The Diagnosis and Treatment of Common Wounds Encountered in Primary Care

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Patients often present to their primary care providers when they experience an open wound. It is estimated that there are 6.5 million patients suffering from chronic wounds in the United States, resulting in an estimated 25 billion dollars in annual medical expenses [1]. Primary care providers play a direct role in the initial and ongoing treatments for a broad range of wound types. These include acute trauma wounds, diabetes-associated wounds, and arterial or venous ulcers, to name a few. Through coordinated efforts and diligent follow-up to prevent and treat the aforementioned wound types, good long-term clinical outcomes are possible. In this chapter, the authors review the basic principles of wound healing and utilize current evidence to offer some clinical strategies involved in the treatment of the most commonly encountered wounds in the primary care setting.

The Four Stages of Wound Healing

Wound healing has classically been divided into four overlapping stages: hemostasis, inflammation, wound proliferation, and tissue remodeling. Within each stage, specific events occur that lead to the formation of the initial granulation tissue and the transformation of the wound bed into fully matured scar tissue. This entire process begins at the outset of the initial trauma.

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Immediately following tissue injury, vasoconstriction occurs in response to thromboxane release, which aids in limiting blood loss. During tissue injury, platelets are exposed to interstitial connective tissues and subendothelial elements (microfibrils, laminins, and collagens), leading to activation and aggregation at sites of vessel injury, along with fibrinogen and thrombin [2]. Platelet plug formation and fibrin deposition occur at the site of vessel injury and primarily help to reduce blood loss [3]. Additionally, the resulting fibrin-fibronectin meshwork that forms acts as a temporary scaffold in the early wound bed, providing inflammatory cells, fibroblasts, and myofibroblasts an early road map for wound repair [2]. Shortly after hemostasis is achieved, histamine release leads to vasodilation which increases the porosity of surrounding blood vessels, allowing easier access to the developing wound bed by leukocytes [4].

The inflammatory stage is heralded by the increased influx of polymorphonuclear leukocytes (PMNs) to the site of injury by way of chemokines and other factors (fibronectin, platelet-derived growth factor) [5]. PMNs remain active in the wound bed during the inflammatory phase for 1–2 days and release granules containing free radicals which help sterilize the surrounding area and proteases which degrade damaged tissues. Following the initial influx of PMNs to the site of injury, monocytes migrate to the wound bed and differentiate into mature macrophages, allowing them to phagocytose pathogens and damaged tissues [6, 7]. Additionally, stimulated by local tissue hypoxia, macrophages release pro-angiogenic factors enabling granulation tissue development and promoting the next phase of wound healing: proliferation.

Approximately 2–3 days following the initial tissue insult, the inflammatory phase of wound healing begins to subside with the decreased presence of many of the PMNs and macrophages that acted to sterilize and prepare the developing wound bed [8]. At this point during wound development, growth factors such as PDGF, TGF-β, and fibronectin attract fibroblasts to the site of injury and promote granulation of the wound bed. Upon their arrival to the site of injury, the fibroblasts secrete a material known as ground substance. Ground substance is a gel-like material which serves as a the extracellular matirix to which inflammatory cells, myofibroblasts and endothelial cells can adhere. Ground substance also provides lubrication for collagen fibers and serves to potentiate the formation of granulation tissue [3]. During the proliferative phase of wound healing, new blood vessel formation and epithelialization occur, permitting closure of the wound. Myofibroblast contraction accelerates this wound closure process and can continue 2–3 weeks following initial injury [9].

After proliferation and wound closure have occurred, scar formation and tissue remodeling take place and can last weeks to months after the original injury. During remodeling, durable type 1 collagen replaces the type 3 collagen meshwork initially secreted by fibroblasts [10]. It is during this longest phase of wound healing that the resulting scar develops its tensile strength with type 1 collagen deposition, approaching 80% of non-wounded tissue [11]. During this protracted phase of wound healing, pathologic scar formation, such as in the formation of wound contractures, hypertrophism, or keloid formation, can occur, often due to persistent inflammation and the pathologic upregulation of specific growth factors and regulators [8, 12].

