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Review Article

Debridement: A review of current techniques

Sajad Ahmad Salati

Department of Surgery, Unaizah College of Medicine & Medical Sciences, Qassim University, Saudi Arabia.

Abstract Debridement is the removal of nonviable material, foreign bodies, and poorly healing tissue from a wound to enhance healing. This article focusses on the indications, precautions, advantages and disadvantages of the variety of currently available debridement options.

Key words
Debridement, debris, wound, wound bed, biofilm, healing, non-healing.

Introduction

Chronic wounds represent a healthcare burden of tremendous magnitude and it is estimated that 1–2% of the population in developing countries experience a chronic wound during their lifetime. The difficulties posed by them have plagued human civilizations for thousands of years. Debridement is a fundamental principle and effective technique of achieving healthy wound bed preparation and involves attempts at clearance of devitalized wound debris containing necrotic and senescent cells, inflammatory enzymes, and biofilms of bacterial colonies.[1-2]

The term "debridement" was introduced by Pierre-Joseph Desault in the late 1700s as he recognized a notable increase in wound healing and overall patient survival as a result of freshening the edges of war wounds prior to closure.[3] Throughout the 20th century, debridement practices have progressed steadily. The World Wars and other major conflicts like Vietnam, Iraq and Afghanistan presented surgeons with complex injuries from diverse weapons leading to innovation. With the evolution of antibiotics, progress in the care of diseases associated with chronic wounds, such as diabetes and venous insufficiency, a corresponding increased need for creative and practical patient care management has arisen.[4] Debridement with various tools and techniques has subsequently evolved for wound bed preparation and this article aims to set out an overview of the indications, advantages, disadvantages, precautions and contraindications of the most commonly used methods of debridement.[5-8]

Address for correspondence
Dr. Sajad Ahmad Salati
Associate Professor, Department of Surgery
Unaizah College of Medicine and Medical Sciences
Qassim University, Saudi Arabia
Email: docsajad@yahoo.co.in

Methods

Comprehensive literature review using PubMed, Scopus and Google Scholar as search engines and reviewing English articles available as full texts. The keywords used were "debridement", "biofilm", "wound bed preparation" and "wound management". Only the literature published in English was included and time limits were set from 1st January 2000 till date. In addition, some important references from earlier dates and abstracts of non-English articles that appeared as cross references in the included articles were also reviewed and two references from 1998-99 were used due to their relevance.

Current techniques of debridement

Currently various techniques of debridement are available and the technique is selected for a particular wound , on the basis of advantage and the disadvantage that the technique offers, in that particular setting **(Table 1)**. These techniques include:

1. *Autolytic Debridement*

Autolytic debridement is the removal of devitalized tissues from a wound by relying

Table 1 Summary of the advantages and disadvantages of various tools of debridement.

Autolytic Debridement	*Advantages* - Selective for the necrotic tissue and hence no damage to surrounding skin; - Safe because it uses the body's natural processes to rid the wound of necrotic tissue - Easy to perform and required no specialized training or skills - Very effective and painless *Disadvantages* - The process is time consuming (may take days to weeks) - The wound required routine monitoring for the signs of infection - Occlusive dressing if chosen may promote anaerobic growth
Enzymatic Debridement	*Advantages* - Works faster than autolytic debridement - If properly applied, there is little risk to healthy tissue *Disadvantages* - Fairly expensive - Healthy surrounding tissue may get damaged if it comes in contact with the chemical agent - A secondary dressing may be required to absorb exudate - May cause burning sensation and wound pain
Surgical Debridement	*Advantages* - Excellent control over tissue removal - Fastest method to achieve a clean wound bed *Disadvantages* - Not cost-effective if an operating room is required - Painful for the patient and hence may require general anaesthesia - Requires skilled healthcare provider
Biologic Debridement	*Advantages* - Highly selective - Reduced malodour *Disadvantages* - May be painful - Not applicable in patients of vermiphobia - Not suitable in bleeding wounds
Mechanical Debridement	*Advantages* - Easy and no special skills requires - Relatively quick - Less pain *Disadvantages* - Not suitable in wounds with pain or hard eschar - Possibility of infection - Risk of damage to viable tissue
Ultrasonic-assisted debridement	*Advantages* - High precision with least possibility of damage to viable tissue *Disadvantages* - Risk of cross-contamination - Pain requiring analgesia

upon the inherent ability of the body, to liquefy and eliminate necrotic debris through its own endogenous enzymes, phagocytic cells, and moisture. Proteolytic and collagenolytic (matrix metalloproteinases) enzymes, are normally present in wound fluid and they disrupt the proteins that bind the dead tissue to the body.[9]

