Wound-bed preparation: the importance of rapid and effective desloughing to promote healing

ABSTRACT

This article describes effective ways of diagnosing and removing slough from a wound bed. It highlights how slough is a key contributor to wound chronicity, and gives practical clinical information on how to address this. The various methods of removing slough will be discussed including the mechanism of action of dressings and other mechanical methods. The ultimate objective of the article is to put the term desloughing on the clinical agenda and increase clinician familiarity with it. The practical focus of the article will help clinicians select a proven method to facilitate the rapid removal of slough, it is hoped that in doing so this will help to prevent chronicity, reduce the potential for bacterial proliferation and promote rapid and effective wound healing outcomes.

Key words: Wound healing ■ Desloughing ■ Debridement ■ Biofilms

Chronic wounds such as venous leg ulcers have an underlying pathogenesis that contributes to the build-up of devitalised tissue. While it is vital to address the underlying pathology, it is essential to effectively remove devitalised tissue (Schultz et al, 2003). Removal of slough and dead tissue is imperative for successful wound management, with some authors claiming that healing is compromised without it (Sieggreen and Maklkebust, 1997; Gottrup, 1999). Shultz et al (2003) argued that the presence of devitalised tissue increases the risk of wound infection, osteomyelitis, sepsis, protein depletion and delays healing. The devitalised tissue also limits the ability to visualise the base of the wound and measure or estimate its depth.

Literature frequently refers to slough and necrotic tissue under the umbrella term of devitalised tissue. However, this article evaluates the evidence on slough alone. This is based on the premise that, given the differences in the formation, manifestations and treatment of slough and necrotic tissue, the two can be studied and considered separately. The causes and constituents of slough are explained, along with its links with the inflammatory phase of wound healing and why slough is an ideal environment for bacterial proliferation. The article also addresses the relationship between slough and biofilm development/proliferation and wound chronicity. Finally, it emphasises that the rapid and selective removal of slough can avoid these deleterious effects, thereby promoting efficient wound healing and improved patient outcomes.

What is slough?

Slough is comprised of the components of phagocytosis and occurs as a consequence of the inflammatory phase of wound healing. In acute wounds, neutrophils remove any dead and devitalised tissue that occurred as a result of the injury, and ingest any debris and bacteria introduced at the time of injury from the wound bed. Once removed, the activity of neutrophils changes and redundant cells undergo programmed cell death (apoptosis) (Hart, 2002; Attinger et al, 2006). The cellular debris is forced out onto the surface of the wound bed where it can be seen as slough, it is then phagocytosed by macrophages (Velnar et al, 2009). This is a natural process that is designed to remove redundant cells with minimal tissue damage. It facilitates rapid progression to the next stage of the healing process by the avoidance of increased inflammation (Velnar et al, 2009).

In chronic wounds, the orderly process of healing is disrupted, this can be a result of underlying disease that leads to repeated ischaemia and reperfusion injury, which results in inflammation (Mustoe, 2004). Prolonged inflammation leads to high levels of matrix metaloproteases (MMPs), and the decreased levels of growth factors, failure to close in a timely and orderly fashion leads to a predominance of elderly active but unresponsive cells (senescence) (Telgenhoff and Shroot, 2005). As a consequence, chronic degradation of the extra cellular matrix occurs as the components of chronic wound fluid become a wounding agent (Attinger et al, 2006). Chronic inflammation leads to increased phagocytosis and apoptosis (Mustoe, 2004), which could lead to corresponding increases in slough.

Differential diagnosis

Slough is a viscous, yellow, relatively opaque fibrinous tissue. It consists of fibrin (non-soluble fibrinogen, which is a by-product of the clotting cascade), white blood cells, bacteria and debris, along with dead tissue and other proteinaceous material (Gray et al, 2010)—in short, the cellular debris resulting from the process of inflammation. In contrast, necrotic tissue is associated with cell death resulting from injury, infection and/or disease processes (Wounds UK, 2013). The different distinguishing characteristics of slough and necrotic tissue are listed in *Table 1*.