Acute Trauma Wounds

Acute trauma wounds are very frequently encountered in the primary care and urgent care settings, making understanding and management of these types of wound imperative for the primary care physician. Two of the most commonly encountered acute wounds include burns (most commonly chemical or temperature related) and lacerations.

Burns

Burns can occur following exposure to chemical agents, extremes in temperature (hot or cold), electricity, friction, or radiation. The most common scenario involving burn injury is from hot liquids or from an open flame during cooking, with smoking and alcoholism acting as risk factors. The presence of burn injuries can also be associated with domestic violence or self-harm, and so clinicians are urged to obtain accurate history and physical examination during initial evaluation.

Burn injuries are classified according to the depth of injury. This ranges from first degree, being the most superficial, to fourth degree, which denotes injury extending to the underlying fat, muscle, and bone. Second-degree burns are divided into two groups, superficial partial thickness and deep partial thickness, which are determined by whether the extent of the burn is limited to the papillary dermis (superficial second degree) or extends beyond the reticular dermis (deep second degree). Third-degree burns extend through the entire dermis to, but not involving, the subcutaneous fat [13, 14].

Symptoms associated with burns include pain at the site of injury, erythema, edema, blistering, and in the case of severe fourth-degree burns, painless blanching [13]. Prognosis varies according to the type and extent of injury. Most first-degree to superficial second-degree burns heal relatively well with conservative measures (e.g., irrigation, cooling of the area, cleaning with soap and water, and dressings with or without topical antibiotics). Deep second-, third-, and fourth-degree burns require close observation as patients are at increased risk of fluid loss and infection [14].

In addition to the depth of injury, the percentage of total body surface area (TBSA) affected is calculated via the Lund-Browder method and categorized as either minor (<10% TBSA adults), moderate (10–20% adults), or severe (>20% adults) and is used to direct appropriate therapy [15]. For most moderate and severe burns, patients should be monitored in dedicated burn centers when possible, as these patients are at increased risk of insensible fluid loss and high risk of infection.

In severe burn injuries, post-injury complications can develop and pose challenging scenarios for patients and clinicians alike. Fibrosis and wound contractures represent the most frequent encountered post-burn scenario and are characterized by

excessive post-burn collagen production. Contraction of the wound site can lead to anatomic deformity and difficulty in performing acts of daily living for many patients [16]. Other post-burn complications, such as heterotopic ossification, can occur in specific patient populations; however current treatment modalities are limited [17].

Lacerations

Lacerations are frequently encountered in the outpatient setting. Lacerations are defined as irregular tear-like lesions typically caused by forms of blunt trauma. They can occur as isolated minor injuries or accompany larger total body injuries. During the initial assessment of the patient, it is imperative to assess the patient's cardiorespiratory status by evaluating their airway, breathing, and circulation (the ABCs), as further diagnostic workup and intense care may be needed in more significant injuries. For simple lacerations, standard wound care measures should be undertaken to minimize the risk of infection and promote early wound closure and healing. These include cleaning and irrigating the wound with sterile water and soap followed by closure with a variety of agents (sutures, adhesives, cyanoacrylate glue, staples, etc.). For patients who present >24–48 hours after the initial injury or if the area of involvement is too large to approximate the edges of the wound, healing by secondary intention without using additional closure agents (i.e., sutures) provides the best clinical outcome. The use of topical antibiotic ointments in the setting of simple, uncomplicated lacerations has not demonstrated benefit in terms of infection rate reduction, and is therefore not a standard treatment recomendation [18].