Autolytic debridement is a conservative approach, indicated for wounds with minimal necrosis, as an adjunct after more aggressive debridement, and in patients who are unable to tolerate pain or more aggressive forms of debridement.[10] It is contraindicated in patients with poor perfusion and stable, dry, and intact eschar. In actively infected wounds or wounds with extensive necrotic tissue or significant tunnelling and undermining, it should only be an adjunct and not be the sole method of debridement. Immunocompromised patients or patients with severe neutropenia have increased risk of infections and hence are to be offered alternate methods of debridement.

To perform autolytic debridement, the wound is covered appropriately with a moisture-retention, semi-occlusive or occlusive dressings like hydrogels, hydrocolloids, transparent films and alginates. These maintain wound fluid in contact with the necrotic tissue to create an environment with a balance in moisture that allows the digestion of devitalized tissues.[11-13]

It is painless usually effective and easy to perform requiring no specialized training, but takes longer time to accomplish. The softening and then the separation of the necrotic tissue commonly occurs within a few days and the failure to achieve significant autolysis within one to two weeks, is an indication to consider other method of debridement.[14]

Protection of the peri-wound skin while using autolytic debridement is imperative. If the moisture-retentive dressing is not applied correctly or if the peri-wound skin is not protected, the wound may become too wet, or liquified slough and necrotic tissue can seep to the peri-wound area, resulting in maceration of the wound edges. In turn, the macerated edges can easily break down with resultant enlargement of the wound.

Various studies have examined autolytic debridement and have tried to compare the impact of different dressings to suggest appropriate options. Motta *et al*.[16] and Brown-Etris *et al*.[17] in two separate studies found no significant difference in healing rate of pressure ulcers between groups treated with polymer hydrogel dressings versus hydrocolloid dressings and transparent absorbent acrylic dressings versus hydrocolloid dressings. Further, a study performed by Kerihuel[18] compared charcoal dressings with hydrocolloid dressings and found no significant impact on healing of pressure or venous leg ulcers (VLUs).

2. *Biologic Debridement*

Biologic debridement is also termed as maggot debridement therapy (MDT), biotherapy and biosurgery. It involves the controlled, therapeutic use of disinfected live larvae ("maggots") of the green bottle fly (Lucilia sericata). Currently, MDT is considered as a secondary tool for patients after surgical debridement or for those who are not candidates for surgical procedures. Maggots have been found to secrete proteolytic enzymes and a wide range of chemicals with antimicrobial properties which include allantoin, urea, phenylacetic acid, phenylacetaldehyde and calcium carbonate.[19]

Due to this property, they can inhibit and destroy a wide range of pathogenic bacteria including methicillin-resistant Staphylococcus aureus (MRSA), group A and B streptococci, and

Gram-positive aerobic and anaerobic strains.[20] However, maggots have been found to be ineffective against certain bacteria like Pseudomonas aeruginosa, Escherichia coli and Proteus spp.[21]

Historically maggots have been used since centuries for wound management.[22] Use of maggots for wound healing have been reported in the accounts of Maya Native Americans and Aboriginal tribes in Australia. Similarly, there are reports of the use of maggot treatment in Renaissance times when the military physicians including Napoleon's general surgeon, Baron Dominique Larrey had observed that soldiers whose wounds had got infested with maggots experienced significantly less morbidity and mortality than soldiers whose wounds had not got infested. During France's Egyptian campaign in Syria, 1798–1801, Larrey had reported that certain species of fly consumed only dead tissue and helped wounds to heal.[22]

