Managing wound exudate in diabetic foot ulcers

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Article points

1. Effective management of wound exudate in diabetic foot ulcers (DFUs) is a key component of any wound management plan and crucial to facilitate healing.
2. Assessment of wound exudate must include patients' medical history, wound history, environment and psychosocial status.
3. Exudate assessment should be integrated into every wound assessment, at every patient visit, with the aim of identifying any factors that might impact on healing.
4. In DFUs, the ultimate goal is to achieve moisture balance, to maximise the positive effects of exudate on healing, while minimising the detrimental effects associated with excessive exudate.

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Effective management of wound exudate in diabetic foot ulcers (DFUs) is a key component of any wound management plan and crucial to facilitate the healing of DFUs. It is important, therefore, that clinicians involved in the management of DFUs understand the role and function of wound exudate and, importantly, can recognise when exudate can become detrimental to the healing process. This article provides an overview of wound exudate, its role and constituents, and outlines current best practice in managing wound exudate to best facilitate wound healing and wound closure in DFUs.

Diabetic foot ulcers (DFUs) and lower-limb amputations are devastating end-stage complications of diabetes mellitus. Moreover, emerging evidence has highlighted the increased mortality rates associated with diabetic foot disease. Vadiveloo et al (2018) investigated amputation-free survival in people at high risk for foot ulceration and found the risk of death to be ninefold the risk of amputation, with chronic kidney disease and cardiovascular disease the strongest determinants of poor outcomes (Vadiveloo et al, 2018). These findings concur with those of previous studies whereby the 5-year survival rate following presentation of a new episode of ulceration was found to be in the order of 50–60%, which is worse than many common cancers (Jeffcoate et al, 2018).

Primary prevention of DFUs is, therefore, pivotal in the management of patients with diabetes who are at high risk of foot ulceration to improve their long-term survival. For those with active diabetic foot ulcers, optimal wound management is key to facilitate wound healing and achieve rapid wound closure. However, DFUs are often hard to heal and can become complicated by infection, requiring hospitalisation and/or lower-limb amputation. Healing rates for DFUs remain poor; a cohort analysis conducted in the UK found that just 35% of DFUs healed within a 12-month period, taking on average 4.4 months to heal, 48% remained unhealed and 17% of DFU resulted in amputation (Guest et al, 2018). Poor healing rates in DFU are associated with the injurious effects of chronic hyperglycaemia on the vascular tree; macrovascular disease giving rise to peripheral arterial disease and microvascular changes causing peripheral neuropathy and an insensate foot that is at an elevated risk of trauma (McIntosh, 2017).

Optimum management of DFU is multifaceted and must include metabolic control, vascular control, management of infection, offloading strategies and effective wound management, in order to improve the healing of DFU. Improving the healing of DFU is imperative for improved patient outcomes, improved long-term survival and to maximise patient wellbeing (Jeffcoate et al, 2018).

The management of wound exudate in DFU is only one component of an overall wound management plan, nonetheless, effective management of wound exudate in DFU is crucial to facilitate healing and achieve wound closure. It is important, therefore, that clinicians involved in the management of DFU understand the role and function of wound exudate and, crucially, know when exudate can become detrimental to the healing process. This article provides an overview of wound exudate, its role and

Table 1. The role of exudate.
■ Maintenance of an optimum moist environment for healing.
■ Provide primary defence against invading microorganisms.
■ Rich in growth factors for tissue repair and regeneration.
■ Facilitate cellular migration of key cells including macrophages and epithelial cells.
■ Provide nutrients for cell metabolism.

constituents and outlines current best practice in managing exudate in DFUs.

The nature and role of wound exudate

Wound healing is a dynamic process that can generally be divided into three sequential and overlapping phases of tissue repair; inflammation, proliferation and regeneration (Gethin, 2012).

Wound exudate is derived from fluid that has leaked from blood vessels in the inflammatory stage of healing and closely resembles blood plasma (World Union of Wound Healing Societies [WUWHS], 2007).