Unfortunately, despite being given the right circumstances, slough can still occur in a previously granulating wound,

Jeanette Milne, Tissue Viability Nurse Specialist, South Tyneside Foundation Trust

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Table 1. Distinguishing characteristics

	Sloughy tissue	Necrotic tissue
Cause/s	Consequence of wound healing process	Consequence of Injury, infection, unrelieved pressure. Underlying disease; infarction, cancer, poison
Pathology	Cellular debris caused by the natural process of programmed cell death (apoptosis)	Interruption in blood supply to the skin results in local ischaemia and cell death and dehydration
Made up of	Redundant white blood cells, fibroblasts and other cellular components of healing	Cellular debris in the form of fibrous proteins, e.g. collagen, and proteoglycans, e.g. components of the extracellular matrix
Colour	Yellow or creamy yellow, white, grey	Black, brown or grey
Description	Adherent, Viscous, slimy and stringy	Dry, hard, thick and leathery, usually firmly attached

and its appearance and soft stringy viscous texture make removal challenging. Unlike necrosis it is almost impossible to remove slough by conservative sharp debridement as it is very difficult to grip with forceps to allow cutting of the devitalised tissue, without causing trauma to surrounding tissue. In addition, patients with chronic wounds tend to have multiple comorbidities, which preclude them from a costly surgical intervention.

It is also postulated that it is difficult for clinicians to distinguish between slough and rehydrated necrosis, which is no longer hard but an adherent, viscous slimy and stringy form of slough. Percival and Suleman (2015) believe that slough and necrosis are distinct things. It could be argued that if slough is a by-product of metabolism, it is produced as a result of the metabolic effort and inflammation required to remove the necrosis. Nonetheless, irrespective of cause, necrosis and slough have been linked to wound chronicity and must be removed to stimulate healing (Shultz et al, 2003).

Grothier (2015) describes some of the clinical challenges facing clinicians in the diagnosis and removal of slough.

Relationship between slough and biofilm

Slough is commonly seen as a superficial layer in acute wounds, but can occur in granulating wounds that are critically colonised as it has been linked to bacterial proliferation and can potentiate infection (Shultz et al, 2003).

It has also been proposed that there is a link between biofilm formation and slough (Percival and Suleman, 2015). Biofilms have been described as a collection of single- or mixed-species microorganisms that attach to a surface or each other; their coexistence enables proliferation within a self-secreted protective matrix (Fonseca, 2011). Wolcott et al (2008) argued that biofilms stimulate inflammation, which in turn intensifies vascular permeability, oedema at the wound edges and exudate production and that this, combined with the resultant congestion, may be linked to the production of slough.

Some authors have hypothesised that slough should be regarded as a by-product of the presence of wound biofilm (Rhoads et al, 2008; Percival and Suleman, 2015). In its initial stages, a biofilm coexists with the host; the relationship is non-pathogenic (not harmful) but as it matures the continued low-level inflammation contributes to the wound becoming chronic, which in turn increases the production of slough and consequent failed progression to healing (Fonseca, 2011).

Wolcott et al (2008) argued that slough helps preserve/nourish the biofilm. In addition Pervical and Suleman (2015) suggest that slough has similar properties to a biofilm. However, Phillips et al (2010) suggest that a definitive link between slough and wound biofilm is yet to be established. It has been argued that there is a visual distinction between the two, with slough being a dense glutinous yellow, and wound biofilm being more gel-like and shiny (Hurlow and Bowler, 2009). However, Wolcott et al (2008) suggested that it is difficult to definitively diagnose a biofilm presence visually and suggested that clinicians focus on the removal of slough, with repeated debridement to disrupt the biofilm and the use of antimicrobial dressings to prevent reformation (European Wound Management Association, 2004; Shultz and Dowsett, 2012). As such, it is suggested that if there is evidence of wound chronicity (i.e. no reduction in wound size), unresolved slough or its presence in a previously granulating wound, the clinician's primary aim should be to deslough the wound as it is hoped that this will also disrupt any biofilms present (Wolcott et al, 2008; Percival and Suleman, 2015).