Successful wound debridement by use of maggots was reported during the American Civil War and the World Wars.[23-24] After the First World War (1914-18), treatment of wounds with maggots had become widespread but with the advent of antibiotics and improved surgical techniques, the use declined in the 1940s. In the last few decades however, the interest has got reignited, due to the efforts of the International Biotherapy Society, founded in 1996, that meets regularly to share experiences around the use of maggots in medicine. Similarly, the Bio Therapeutics, Education and Research (BTER) Foundation was established in early 2003 for the purpose of supporting patient care, education, and research into maggot therapy and other forms of symbiotic medicine. The U.S. Food and Drug Administration (FDA) has also granted permission in January 2004 to produce and market maggots for use in humans or animals as a prescription-only medical device for debriding non-healing necrotic skin and soft tissue wounds, including pressure ulcers, venous stasis ulcers, neuropathic foot ulcers, and non-healing traumatic or post-surgical wounds. A survey of US Army doctors published in 2013 found that 83% of respondents were familiar with MDT, and of those familiar, 63% were aware of FDA approval for the product and 10% had used the product themselves. The three most frequently cited reasons for not using the therapy were no need (52%), no access (23%), and insufficient experience (19%).[25] Wang *et al.* conducted a retrospective study of 25 patients with diabetic foot ulcers and 18 patients with pressure ulcers after spinal cord injury treated by maggot therapy or traditional dressing. Changes in the lesions were observed and bacterial cultures tested. All ulcers healed completely. The times taken to achieve bacterial negativity, granulation and healing of lesions were all significantly shorter in the maggot therapy group than in the control group, both for diabetic foot ulcers ($P<0.05$) and pressure ulcers ($P<0.05$).[26] Sherman reported a retrospective comparison of changes in necrotic and total surface area of chronic wounds treated with either maggot therapy or standard (control) surgical or nonsurgical therapy. In this cohort of 18 patients with 20 nonhealing ulcers, six wounds were treated with conventional therapy, six with maggot therapy, and eight with conventional therapy first, then maggot therapy. Maggot therapy was found to hasten growth of granulation tissue and achieve greater wound healing rates.[27] Tantawi *et al.* applied maggots in 10 patients with 13 diabetic foot ulcers unresponsive to conventional treatment and surgical intervention and found this mode to be a rapid, simple and efficient method of treating these ulcers.[28]

Currently, there are two methods of larval application for wound debridement. The first method is using larvae sealed within a dressing

called biobag which comes in varying sizes to match different wound sizes. Throughout the treatment period, the larvae remain sealed inside the biobag. The second method is to apply free-range larvae directly on to the wound. Biobags or else the free-range larvae can be left in the wound for up to 4 days per application. The number of applications required for complete wound debridement depends on the type of wound. In an optimum wound environment maggot undergo moulting twice, increasing in length from 1–2 mm to 8–10 mm, and in girth, within a period of 2-3 days by dissolving necrotic tissue through extracorporeal digestion. MDT may cause pain or discomfort, particularly in already painful wounds. This usually occurs about 24-36 hours into therapy, and requires analgesics or else the removal of the maggots. The maggots should be contained within the wound. If they escape onto unprotected skin around the edges of a wound, the larval secretions can potentially cause a skin rash that resembles a superficial burn. For the application of MDT, a moist, exudating wound with sufficient oxygen supply is a prerequisite. Wounds which are dry, or open wounds of body cavities do not provide a good environment for maggots to feed and hence are not suitable for this treatment. Patients and healthcare providers may find maggots distasteful, although studies have shown that this does not cause patients to refuse the offer of maggot therapy. Furthermore, it is contraindicated for use in patients of vermiphobia and in the treatment of fistulae, exposed vessels and wounds in proximity to vital organs.[29]

3. *Enzymatic Debridement*

The wound healing process is predominantly mediated by matrix metalloproteinases (MMPs) and hence dysregulation of MMPs can potentially result in failure of wound healing. It has been found experimentally and in clinical applications, that the topical application of non-human proteases has beneficial therapeutic effects in events where MMPs fail due to dysregulation.[30]

The most frequently used proteases are collagenases, serine proteases and cysteine proteases. Animal secretions from fish epithelial mucus, maggot (Lucilia sericata) secretory products and snake venom contain different types of proteases capable of degrading the same substrates as MMPs and their therapeutic activity has also been demonstrated.[31-32]

Enzymatic debridement is currently an adjunct to surgical debridement or else the primary technique for debridement when alternative methods such as surgical debridement is not feasible due to any considerations like bleeding disorders. Collagenase derived from fermentation by Clostridium histolyticum is used in clinical practice currently. It comes in an ointment form containing 250 collagenase units per gram of white petroleum. It is recommended that the ointment be applied daily and discontinued when healthy granulation occurs. The area of eschar should be cross hatched before application of an enzymatic debridement product to encourage deeper penetration and as most enzymes work best in a moist environment, the wound should be kept covered after application. In enzymatic debridement, the clinician should monitor for signs and symptoms of infection. Ramundo and Gray undertook a systematic review in 2009 to summarize and ranks evidence concerning the safety and efficacy of the selective enzymatic debriding agent collagenase and found that a preponderance of evidence confirms that collagenase ointment is a safe and effective choice for debridement of cutaneous ulcers and burn wounds.[33]