Diabetic Foot Wounds

Lower extremity wounds are a common cause for increased morbidity in diabetic patients, with an estimated increased risk of 25% in both type 1 and 2 diabetic patients compared to nondiabetic patients [19]. Needless to say, adequate preventative measures and outpatient follow-up can help reduce the risk of development of these wounds and their complications, decreasing patient morbidity and health system financial burden.

Prevention of wound development through proper lifestyle and foot hygiene adjustments has shown to have a positive benefit for patients and reduce ulcer development. This includes smoking cessation, not walking barefoot, daily foot inspections and washing with lukewarm water, and maintaining neatly trimmed toenails that conform to the shape of the toe. Custom shoes for patients with misshaped feet or those with previous ulcers may also help reduce the incidence of new ulcers [20, 21].

The development of foot ulcers in diabetic patients occurs most often in the setting of peripheral neuropathy. Unable to accurately sense and respond to pain and pressure, patients suffer repeated trauma to the skin and microcirculation of the foot, leading to ulcer development. Chronic neuropathy can lead to the formation of claw toes as a result of unopposed extension from the larger muscles of the lower leg against the waning ability of affected smaller intrinsic muscle groups of the foot. This leads to increased pressure exerted on the metatarsal head which, over time, predisposes the area to ulcer formation and is a common site of occurrence [22]. Other later complications of peripheral neuropathy in diabetics include diabetic neuropathic arthropathy, also called Charcot arthropathy. Charcot arthropathy is characterized by collapse of the arch of the midfoot and periarticular joint dislocation, leading to swelling, erythema, and anatomic deformity. Patients who develop diabetic neuropathic arthropathy are at significantly elevated risk of ulceration and its many associated complications (osteomyelitis, systemic infection) [23].

Stratifying diabetic foot wounds was first described by Wagner and relied heavily upon clinical appearance and evaluation of the ulcer; however it did not take into account vascular status of the patient's foot [24]. An updated model for classifying diabetic foot ulcers was introduced first at The University of Texas and included grading (0–3 based on wound depth) and staging (infected, non-infected, ischemic, ischemic and infected) of the wound [25]. The UT system has proven to be of significant benefit for accurate wound assessment and has inspired the development of additional classification schemes (WIfI, PEDIS) [26–28].

Treatment for diabetic foot ulcers begins with grading and staging of the wound, using the widely accepted UT classification scheme [26]. General care principles with regard to treatment include assessing the patients' overall clinical status, evaluating the presence of infection, and addressing poor glycemic control, arterial insufficiency, and bony deformities. Superficial non-infected ulcers (grade 0, stage A) can typically be debrided in the outpatient setting under local anesthesia. For deeper grade 2–4 ulcers, surgical debridement in the operating room is recommended, especially in the setting of infection and/or ischemia (stages B, C, D).

Dressing diabetic foot ulcers serves an important purpose in promoting healing and preventing infection. A variety of agents are available for use depending on the clinical status of the wound bed and include hydrogel, absorbent, and/or antimicrobial dressings and wound packing materials, such as sterile ribbons, for deep ulcers. Additionally, many adjuvant topical therapies exist that promote cellular regeneration and angiogenesis. Clinicians are advised to consider these adjuvants in patients at risk of infection and difficult-to-heal wounds. In cases of difficult-to-heal ulcers, hyperbaric oxygen therapy has been employed with varying levels of success [29, 30].

Following dressing of the wound, it is best to employ pressure offloading techniques for areas repeatedly exposed to trauma and/or frequent pressure. These techniques include the use of total contact casts, cast walkers, and custom shoes. Total contact casts are fiberglass or plaster shells that encase the entire foot, allowing for even distribution of pressure across the sole of the foot. This provides excellent healing for ulcers in the forefront of the foot and is the first-line therapy for uncomplicated, nonischemic, non-infected plantar ulcers [31]. Conversely, there are