Wound exudate is an essential component of the wound healing process. It contains key components for clotting in the acute stage of healing, namely fibrin and platelets, lymphocytes and macrophages for immune defence. It also includes water, nutrients, inflammatory mediators, electrolytes, leukocytes, proteases, growth factors and waste products as the wound progresses through the various stages of healing (WUWHS, 2007). These constituents and substances play an important physiological role in tissue repair as outlined in *Table 1*. The quantities of individual components of exudate vary between individuals and throughout the lifespan of the wound, depending on the stage of healing (Fletcher, 2003).

Acute wound fluid

In an acute wound, it is well recognised that the initial injury initiates an inflammatory process whereby inflammatory mediators (e.g. histamine) increase capillary permeability and blood vessels leak increased fluid. This excess fluid enters the wound and forms the basis of wound exudate (WUWHS, 2007). The role of wound fluid is multiple in the acute phase of wound healing (*Table 1*). Acute wound fluid plays an important role in the primary defence against infection. Acute wound fluid is rich in leukocytes and proteases; cells that play an important role in separating slough and necrotic tissue from the wound bed through autolysis (Beldon, 2016). In a healing wound, the volume of wound exudate generally reduces over time as the wound progresses through the various stages of wound healing (White and Cutting, 2006). However, in non-healing wounds, exudate production may continue or become excessive due to a chronic inflammatory state or other physiological processes (WUWHS, 2007).

Chronic wound fluid

DFUs are complex in aetiology and difficult to heal. Inflammation is a prerequisite to healing, however, the healing of DFUs is often dysregulated, with many wounds 'stuck' in a non-healing inflammatory state (Gethin, 2012; Speak, 2014). Chronic wounds exhibit a prolonged inflammatory response, which can provide an ideal environment for bacterial infiltration and proliferation. It is, therefore, important for clinicians to be aware that the constituents of chronic wound fluid differ somewhat to that of the acute wound. In chronic wounds, there appears to be an imbalance between the degradative substances, such as metalloproteinases (MMPs) and tissue inhibitors of MMPS. Resultantly, chronic wounds have high levels of MMPs that can degrade and break down proteins, and have an inhibitory effect on growth factor activity (Fletcher, 2003).

Furthermore, healing wounds produce exudate containing active growth factors, which are not present in the exudate of chronic wounds (White and Cutting, 2006). In DFUs, infection is a major contributor to impaired wound healing. Immunopathy in diabetes causes decreased function of white blood cells, specifically macrophages and neutrophils. These cells play an important role in the early phases of wound healing and in immune defence. Infection, therefore, is a major contributor to non-healing in DFU and can spread rapidly in the diabetic foot, causing limb-threatening cellulitis, abscesses and osteomyelitis (McIntosh, 2017).

Key words
- Diabetic foot
- Foot ulcer
- Wound exudate
- Wound management

Table 2. Physiological conditions that lead to excessive wound exudate (adapted from Beldon, 2016).

Physiological condition	Outcome
Lymphoedema	Any condition that increases capillary leakage and gives rise to tissue oedema can increase exudate production.
Venous hypertension	Venous hypertension can give rise to chronic venous leg ulcers.
Congestive cardiac failure, hepatic and/ or renal failure	Can cause oedema of the lower limbs and highly exuding leg ulcers.
Obesity	Can cause venous hypertension, which can give rise to chronic venous leg ulcers.
Malnutrition	High exudate volume can be associated with hypoalbuminaemic oedema linked to malnutrition.
Infection	The presence of infection often leads to increased exudate production.

Volume of exudate

If the volume of exudate becomes excessive, there is risk of periwound maceration and excoriation of the surrounding skin, which can result in deterioration of the wound (Beldon, 2016). This can complicate the healing process and lead to adverse patient outcomes. A holistic approach to patient assessment is essential to identify any comorbidities and physiological conditions that might contribute to their overall health. Physiological factors that give rise to increased exudate production are detailed within *Table 2*. Exudate volume can also give an indication of a changing wound status; an altered inflammatory response coupled with the effects of the presence of bacteria in chronic wounds can give rise to increased vascular permeability and extravasated fluid (Speak, 2014).