Debridement

Debridement is seen as a key tool for reducing the devitalised tissue and cellular burden found in chronic wounds (Schultz et al, 2003). Debridement is defined as the reduction or disposal of dead, infected or compromised tissue, cells and foreign material from a wound bed (National Institute for Health and Care Excellence (NICE), 2001). It is an umbrella term and can comprise a single clinical action or the use of multiple methods synergistically or sequentially that facilitate removal (NICE, 2001; Ayello and Cuddigan, 2004). To achieve an acceptable rate of healing, wounds must be properly cleansed and debrided/desloughed. Methods include surgical (by far the quickest), sharp, hydrosurgical, mechanical, autolytic, chemical and bio-surgical (larvae) (Strohal et al, 2013). The method should be selected on the basis of the best available evidence, taking into account both efficacy and cost (Lewis et al, 2001; Wounds UK, 2013).

Delays in the treatment of sloughy wounds are a prime cause of non-healing (Schultz et al, 2003; Strohal et al, 2013). This was also acknowledged at a workshop held at the European Wound Management Association (EWMA) 2015 Conference, where several key opinion leaders debated whether the solution is to create a new category, 'desloughing', that would sit alongside debridement, as this term might encourage clinicians to focus more on the (rapid) removal of slough (Cowan, 2015).

Desloughing

Clinically desloughing aims to eliminate cellular debris/devitalised tissue that is produced either as part of the normal healing process or occurs as a result of chronicity. The term desloughing covers two concepts:

- Natural desloughing, which is achieved by the endogenous action of enzymes produced automatically from white blood cells (autolyisis)

- Assisted desloughing, which describes the process whereby different methods are used to cleanse the wound. It is required when the body's natural autolytic processes are unable to cope with the quantity of tissue damage and the wound fails to progress and chronicity ensues. (Grothier, 2015; Percival and Suleman, 2015)

Practitioners must know when and how best to intervene, thereby aiding the elimination of waste within the wound and reviving the healing cascade. Once this phase is complete tissue reconstruction can begin.

Types of desloughing

This section outlines the different methods of debridement, and focuses on those most suitable for the removal of slough.

Autolytic desloughing

Wound fluid contains macrophages and neutrophils that digest and dissolve necrotic tissue (Ayello et al, 2004). Phagocytic cells and the proteolytic enzymes liquefy the debris, which is then ingested by macrophages (Ayello et al, 2004). A moist wound environment is key to facilitating autolytic debridement. This can be achieved with an occlusive dressing, e.g. a hydrocolloid, which covers both the wound and surrounding skin, trapping moisture vapour in the wound bed. Alternatively, use of dressings with retentive properties that actively donate or manage moisture, e.g. an alginate, foam, gelling hydrofiber or hydrogel are also commonly used to balance moisture levels in the wound. The action of these dressings is passive in that the endogenous enzymes in the moist environment target and liquefy necrotic tissue and by association slough, but not surrounding healthy tissue (Sieggreen and Malkebust, 1997). As autolytic debridement is selective, it does not cause patients pain (Ayello and Cuddigan, 2004). A disadvantage is that it is the slowest method of debridement and delayed removal of devitalised tissue prevents healing and potentiates biofilm formation, which in turn can result in wound infection (Shultz et al, 2003). It also prevents the accurate assessment of wound severity and dimensions. Nevertheless, its selective nature and acceptability to both patients and clinicians make it a popular choice (Ayello and Cuddigan, 2004).

When selecting a dressing, it is important to check that its properties are appropriate for the anatomical location and wound type, and that it is conformable, can adhere to/protect the surrounding tissue, and that its overall fluid-handling capacity is appropriate. Where exudate levels are raised, care must be taken to ensure the dressing is sufficiently absorbent to avoid maceration of the surrounding skin (Davies, 2004). If the wound is showing signs of critical colonisation or local infection, an antimicrobial dressing should be considered (Attinger et al, 2006).