disadvantages to using the total contact cast including the inability to inspect the affected foot, patient inconvenience for performing daily acts of living (bathing, etc.), and the possibility of additional wound development from improperly placed cast [32]. Cast walkers are similar in design to total contact casts; however they differ in their ability to be removed by patients themselves. Improvements in pressure offloading can be achieved using cast walkers compared to typical shoes; however the advantage over total contact cast remains to be determined. Disadvantages of cast walkers primarily include poor patient compliance, as the device can be removed unlike total contact casts. Following resolution of the wound, it is important for patients to use customized shoes with orthotic inserts to help prevent recurrence of ulcers. The use of prescriptive shoes has been shown to decrease the risk of re-ulceration of plantar-based ulcers and is generally recommended as an ongoing pressure offloading technique for patients who have had previous ulcers [33].

Venous Leg Ulcers

Epidemiology

A wound located on the lower extremity may result from one or a combination of several factors. Nearly 70% of all lower extremity ulcers are of venous origin. It has been estimated that, at any given time, 1% of the US population has a venous leg ulcer (VLU) [34]. Thirty to seventy percent of VLUs remain open and unhealed at 6 months, and up to 20% of VLUs remain unhealed for greater than a year. Risk factors for venous ulceration include obesity, advanced age, history of local injury, and history of deep venous thrombosis or phlebitis. Self-reported quality of life (QOL) scores are greatly diminished in the venous ulcer patient. In fact, studies suggest that rates of depression and low self-esteem correlate directly with the length of time a VLU remains unhealed [35]. These statistics add to the importance of recognizing and treating the patient with lower extremity venous disease as early as possible.

Diagnostic Signs and Symptoms

Leg edema and skin discoloration can be early signs of venous disease, often occurring even prior to ulcer formation (Fig. Fig. 1). Edema is usually a result of venous valve incompetence or inefficiency of the calf muscle pump mechanism, and the skin discoloration a result of capillary rupture and hemosiderin deposition over time.

Most venous ulcers are located above or near the medial malleolus, in the classic “gaiter” distribution. Venous ulcers usually have a shallow, moist wound bed with an irregularly contoured border (Fig. Fig. 2). Varying degrees of fibrin and slough deposition can be seen, and the venous ulcer patient will report varying degrees of mild to moderate pain [36].

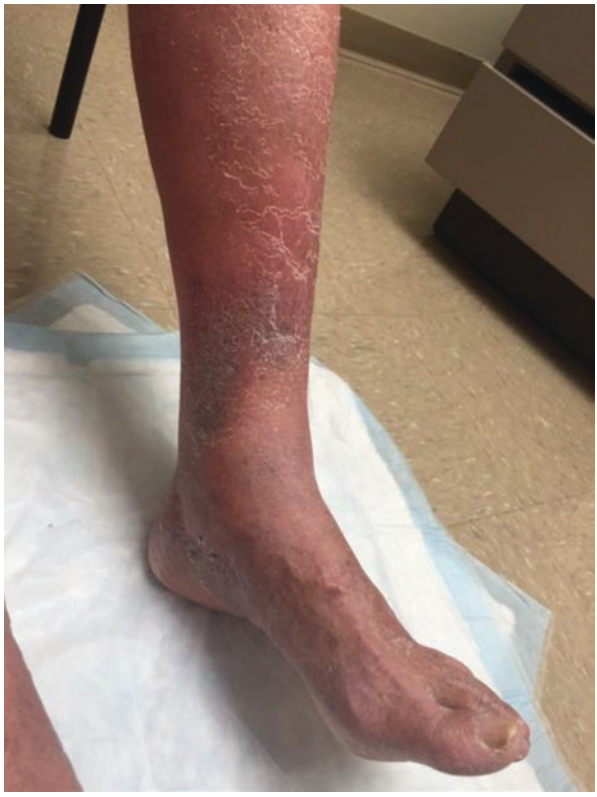

Fig. 1 Venous insufficiency, with evidence of edema, small varicosities, a healed area of former ulceration over the medial malleolar region, and resultant hemosiderin skin staining