In DFUs, peripheral neuropathy and peripheral arterial disease can mask the signs and symptoms of infection. Indeed, up to 50% of patients do not present with the classic signs of infection (heat, erythema, pain and swelling) (WUWHS, 2016). Clinicians involved in managing DFU should look for more subtle signs of infection, including increased exudate, malodour, friable or dull granulation tissue and undermining wound edges (McIntosh, 2017).

Failure to manage high volumes of exudate in patients with DFU can lead to adverse clinical and patient outcomes, including increased risk of infection and a reduced quality of life due to leaking, discomfort and malodour (Speak, 2014). While low exudate production in DFUs is associated with peripheral arterial disease, microangiopathy and ischaemic foot ulcers or indicative of a systemic problem, such as dehydration (WUWHS, 2007). In ischaemic DFUs, it is vital to keep necrotic tissue dry to prevent infection and allow for auto-debridement (WUWHS, 2016).

Assessing wound exudate

According to Beldon (2016) wound exudate is a good indicator of the state of the wound. Therefore, exudate assessment should be integrated into every wound assessment, at every patient visit, with the aim of identifying any factors that might impact on healing (Speak, 2014). Any changes to consistency, colour, volume, viscosity or smell should act as a red flag and trigger a reassessment of the wound. It is important to discuss the appearance of and any changes to exudate with the patient. *Table 3* provides an outline of the types of exudate, colours, consistency and odour, and their clinical indications.

Exudate and infection in the diabetic foot

Infection in the diabetic foot is associated with significant morbidity and mortality. In the presence of diabetes, infection can spread rapidly

Table 3. Categorising Wound Exudate (adapted from White and Cutting 2006; WUWHS, 2007).	
Type of wound exudate	
Serous exudate	Serous, clear, straw-coloured exudate is considered as 'normal' exudate, however, may be associated with infection with fibrinolysin-producing bacteria, including *Staphylococcus aureus*
Sanguinous	Thin red-coloured exudate that may indicate bleeding within the wound bed.
Serosanguinous exudate	Clear, thin exudate. Considered normal.
Haemorrhagic exudate	Thick, red exudate. Indicative of infection or trauma.
Purulent exudate	Indicative of infection, contains leukocytes and bacteria.
Fibrinous exudate	Contains fibrin and protein strands.
Colour	
Clear/amber	Clear/straw-coloured exudate is considered as 'normal' exudate.
Cloudy, milky	May indicate the presence of fibrin strands due to inflammation or infection.
Pink or red	Due to the presence of erythrocytes in the wound fluid and indicates capillary damage.
Green	May be indicative of bacterial infection, for instance, *Pseudomonas aeruginosa*.
Yellow or brown	May be due to the presence of slough or associated with the use of iodine-containing products or dressings.
Grey or blue	May be related to the use of silver containing products or dressings.
Exudate consistency	
High viscosity (thick)	High protein content due to: - Infection - Inflammation - Necrotic tissue
Low viscosity (thin)	Low protein content due to: - Concomitant disease (venous disease, congestive cardiac disease) - Malnutrition
Odour	
Malodour	Unpleasant odour can be due to: - Bacterial growth or infection - Necrotic tissue NB. The interaction of some wound dressings e.g. hydrocolloids can produce a characteristic wound odour.

to deeper structures, including the underlying bone causing osteomyelitis, limb- and life-threatening infections. Prompt identification, rapid diagnosis, timely referral for specialist review and appropriate management strategies are all vital steps in the quest to minimise the adverse outcomes associated with diabetic foot (McIntosh and O'Loughlin, 2016). Criteria for identifying infection in the diabetic foot include; local swelling or induration, erythema, local tenderness or pain, purulent exudate, pus/abscess, increased volume of exudate (serous exudate with inflammation; seropurulent; haemopurulent) and wound malodour (European Wound Management Association, 2006; Lipsky et al, 2012).

