

Exudate monitoring in traumatic wounds

KEY WORDS

- ▶ Traumatic wound
- ▶ Healing
- ▶ Moisture
- ▶ Metalloprotease
- ▶ Exudate

The successful treatment of traumatic wounds is probably the most challenging problem in surgery today. Traumatic wounds that are not amenable to surgical closure may heal by secondary intention, but often, signs of progress are made subjectively. The aim of this article was to determine whether new wound monitoring devices will provide the clinician with more information about the wound on which to base their clinical decision-making. New approaches to both elevated protease activity (WOUNDCHek™ Protease Status; Systagenix) and moisture control (WoundSense™; Ohmedics Ltd) are discussed here, designed to provide easy-to-interpret, rapid, point-of-care results that will aid treatment decisions in complex wounds. These new wound monitoring devices should better inform clinicians on identifying those complex wounds with a high probability of nonhealing and, therefore, aid in the treatment of such wounds.

Wounds, whether acute or chronic, are at best unpleasant and, at worst, dangerous. As the skin is a physical and an immunological barrier to infection, any defect in the skin may enable bacterial invasion.

Dressing changes, even those that incorporate the most patient-friendly dressings, can be tedious and time-consuming for patients, as well as reducing their quality of life. Dressing changes are also a major financial burden to society. Therefore, clinicians strive to achieve wound closure if at all possible, as well as preventing wounds from growing larger.

Traditionally, even amenable wounds only undergo surgical closure when clinicians deem them ready. The decision about whether or not to close the wound is usually highly subjective and mostly dependent upon the appearance of the wound, with little objective data available to help inform the decision.

This decision can prove to be the wrong one in two ways. Firstly, people with wounds that are amenable to closure may have had their operation delayed unnecessarily due to the clinician's reluctance to close the wound "too soon," in case the patient subsequently experiences problems. Secondly, attempts at surgical closure may be carried out when conditions are not, in fact, right. Typically,

this will lead to wound closure failure, either through dehiscence or loss of skin grafting.

Wounds that are not considered amenable to surgical closure often have dressings repeatedly applied in the hope that the wounds will heal themselves by secondary intention. Signs of progress in this regard are again mostly subjective, relying on the individual clinician noticing whether the wound is reducing in size, week by week, and whether the wound appears healthy. Dimensions of the wound may or may not be recorded.

However, recent developments in wound monitoring have, at last, enabled a more subjective assessment of the complex wound environment.

THE CHALLENGES OF TRAUMATIC WOUNDS

The successful treatment of traumatic wounds is probably the most challenging problem in surgery today. The primary purpose of the treatment of wounded patients is to save lives by preventing or arresting haemorrhage, allaying shock, and by preventing or controlling infection. The secondary purpose is to save the injured part and restore it as rapidly and as effectively as possible to normal function and appearance. To do this effectively, the blood supply must be optimised and any necrotic

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tissue must be removed as this can act as a focal point for bacteria. Contaminated and infected wounds are left open after debridement.

Closure

Knowing the appropriate time to close a traumatic wound is not only difficult, it can also be risky; closing too early can lead to regression of the wound and further tissue damage, while leaving the wound open exposes the patient to potential contamination and infection, as well as subjecting the patient to additional theatre visits, dressings, and in-patient stays.

Current practice relies heavily on the experience of the clinician, since there are few objective tests available to provide information on the underlying biochemistry and condition of the wound.

Traumatic wounds are particularly challenging due to their large size, the level of exudate they produce, and the level of contamination or damaged tissue present (Figure 1). The introduction of negative pressure wound therapy (NPWT) has helped with the control of exudate and in the management of these wound types (St Mart et al, 2009). However, knowing when a wound is free of foreign material and has a low bioburden, or whether the underlying inflammatory process has resolved, is still problematic.

While these fundamental processes are ongoing, the wound contains elevated levels of inflammatory cytokines, free radicals and proteases, which create a hostile wound environment (Salim, 1991; Kirsner et al, 1993; Palolahti et al, 1993; Harris, et al, 1995).