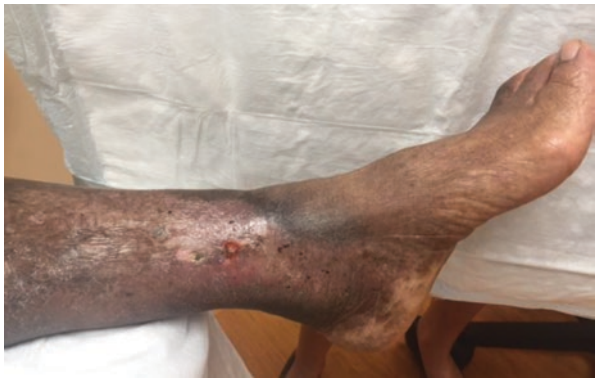

Fig. 2 A small, shallow, moist ulceration can be seen just proximal to the medial malleolus, in the typical "gaiter" distribution described for venous leg ulcers (VLUs)

Assessment and Management

It is important to assess the length, width, and depth of the venous ulcer at each follow-up visit. Additionally, the skin surrounding the wound should be monitored for cellulitis. Measurements and evaluations should take place at regular intervals, using the measurement standards accepted by the individual institution [37].

Edema control accelerates the rate of healing and decreases the chance for recurrence for venous ulcers. Besides external compression, regular exercise, leg elevation for 1 hour daily, and sodium restriction all aid with edema control. In general, 20–30 mmHg knee-high compression is a tolerated and effective means of compression therapy. A review of 39 randomized controlled trials demonstrated that a four-layer bandage system resulted in a significantly shorter time to complete healing than other means of compression for edema control. However, ease of use and patient compliance are often cited as superior with single-layer, knee-high compression stockings [38]. Before adding aggressive compression therapy, adequate arterial circulation should be confirmed, as discussed in the next section on arterial ulcers.

Topical wound dressing choice depends not only on wound characteristics but also on patient and provider preferences. Besides wound healing, the goals of topical wound therapy for venous ulcers should be to maintain a moist healing environment and prevent infection [39]. A Cochrane review of 42 trials revealed that no single topical dressing choice is superior to another, in terms of rate of healing and recurrence of VLU [40]. Table 1 provides a concise review chart for some common topical dressing choices. Healing may be augmented through the use of topical dressings in conjunction with manual debridement by a healthcare professional. Debridement may be discontinued, and topical treatment maintained, once red granulation tissue covers the majority of the wound surface area [41].

Table 1 Some common topical wound dressings

Dressing class	Secondary dressing required?	Dressing frequency	Dressing description	Cost
Hydrogel	Yes	Daily	A gel, maintains moist wound bed, facilitates debridement	$
Hydrocolloid	No	Every 3–5 days	Self-adherent dressing, maintains moisture, occlusive/not to be used if infection suspected	$
Foam	Yes/no	Every 2–3 days	Some brands self-adherent, absorptive, for moderate to heavily draining wounds	$
Alginate	Yes	Every 2–3 days	Ideal for heavily draining wounds: able to absorb 20–30 times dressing weight	$
Saline-impregnated gauze	Yes	Daily or multiple times daily	Maintains moist wound environment, provides some autolytic debridement	$
Collagenase	Yes	Daily	Enzymatically debrides necrotic and nonviable tissue, inactivated by silver-containing products	$$$
Collagen	Yes	Every other day	Promotes collagen matrix formation, works best if wound bed is 90–100% red/granulation tissue	$$

The addition of pentoxifylline or aspirin, either one taken orally on a daily basis, has been demonstrated to be a beneficial adjunct to compression and topical therapy in recent studies. These medications could be considered after a risk-benefit analysis has been performed for the individual patient [42, 43].