When a holistic assessment of the patient and local assessment of the wound suggests that infection is the likely causative factor of excess exudate then rapid initiation of antimicrobial therapy is vital to minimise adverse patient outcomes, including limb-threatening and life-threatening infection and amputation (Speak, 2014; McIntosh and O'Loughlin, 2016).

Managing exudate in DFU

Comprehensive assessment and timely and appropriate intervention are essential for the successful management of wound exudate and to facilitate improved wound healing in DFU (Beldon, 2016). The ultimate goal is to achieve moisture balance to maximise the positive effects of exudate on the healing process, while minimising the detrimental effects associated with excessive wound exudate (WUWHS, 2007). Clinicians should consider the wound characteristics and the needs of the patient when selecting appropriate exudate management options (Speak, 2014).

Regular debridement is an important component of DFU management. Regular debridement facilitates the removal of dead, devitalised or infected tissues thus reducing infection risk by decreasing the bacterial burden within the wound. Furthermore, regular debridement facilitates the drainage of wound exudate (McIntosh, 2017).

Wound dressings for DFU

There is a plethora of wound dressings available for the management of DFU. Yet, despite their widespread use, there is a paucity of high-quality evidence available to support the use of any one dressing over another in the management of DFU. A recent Cochrane review summarised the evidence for the effectiveness of wound dressings for the healing of DFU. Data were derived from 13 systematic reviews, which included 17 clinical trials (Wu et al, 2015). The authors concluded there is currently no robust evidence for differences between wound dressings for any outcome in foot ulcers in people with diabetes. In the absence of a strong evidence base, dressing selection should be suited to the patients' needs and wound characteristics, unit cost and patient preference (Wu et al, 2015).

In highly exuding DFUs the aims of dressing include managing the high volume of exudate, achieving moisture balance and prevent periwound maceration/excoriation (WUWHS, 2017). Frequency of wound dressing change is important in achieving these goals. Superabsorbent dressings are designed to absorb high volumes of wound exudate, hold and lock the fluid into the structure of the dressing, which may reduce the need for frequent dressing changes (Beldon, 2016). However, as infection is a likely cause in highly exuding DFU, regular inspection of the wound is crucial as infection can spread rapidly in the diabetic foot.

Furthermore, dressings laden with exudate can increase pressure on the wound, can become malodorous and lead to maceration and further tissue breakdown (Ousey et al, 2013). When selecting a wound dressing for the management of highly exuding DFU, the chosen product must be able to cope with the high volume of exudate and withstand weight-bearing forces on the foot while being accommodated within any offloading device (WUWHS, 2016). Effective offloading is essential to facilitate the healing of DFU. Choice of modality will depend on a number of patient and wound-related factors, including concordance, mobility levels and the presence/absence of infection.

Negative pressure wound therapy (NPWT) may be beneficial for highly exuding DFUs. NPWT devices apply sub-atmospheric pressure to open wounds to promote wound healing by removing excessive exudate from the wound and

promoting tissue regeneration (Liu et al, 2017). A systematic review and metaanalysis of NPWT for patients with DFU found that when compared with standard dressing changes, NPWT had a higher rate of complete healing of ulcers, shorter healing time, greater reduction in ulcer area, greater reduction in ulcer depth and fewer amputations (Liu et al, 2016).

In a wound with low exudate levels, that contains slough, dressings should be selected with the aim of increasing wound moisture to aid autolysis and achieve moisture balance. In the case of black, dry, necrotic toes due to ischaemia, the primary goal is to keep the toe dry, prevent infection and protect adjoining or adjacent issues (WUWHS, 2016).

In infected DFUs, an antimicrobial regimen may involve direct application of a topical antimicrobial or dressings impregnated with antimicrobial agents. While there is a distinct lack of robust evidence to support any one type of topical antimicrobial dressings over another for the management of DFUs, their use, nonetheless, may prove beneficial in the management of superficial wound infection, exudate and odour management. The use of topical antimicrobials on uninfected DFUs is debatable. However, because infection can spread rapidly in the diabetic foot and the signs of infection are frequently masked, clinicians may apply a lower threshold for treating bioburden in DFUs than in other wound types (WUWHS, 2016).