Marrazi *et al*. retrospectively assessed the

outcomes of 647 burns and 332 chronic ulcers treated with collagenase in an outpatient setting and concluded that collagenase treatments in outpatient clinics are effective and well accepted in patients with burns affecting ≤15% BSA or with chronic ulcers of various aetiologies. Implementation of collagenase treatments in outpatient clinics has the potential to improve wound healing and may also decrease the cost of wound care.[34] Patry and Blanchette however are of the opinion that there is still very limited data on the effect of collagenase as an enzymatic debridement technique on wounds and that more independent research and adequate reporting of adverse events are warranted.[35] In very recent works, Perera *et al*. have called upon more research on the biomedical application of digestive enzymes from tropical marine crustaceans[36] and Melendez-Martinez *et al*. demonstrated that Crotalus spp. are a valuable source of proteases that can aid chronic wound-healing treatments.[37]

4. *Mechanical Debridement*

As the name implies, mechanical debridement involves the physical removal of necrotic debris from a wound.[7] A wide range of methods are used in clinical practice that include wet-to-dry dressing changes, hydrotherapy and wound irrigation. Wet to dry dressing, consists of application of moist gauze to a wound bed that requires debridement, which is then covered with a sterile bandage. After a set period of time, the dressing will dry out, which allows the tissue to adhere to the gauze and when the dressing is removed, the necrotic tissue and slough that adhered to the gauze is also removed. This type of debridement is also referred to as "non-selective debridement" as both healthy and unhealthy tissue get removed with this process.[38] This type of mechanical debridement is indicated for decontaminating wounds with moderate amounts of necrotic debris and specifically can be used for contaminated or infected laparotomy wounds, perianal/ groin wounds, and foot wounds. The advantage to this technique is that the cost of the actual material (i.e., gauze and saline) is low. Disadvantages include that wet-to-dry dressing changes traumatize healthy or healing tissue along with necrotic debris and removes neo-epithelium each time the dressing is changed. Additionally, this method can cause excessive pain as well as bleeding with every dressing change besides being time consuming.[38]

Hydrotherapy is a version of mechanical debridement and consists essentially of wound soaks in a water bath or whirlpool. The water temperature in the bath is maintained between 33.5-35.5°C for most patients. Extra care is required in patients of peripheral vascular disease and the water temperature should not exceed 1°C above skin temperature. This technique is effective and relatively easy to perform; however, over-soaking can lead to tissue maceration, waterborne pathogens may cause contamination or infection, and disinfecting additives may be cytotoxic. In recent years, a uniquely modified version of Hydrotherapy in form of hydro-responsive wound dressing (HRWD) has been introduced to provide an optimal healing environment. The first step involves application of HydroClean plus which is a specialised dressing that enables removal of devitalised tissue through autolytic debridement and absorption of wound fluid. Irrigation and cleansing provided by Ringer's solution from the dressing further removes any necrotic tissue or eschar. Once effective wound bed preparation has been achieved a second dressing, HydroTac, provides an on-going hydrated wound environment that enables re-epithelialisation to occur in an unrestricted fashion.[39] Multiple studies have found that this acts as an efficient debridement tool providing

rapid, effective and pain free debridement in a variety of wound types.[40,41]

Pressurized water irrigation (typically from 2-10 psi) is another tool for debridement and it removes loose, devitalized tissue and controls bacterial load. Irrigation is often recommended for acute wounds with a presumed high bacterial load and forms a basic component of standard open fracture care. An instrument, called the Versajet system [Versajet Hydrosurgery System (Smith & Nephew, Hull, UK)], is based on fluid jet technology and has been advocated as an alternative to standard surgical debridement. This tool excises and aspirates the unwanted tissue by using the Venturi effect.[42] Versajet allows a precise and selective debridement, by making it possible to remove only the tissue centred in the working end and spare the healthy tissue, besides being highly effective in reducing the bacterial load of the ulcer bed. The pain caused by Versajet is mild and tolerable, especially when set for gentle debridement. If multiple treatments are required, the combined use with moist dressings act synergistically, as the dressings soften the necrotic tissue, thus facilitating Versajet debridement. This tool seems to be particularly helpful in concavities, tight spaces, and in burn wound excision.[43] Very recently Schoeb *et al*.[44] and Bahls *et al*.[45] independently proposed the concept integration of the waterjet technology into novel robotic system for efficient and autonomous performance of waterjet wound debridement. However, there has been some concern regarding bacterial spread resulting from wound irrigation systems and hence this tool should not be used when the fluid is likely to collect in dead space.[46]