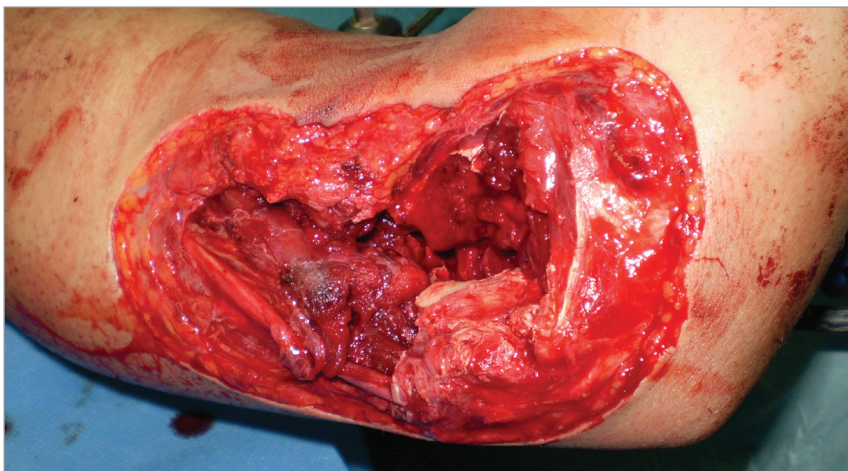


Figure 1. Traumatic wound to patient's elbow caused by an improvised explosive device explosion in Afghanistan.

The presence of bacteria exacerbates this situation and amplifies what is already hostile and highly proteolytic environment (Davies et al, 2001).

Until this proteolytic environment is dealt with, it is inappropriate to close the wound or to use a graft or synthetic scaffold/matrix due to wound dehiscence and/or degradation of the graft or scaffold being likely outcomes. Thus, premature wound closure can be detrimental to a successful clinical outcome.

DIAGNOSTIC TESTS

A diagnostic test that detects elevated levels of inflammatory-based protease activity in wound fluid could provide useful information about wound status and help provide direction to the clinician as regards when not to close a wound (World Union of Wound Healing Societies [WUWHS], 2008; Wounds UK, 2011).

Previous studies have shown that a multiplicity of proteases and mediators are involved in the inflammatory process and that these proteases not only interact with each other, but often act synergistically to degrade soft tissue components, such as collagen (Ferry et al, 1997; Medina et al, 2005; Meyer-Hoffert and Wiedow, 2011).

Consequently, to truly reflect the proteolytic state of the wound, it is necessary for a diagnostic test to measure the activity of multiple proteases, adding to the complexity of test development (Gibson et al, 2009). Furthermore, for the detection of elevated protease activity (EPA) levels to be clinically useful, the clinician needs to know the level above which protease activity is likely to impair wound healing and when interventions to modulate protease activity are most likely to prove beneficial (Serena et al, 2011; Snyder and Cullen, 2011).

Protease test

There is a protease status test available (WOUNDCHEK™ Protease Status; Systagenix) that acts as a point-of-care diagnostic test, developed to detect EPA in chronic wounds. The clinical verification of this test has determined the level at which these inflammatory proteases are detrimental to the wound-healing process, and has demonstrated that chronic wounds with EPA also have a 90% probability of nonhealing, unless an appropriate intervention is used (Serena et al, 2011).

While the prevalence of EPA in chronic nonhealing wounds was found to be approximately 28%, that prevalence will vary depending on the mixture of wound types being investigated (Harding et al, 2012). For example, healthcare settings with a higher incidence of inflammatory wounds, such as vasculitis or pyoderma gangrenosum, are likely to see a higher prevalence of EPA, and settings where advanced therapies are used extensively, particularly collagen/oxidised regenerated cellulose dressings, are likely to see a lower frequency of EPA. Further studies, however, are required to confirm the prevalence of EPA in nonhealing traumatic wounds.

