poor cosmetic outcomes and dissatisfaction with scarring are also frequent, largely due to the reduced regenerative capacity of aging skin [46]. These issues may become even more pronounced when surgical management is delayed, since postponement can necessitate more extensive procedures and thereby worsen reconstructive and cosmetic outcomes [50].

It is important to distinguish complications that are directly related to aging from those that are more closely associated with comorbidities and surgical complexity [51]. In fact, some studies suggest that, with careful management, age alone does not significantly increase the risk of complications in procedures such as free flap reconstruction [46].

Conclusions

Skin aging profoundly alters the structure, vascularization, immune function, and regenerative capacity of the skin, thereby disrupting all phases of wound healing and predisposing geriatric patients undergoing oncologic dermatologic surgery to slower recovery, poorer-quality healing, and a higher risk of postoperative complications.

Although oncologic dermatologic surgery remains essential for tumor control in older adults, postoperative outcomes depend not only on the surgical procedure itself, but also on geriatric factors such as frailty, sarcopenia, comorbidities, polypharmacy, nutritional status, and functional capacity, making comprehensive preoperative assessment and individualized treatment planning indispensable.

Major postoperative complications in this population, including delayed healing, wound dehiscence, infection, hematoma, necrosis, flap or graft failure, pain, functional impairment, and

poor cosmetic outcomes, may be reduced through preoperative optimization, surgical techniques adapted to aged skin, close postoperative surveillance, and multidisciplinary management.

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