Monofilament wound debridement pad (WDP) is another innovation of recent years, that has been found to debride wounds effectively, easily and safely leading to progress in healing to the satisfaction of both health professionals and patients. These pads by prefabrication in various forms, have been found to be effective in wounds of various aetiologies, locations and shapes, such as in cavity wounds and those in hard-to-reach locations.[47-52] Bahr *et al*. conducted a multicentre, prospective, observational evaluation assessing the debridement efficacy (that is, achievement of 100% granulation tissue on the wound bed), safety, patient comfort and user satisfaction of monofilament fibre product (Debrisoft). The results indicated the potential for the monofilament fibre product to replace several modes of debridement, based on its efficacy, short procedure, ease of use and patient comfort.[53]

5. *Surgical Debridement*

Surgical debridement is the commonest adopted option and the standard against which other techniques are judged. It involves the accurate assessment of wound depth and severity followed by the direct removal of necrotic and desiccated tissues with microbial load, providing the most efficient method of wound bed preparation. Wounds with extensive, adherent eschar and slough often require surgical debridement and clearly benefit from it.[54] It's however non-selective and some healthy tissue is invariably removed during the procedure. Besides, not all patients are surgical candidates, and those who tolerate the procedure may be limited by bleeding tendency and pain tolerance.[10]

Traditionally, surgical debridement is performed with a scalpel blade, curettes or scissors to excise the necrotic tissue in segments. The Weck knife is a specialized scalpel that can be used for tangential excision of tissue. Tissue is frequently removed to just beyond the interface between the wound margin and healthy tissue so that

slight margin of normal tissue is excised. Osteotomes and rongeurs may be needed to remove tougher tissues like bone.[46]

6. *Ultrasonic-assisted debridement*

Ultrasonic-assisted wound (UAW) debridement is a recently introduced debridement method that uses low-frequency ultrasound waves. This tool allows precise surgical debridement layer by layer, from superficial to deep while protecting underlying viable tissues. Studies have shown that the three clinical effects of traumatic selective tissue debridement, wound stimulatory effects and antibacterial activity facilitate early healing of wounds, reducing the cost to the healthcare system and improving the patient's quality of life.[55-56]

Lazaro-Martínez *et al*. studied ultrasonic assisted debridement in of neuroischaemic diabetic feet and showed a significant bacterial load reduction in DFU tissue samples as a result of UAW debridement, independent of bacterial species, some of which exhibited antibiotic-resistance. Significant bacterial load reduction was found to correlate with improved wound conditions and significant reductions of wound size.[57] Messa *et al*. retrospectively analysed the clinical outcomes and cost of ultrasonic debridement in a complex, heterogeneous cohort of chronic extremity wounds and found the tool to be safe and reliable.[58] Ramundo and Gray systematically reviewed the literature and found that ultrasound treatment has been used on wounds associated with neuropathy, limb ischemia, venous insufficiency, trauma, as well as poorly healing surgical wounds with a few adverse effects. Pain, if reported, can been successfully addressed with topical analgesia.[59]

Swanson *et al*. recently published the results of a closed international expert meeting that was held to review the existing evidence base, present preliminary findings of research currently in progress and discuss individual cases selected from the clinical experts' own practice related to UAW debridement. The panel also explored the potential barriers to the implementation of UAW debridement and how these might be addressed. It was concluded that there was sufficient evidence that UAW debridement is an effective method of cleansing and debriding almost all hard-to-heal wounds. Patients who are most likely to benefit from it are not medically stable, on anticoagulants, unable to visit a hospital for wound treatment, and/or have wounds with a poor vascular supply or are close to critical structures. The panel also observed that UAW debridement can be used to prepare the wound for negative pressure wound therapy (NPWT) or as an adjunctive to it. Given the potential for the procedure to cause pain, the panel considered that patients will benefit from topical analgesia. The panel noted that health professionals, patients and visitors must be protected from the aerosolization associated with UAW, to reduce risk of cross-contamination.[60]

Conclusion

Chronic wounds represent a significant healthcare issue and debridement is an important concept in their management. There is wide range of techniques and tools available, each with some advantages and disadvantages. The method that is chosen from this wide variety depends upon the nature of the wound.

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