Autolysis requires at least some level of exudate to be effective (Ayello et al, 2004). Dry sloughy wounds can be hydrated by the application of a hydrogel, an occlusive dressing or honey (the latter only if increased bioburden is suspected) (Strohal et al, 2013). Conversely, exuding sloughy wounds can be dressed with alginate dressings such as Sorbsan (Aspen Medical), Tegaderm alginate (3M), Algisite M (Smith & Nephew) or Hydrofibre dressings Aquacel (Convatec Ltd). These products form a gel when they absorb exudate, which prevents the desiccation of slough and facilitates autolysis.

Autolytic debridement is contraindicated in the treatment of ischaemic limbs or digits, which should be kept dry to prevent infection (Baharestani, 1999; Ayello et al 2004; Davies, 2004).

Mechanical desloughing

Mechanical desloughing is often associated with the use of wet-to-dry gauze, where wet gauze is placed on the wound, allowed to dry and then removed along with any adhered devitalised tissue. This method is popular in the USA but has been associated with patient pain and discomfort due to the removal of the adherent gauze (Ayello et al, 2004; Davies, 2004). This form of debridement is non-selective, slow and often painful, and is rarely practised in the UK. However, the umbrella term now refers to several different approaches designed to actively remove debris from the wound bed (Davies, 2004). Recent additions to this category include the use of monofilament debridement pads (Debrisoft (Activa Healthcare) and UCS Debridement (Medi UK) to facilitate the removal of hydrated devitalised tissue. Although its supporting evidence is limited (NICE, 2014), if used properly they quickly remove slough, are relatively easy to use and usually well tolerated by patients.

A relative newcomer to the world of desloughing is UrgoClean® (Urgo Medical), which has an acrylic core covered with non-woven polyacrylate fibres that absorb exudate and trap slough (Eloy et al, 2010). The dressing has a soft-adherent lipido-colloid coating (TLC Technology) that can be removed atraumatically (Meaume et al, 2010; Trudigan et, 2014). A clinical evaluation reported that it was acceptable to patients, controlled exudate and promoted autolysis of slough (Trudigan et al, 2014). The dressing is positioned in the mechanical desloughing category as it has been specifically designed to lift and bind to the components of slough, thereby facilitating its removal (Grothier, 2015).

Figures 1–4 illustrate different types of sloughy wounds and the desoughing strategies for them.

Patient-related factors

Older people have decreased amounts of endogenous proteases, such as collagenase, in their wound fluid (Himel, 1995). Baharestani (1999) suggested that this impairs autolysis, which reduces cell proliferation and can lead to wound chronicity. Autolysis is not only dependent on the moisture balance within the wound, but also its temperature, pH and availability of enzymatic co-factors (Sieggreen and Malkebust, 1997; Baharestani, 1999). To optimise outcomes, clinicians must match their understanding of a product's characteristics to the status of the wound in order to ensure that it creates the optimum environment for the removal of slough.

Strohal et al (2013) suggested that the key to improving patient outcomes is to establish an accurate diagnosis—in other words, to answer questions such as: why is there a build-up of slough, and is this associated with chronicity, bioburden or both? The answer should allow clinicians to set an outcome against which success can be measured. Once a goal is set, the treatment most likely to achieve it should be selected. Holistic patient assessment is central to the realisation of any goal; the underlying cause of the wound must be treated and

Figure 1. Slough associated with biofilm/bioburden: cleanse with a surfactant solution, followed by mechanical desloughing or larvae. Use an antimicrobial with the appropriate absorbent properties for the exudate level present

Figure 2. Wet superficial slough: cleanse with a surfactant solution, followed by mechanical desloughing using a dressing with the appropriate absorbent properties for the level of exudate present