Poor prognostic indicators for healing include the following: venous ulcer present for greater than 12 months, diameter larger than 10 cm, or mean wound area reduction ≤30% by week 4 of treatment [35]. To maximize the patient's chance for healing with appropriate treatment, a wound biopsy should be performed on wounds present for longer than 3 months, or for a significantly painful ulcer, in order to rule out malignancy or autoimmune wound subtypes such as pyoderma gangrenosum [44]. Additionally, a referral to a wound specialist should be considered for any venous ulcer failing to diminish in diameter by 30% after a trial of 4 weeks of conventional treatment [45].

Arterial Ulcers

Epidemiology

Peripheral arterial disease (PAD) is present in 18.8% of Americans who are 70–79 years old. Atherosclerosis, calcification, and the resultant arterial narrowing compromise the circulation to the skin over the peripheral digits and limbs. This can result in ulcer formation if left untreated. Male gender, family history, and advancing age are non-modifiable risks for PAD. Smoking, hypertension, hyperlipidemia, and diabetes are other, modifiable risk factors. Also important to recognize is that almost one-third of patients with PAD have concomitant coronary artery disease [46].

Diagnostic Signs and Symptoms

Even prior to ulceration, the patient with PAD may present to the healthcare professional with thin, shiny, and dry skin on the lower extremity. Hair loss on the lower leg, diminished lower extremity pulses, and dependent erythema are also common clinical examination findings. The rule of "5 P's" is an easy way to remember some common findings in the patient with PAD (Table 2).

Lower extremity ulcers of arterial origin are usually located on or near the lateral malleolus or along the distal foot and toes. Sites subject to trauma or friction are often prone to the development of an arterial ulcer.

Arterial ulcers are usually dry and have smooth, even wound margins, giving a "punched-out" appearance. Often, arterial ulcers are covered with a dry, dark or black eschar. In the setting of limb or digit ischemia, these changes may be accompanied by pallor or cyanosis of the digits and/or limb involved (Fig. Fig. 3). In the

Table 2 The "5 P's" of lower extremity arterial insufficiency

Pain	Often severe claudication symptoms described, may change over time
Pulseless	Variable, use Doppler or ABI if suspicion is high
Pallor	Common and not positional in acute ischemia, present mainly on elevation in PAD (with erythema present on leg dependency)
Paresthesia	Complete numbness in acute ischemia, variable in all other PAD patients
Paralysis	A late, poor prognostic sign