The published data on the protease status diagnostic test also established that very few healing wounds had EPA, supporting the predictive nature of EPA with regard to nonhealing status (Serena et al, 2011). It is certainly true that the use of an easy-to-interpret, rapid, point-of-care diagnostic test, which is able to detect EPA, would enable clinicians to identify wounds with a high probability of nonhealing. This could, in turn, aid treatment decisions and facilitate the targeted use of appropriate therapies.

TREATMENT PLAN

If a traumatic wound was found to have elevated protease activity (EPA) then it would indicate that the wound was still inflamed and should not yet be closed. Furthermore, it would suggest to the clinician that the wound could potentially benefit from any of a combination of the following steps:

- ▶ Further debridement to remove foreign/necrotic material.
- ▶ Antibiotics/antimicrobials to help control the bacteria bioburden in the wound.
- ▶ Anti-protease/anti-inflammatory therapies to reduce the underlying inflammatory process.

If the wound has low protease activity, this would help the clinician confirm that the underlying inflammatory process was reduced to a level associated with healing progression or a decreased probability of nonhealing, such that, if appropriate, the wound could be closed.

Moisture content

One aspect of wound healing considered essential in modern clinical practice is the control of moisture in the wound bed. Moisture has long

been noted as an essential part of the wound-healing environment (Bull et al, 1948; Winter, 1962; Hinman and Maibach, 1963).

Achieving the correct moisture level in the wound environment currently relies on good clinical judgement and appropriate dressing selection. It is a delicate balance — a wet wound environment introduces the possibility of maceration and wound decay, while an environment that is too dry will impede healing (Schultz et al, 2005).

The importance of moisture in the wound environment has seen it incorporated as a key aspect of clinical practice in concepts such as the TIME guidelines (WUWHS, 2007), which classifies the four main components of wound bed preparation as: Tissue management (T), Control of infection and inflammation (I), Moisture imbalance (M), and Advancement of the epithelial edge of the wound (E). TIME defines dressing moisture levels as dry, moist, wet, saturated, and leaking, to help guide exudate management in clinical practice: .

However, these techniques rely on direct observation of the wound with the dressing removed and are somewhat subjective, depending on the skill and motivation of clinicians.

In 2009, a diagnostic sensor for moisture detection was introduced that allows clinicians to measure wound moisture without disturbing the dressing (McColl et al, 2009; Connolly et al, 2010).

This system (WoundSense™; Ohmedics Ltd) (Figure 2) comprises a sterile moisture sensor that is placed on the wound before the dressing is added. The sensor can then be checked as required on a daily or more frequent basis through the use of a handheld meter.



Figure 2. A disposable, sterile, moisture sensor for wound moisture monitoring.

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The meter provides a moisture reading on a simple five-drop moisture scale where a reading of 1 means the dressing is very dry and 5 means the dressing is very wet. A reading of 3 signifies moisture and for most wounds indicates ideal moisture conditions for healing. The sensor measurement is based upon low current electrical impedance measurements, taken via a pair of silver chloride electrodes, which are printed on a flexible, biocompatible polymer. The electrode sensing area is covered by a porous, nonadherent layer, which allows moisture to contact the electrodes, but avoids electrode adherence to healing tissue.

The use of the sensor allows decisions about dressing changes to be made without disturbing the wound bed or opening a dressing unnecessarily, which increases the risk of infection. Also, many dressings rely on moisture to activate an antimicrobial agent (such as silver), and the ability of an external sensor to tell the clinician whether the dressing is too dry is very useful.

Similarly, the ability to detect when a dressing is too wet in heavily exuding wounds would help clinical decisions around the timing of dressing changes, as well as which dressing to use.

CONCLUSION

Until now, clinicians have been guided by their clinical instincts to determine which wounds are safe to close, and which dressings are appropriate for each wound. Although they usually make the correct decision, this is not always the case.

The new wound monitoring devices detailed in this article will provide the clinician with more information on which to base their decision-making, which can only be good for clinicians, healthcare providers and, most importantly of all, patients. **WUK**

Disclaimer

The views expressed here are those of the author, not those of the Ministry of Defence.