Figure 3. Thick slough: cleanse with a surfactant solution, followed by mechanical desloughing using a dressing with the appropriate absorbent properties or larvae for the level of exudate present

Figure 4. Dry adherent slough: autolytic desloughing, followed by products that will hydrate the slough

any comorbidities addressed, for example, tight glycaemic control and offloading should be implemented in patients with diabetic foot ulcers. Failure to achieve goals within a desired timeframe warrants reassessment of both the patient (to ensure the initial diagnosis was correct) and of the method of desloughing used (to see if an alternative is required). If the slough does not respond to treatment or reoccurs, and the wound fails to progress, the clinician should refer the patient to a specialist practitioner for assessment and advice.

Sloughy wounds are often associated with symptoms such as pain at dressing change, excessive exudate and malodour, which impair wellbeing (Wounds International, 2012). In the author's experience, methods that facilitate the rapid selective and painless removal of slough, and also manage exudate and reduce malodour are preferable to patients. Other factors that influence dressing selection include dressing wear time, the patient's dexterity, frequency of application, the patient's ability to self-care, and their personal hygiene needs (Wounds International, 2012; Wounds UK, 2013).

It is important to engage the patient in treatment choices and ensure they have the tools to make an informed choice. Patients with longstanding wounds may have fixed opinions on the acceptability of a treatment regimen, based on previous experience, particularly of negative effects. These can usually result from failure to address the underlying aetiology, pain and exudate, as well as factors such as incontinence and fragile skin, sensitivity to dressings, knowledge of the practitioner, expectations and adherence with treatment.

Clinical challenges and dilemmas

This article has discussed that slough differs from necrosis in both its biological characteristics and its appearance. However, anecdotally the prevailing view of clinicians is that the only difference between the two is moisture; i.e. slough is thought to be rehydrated necrosis. The presence of slough in a wound is often viewed as progression towards the removal of necrosis. Perhaps this is further compounded by the concept of applied wound management (Gray et al, 2010) which supports the use of the colour continuum, which suggests a progression from black to yellow tissue. This is further compounded by an inability to definitively differentiate the two diagnostically by visual inspection alone. It is perhaps simpler to understand

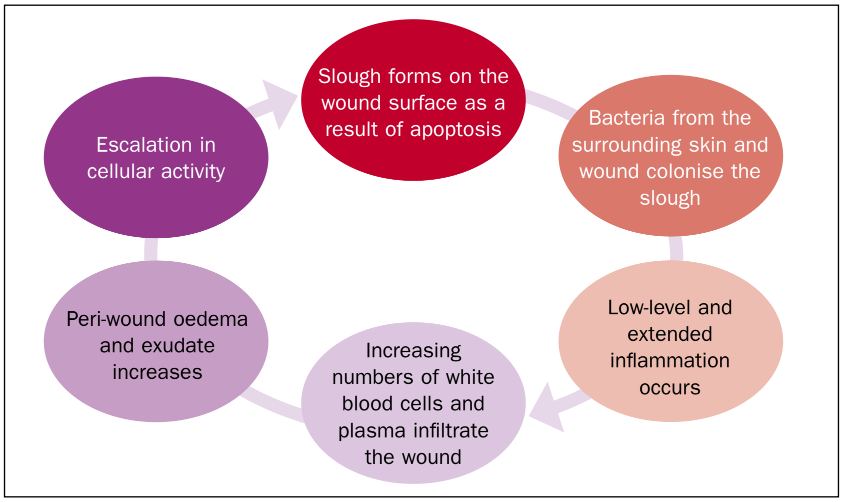

Figure 5. The cycle of slough formation

the mechanism by which slough forms in a chronic wound, (*Figure 5*) as its presence may only cover part of the surface, or there may be a thin layer that may or may not have been there at a previous assessment. Slough can and does recur and poses a challenge even to experienced clinicians.