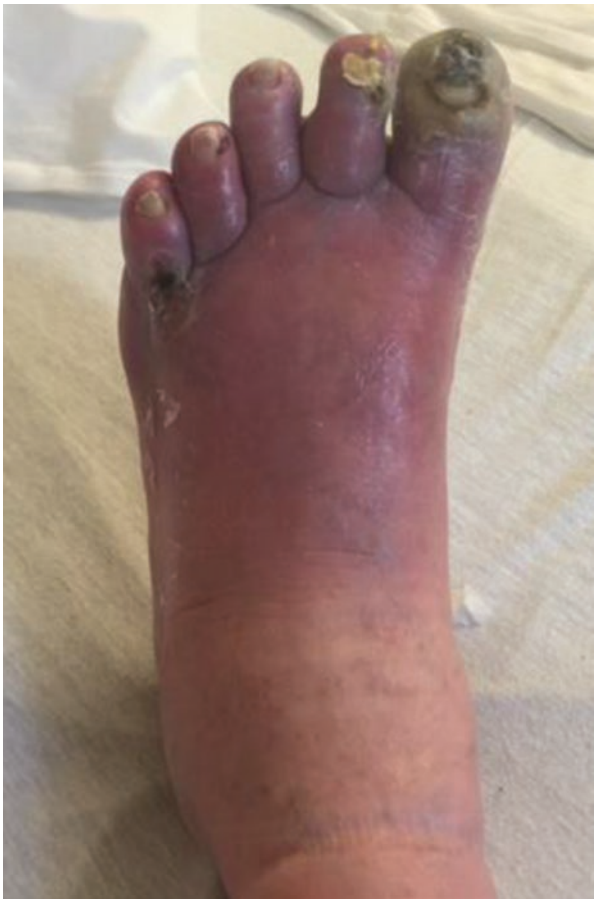

Fig. 3 Arterial ulcerations on the distal great toe, associated with dry eschar and evidence of ischemia, with notable great toe pallor and cyanosis. Additional arterial eschar can be seen on the second, fourth, and fifth toes. Dependent erythema, shiny skin, and thickened toenails are also seen in this patient with peripheral arterial disease

early stages, arterial wound beds are more pale pink, dry, and often deeper than wounds of venous origin. Unlike the mild to moderate pain reported in a venous ulcer, the patient with an arterial ulcer often will report a significant degree of pain. Additionally, the skin surrounding an arterial ulcer is often erythematous, sometimes even in the absence of infection. Nevertheless, vigilance for infection is important, as arterial ulcers are prone to gangrene and overt infection [46].

Table 3 Ankle-brachial index interpretation

ABI result	Interpretation
0.9–1.2	Normal
0.8–1.9	Mild ischemia
0.4–0.8	Moderate ischemia
Less than 0.4	Severe ischemia

Assessment and Management

The presence of pedal pulses is only 26% sensitive in ruling out PAD. An ankle-brachial index (ABI) is a fairly easy and completely noninvasive means of evaluating the patient with suspected PAD. ABI testing can be performed and interpreted by trained clinicians in the office setting but is usually performed in an outpatient radiology or vascular center. The interpretation of ABI results is outlined in Table 3. A normal ABI is 0.9–1.2, and a result less than 0.9 is 95% sensitive and 99% specific at suggesting PAD as a diagnosis. Falsely elevated ABI results can be seen in patients with diabetes as well as in patients with chronic renal disease [47, 48]. A vascular surgery referral is warranted for an ABI result of less than 0.6; the urgency of this consultation increases as the ABI decreases and is dependent on the overall clinical picture. Likewise, external compression therapy should be avoided, pending their vascular surgery consultation, for those patients who have an ABI of less than 0.6 or those who experience an increase in pain with compression therapy [49].

The aims of management for arterial ulcers include pain control, maintenance of a dry and clean wound environment, and consideration for revascularization. It is important to remember the dry wound healing principles used for arterial ulcer treatment are in contrast to the moist healing modalities used in treating a venous ulcer. A dry, clean arterial wound environment should be sustained through the use of daily skin prep application, daily topical iodine, or a simple dry gauze or foam dressing [46]. A recent review of topical treatments for arterial ulcers demonstrated insufficient evidence that any one topical treatment choice results in superior rates of healing [34].

If not contraindicated, antiplatelet medications can be used for the treatment of mild to moderate PAD, to prevent the development of limb ischemia (Table 4). Medical options are also available to aid with controlling claudication symptoms and are most effective when used as part of a regular exercise and smoking cessation program. Of note, cilostazol and pentoxifylline are the only two medications with FDA approval for the treatment of claudication symptoms [50].

The details surrounding surgical revascularization are beyond the scope of this chapter. However, it should be noted that in many cases, an arterial wound will not heal without revascularization. An arterial wound could be considered for manual debridement only after revascularization has been successfully completed, thus minimizing the risk of infection, gangrene, and limb loss associated with debriding an area with inadequate blood supply [46].

Table 4 Antiplatelet agents

Aspirin	Decreases prostaglandin synthesis through inactivation of cyclooxygenase (COX) enzyme
Clopidogrel	Inhibits platelet aggregation by inhibiting adenosine diphosphate (ADP) chemoreceptor on platelet membranes
Dipyridamole	Inhibits platelet aggregation through inhibition of ADP
Ticlopidine	Inhibits platelet aggregation through inhibition of ADP

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