REFERENCES

- Bull J, Squire J, Topley E (1948) Experiments with occlusive dressings of a new plastic. *Lancet* 2(6519):213–4
- Connolly P, Watret L, McColl D, MacDougall M (2010) Wound moisture can be measured without disturbing the dressing. *EWMA J* 10(2): (Suppl) 38
- Davies CE, Wilson MJ, Hill KE et al (2001) Use of molecular techniques to study microbial diversity in the skin. Chronic wounds re-evaluated. *Wound Rep Regen* 9:332–40
- Ferry G, Lonchamps M, Pennel L et al (1997) Activation of MMP-9 by neutrophil elastase in an in vivo model of acute lung injury. *FEBS Letts* 402(2–3):111–5
- Gibson D, Cullen B, Legerstee R et al (2009) MMPs Made Easy. Available at: <http://bit.ly/Z18ztk> (accessed 08.10.2012)
- Harding K, Serena T, Queen D et al (2012) *Preliminary Results: Testing for Elevated Protease Activity in Clinical Practice*. Poster presentation. 22nd European Wound Management Association conference, Vienna: 23–25 May
- Harris IR, Yee KC, Walters CE et al (1995) Cytokine and protease levels in healing and non-healing chronic venous leg ulcers. *Exper Dermatol* 4:342–9
- Hinman CD, Maibach H (1963) Effect of air exposure and occlusion on experimental human skin wounds. *Nature* 26(200):377–8
- International Consensus (2011) The Role of Proteases in Wound Diagnostics: An Expert Working Group Review. Wounds International, London. Available at: <http://bit.ly/X9pywl> (accessed 26.03.2013)
- Kirsner RS, Katz MH, Eaglstein WH, Falanga V (1993) The biology of wound fluid. *Wounds* 3:122–8
- McColl D, MacDougall M, Watret L, Connolly P (2009) Monitoring moisture without disturbing the wound dressing. *Wounds UK* 5(3):94–9
- Medina, A, Scott, P, Ghahary A, Tredget E (2005) Pathophysiology of chronic non-healing wounds. *J Burn Care Res* 26(4):306–19
- Meyer-Hoffert U, Wiedow O (2011) Neutrophil serine proteases: mediators of innate immune responses. *Curr Opin Hematol* 18(1):19–24
- Palolahti M, Lauharanta L, Stephens RW et al (1993) Proteolytic activity in leg ulcer exudate. *Exp Dermatol* 2(1):29–37
- Salim AS (1991) The role of oxygen-derived free radicals in the management of venous (varicose) ulceration: a new approach. *World J Surg* 15(2):264–9
- Schultz G, Mozingo D, Romanelli M, Claxton K (2005) Wound bed healing and TIME: new concepts and scientific applications. *Wound Repair Regen* 13(4 Suppl):S1–11
- Serena T, Cullen B, Bayliff S et al (2011) Protease activity levels associated with healing status of chronic wounds. Poster presentation. *Wounds UK*, Harrogate: 14–16 November
- Snyder R, Cullen B (2011) Point of care diagnostic tests in wound management: targeted therapy for excessive protease activity – the first frontier. *Wound Care Hyperb Medicine* 2(3):54–61
- St Mart JB, Jeffery S, Clark J (2009) Using negative pressure wound therapy to manage severe military trauma wounds. *Wounds UK* 5(3):56–64
- Winter G (1962) Formation of the scab and the rate of epithelisation of superficial wounds in the skin of the young domestic pig. *Nature* 20(193):293–4
- World Union of Wound Healing Societies (2007) *Principles of Best Practice: Wound Exudate and the Role of Dressings. A Consensus Document*. MEP Ltd, London
- World Union of Wound Healing Societies (2008) *Principles of Best Practice: Diagnostics and Wounds. A Consensus Document*. MEP Ltd, London
- Wounds UK (2011) Proteases diagnostic in wound care: round-table meeting. *Wounds UK* 7(Suppl):1–10