There are no accurate figures to suggest the prevalence of slough in wounds. Experience suggests that it is present in the majority of wounds during their evolution and its removal is challenging as is its reoccurrence in some cases. It is clear from reviewing the literature that no method is able to remove all devitalised tissue in a single application. As such a combination of methods is required. Emerging evidence suggests best practice includes disruption of the outer membrane of slough with surfactants, the rapid removal of slough with dressings, consideration of the use of antimicrobials and the adoption of therapies that prevent reoccurrence, or adoption of maintenance therapies to remove its build up at dressing changes (Pervical and Suleman, 2015).

Economic considerations

The cost and availability of any dressing material, along with the application time, clinician skill, care setting, frequency of application and duration of use to achieve the desired outcome all impact the health economic value of a product.

Advanced dressings are often more costly than older products when comparing unit cost, but this must be considered in light of the evidence for each in terms of efficacy and speed. The largest cost associated with wound care is nursing time—using a product that minimises the frequency of dressing changes, will positively impact on cost even if it takes the same time to achieve the goal of care (Posnett and Franks, 2007). Financial comparisons should be made on overall treatment costs, not dressing cost alone. Failure to make an accurate diagnosis and implement treatments that address underlying systemic and local causes is a major factor in the overall cost associated with the treatment of chronic wounds globally (Wounds International, 2013). People are living longer and are surviving illnesses owing to advances in medical technology and symptom control with medication. As a result people with multiple comorbidities present with wounds and it is predicted that by association wound-related complications will also escalate (Sen et al, 2009). Securing funding for wound management is challenging in times of austerity, and practitioners must ensure that their management strategies consider cost and improve patient outcomes. Establishing the value of any treatment is dependent on having data that proves efficacy. Unfortunately there are very few high-quality studies of cost effectiveness in wound management on which to base practice decisions. Economics in wound healing centre on delivery of treatments that simultaneously correct any established pathophysiology and facilitate local resolution to wound-related symptoms such as slough. Any that also minimise dressing changes and the overall number of interventions and time to closure will also lead to savings.

KEY POINTS

- Slough is a key contributor to wound chronicity
- Rapid and selective removal of slough and other cellular debris facilitates healing
- The chosen method must be aligned to patient preference and desired wound-care outcomes
- Cost-effective wound management must focus on treating the underlying cause of the wound

Conclusion

Removal of slough requires knowledge and skill. To address sloughy wounds, clinicians must match the dressing to both the dominant tissue type and its presenting features. This article has discussed patient-related factors and wound symptoms that impact on the choice of product. Nonetheless, it is imperative that clinicians balance these with speed of removal required to facilitate healing and reduce complications associated with the failure to do so. It is clear that failure to address high levels of cellular debris potentiates bacterial bioburden and the potential for chronicity. Wound debridement and the removal of slough (desloughing) is a vital function in wound healing. Chronic wounds often have decreased cellular activity, increased amounts of protease activity, and may stall in various stages of wound healing (Shultz et al, 2003). As a result, debridement and mechanical desloughing are necessary to convert a chronic wound into an acute one by removing dead, devitalised and protein-rich substances such as MMPs, thereby helping to stimulate cellular activity and coordinated tissue regeneration and deposition. Successful wound management depends on a flexible approach to the selection and use of products based on an understanding of the healing process, combined with a knowledge of the properties of the various dressings available. Consideration must be given to approaches that decrease patient pain, this can be achieved by using dressings that facilitate the rapid but atraumatic removal of slough, while simultaneously offering protection to healthy tissue. In addition any dressing used must be easy to remove, leave no dressing debris in the wound bed, and suitable for use in all care settings, as the skill of the clinician and patient is central to the choice of method (Grothier, 2015). Without such knowledge and careful consideration of all the factors, dressing selection is likely to be arbitrary and potentially ineffective and waste both time and physical resources.

Removing all non-viable tissue is the first step in wound-bed preparation (Robson, 2012). Whichever technique is selected, once the slough has been removed, the formation of granulation tissue can take place unhindered. BJN

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