Wound-related factors

Failure to effectively manage high volumes of wound exudate can result in several wound-related problems, including (WUWHS, 2007):

- Leakage and soiling
- Excoriation
- Maceration
- Periwound skin changes
- Discomfort/pain
- Odour
- Infection
- Delayed healing
- Protein loss/fluid/electrolyte imbalances
- Delayed autolysis.

Patient-related factors

The consequences for the person living with a highly exuding and/or malodorous DFU are far reaching and can lead to significant personal distress and social isolation (WUWHS, 2016). Malodour, in particular, may be a cause of embarrassment and psychosocial distress. Wound odour may be caused by a range of factors, including the presence of necrotic tissue, infection, a high bacterial burden, high levels of exudate and, in some cases, poor wound management (Gethin et al, 2015).

It is important that clinicians work with individuals living with DFU to identify and address their concerns, engender concordance through empowerment and choice while implementing an effective wound management plan through shared decision making with the patient (International Consensus, 2012). Patient-focused, personalised care planning is key to identifying and establishing issues that significantly impact the patient, addressing their fears and concerns and achieving better patient and clinical outcomes in DFU management (WUWHS, 2016).

Wound diagnostics and future advances?

Several biomarkers, including those present in wound exudate, could form the basis of potential diagnostic tools for use in the management of DFU in terms of predicting prognosis and outcomes. However, considerable research is required before any such diagnostic tool can be fully developed (WUWHS, 2008). Further research is necessary to characterise the relationships between potential biomarkers in wound fluid, for instance, further analysis of their activities and interaction between markers, such as wound PH, enzyme activity, growth factors and inflammatory mediators is warranted (WUWHS, 2008).

López et al (2014) attempted to characterise the cell populations present in wound exudate, to examine the validity of these populations in identifying the wound phase to find possible predictors of healing, and to anticipate events in favour of a more rapid recovery. They found that platelets and neutrophils in wound exudate might be useful prognostic indicators of the inflammatory or proliferative phase and concluded that elevated levels of

neutrophils and platelets in wound exudates may serve as a predictor of progression to the inflammatory phase.

Further research is needed to further clarify and understand the role of exudate and its various constituents, which may help in the development of future novel approaches to wound diagnostics.

Conclusion

Effective management of wound exudate in DFUs is a critical component of an overall wound management plan, which should aim to optimise the wound bed, prevent and treat exudate-related problems, enhance quality of life and improve patient wellbeing. Exudate assessment should, therefore, be integrated into every wound assessment so that timely and appropriate intervention can be instigated. Clinicians should consider the wound characteristics and the needs of the patient when selecting appropriate exudate management options to facilitate the successful management of wound exudate and to facilitate improved healing in DFUs. ■

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1. Which single ADDITIONAL risk factor is MOST likely to worsen the increased mortality rate and poor outcomes associated with having a diabetic foot ulcer? Select ONE option only.

   A. Chronic liver disease
   B. Chronic kidney disease
   C. Chronic obstructive pulmonary disease
   D. Peripheral neuropathy
   E. Retinopathy

2. According to Jeffcote et al (2018), what is the ESTIMATED five-year survival rate (per cent) following presentation with a new episode of a diabetic foot ulcer? Select ONE option only.

   A. 10
   B. 25
   C. 33
   D. 50
   E. 66

3. Which ONE of the following, if present within wound exudate, MOST significantly contributes to the poor healing of diabetic foot ulcers? Select ONE option only.

   A. High leukocyte count
   B. High protease levels
   C. High macrophage count
   D. Low growth factor levels
   E. Low metalloproteinase levels

4. A 47-year-old woman with a chronic diabetic foot ulcer attends for a dressing change.

   Which ONE of the following signs is MOST likely to suggest an infected wound? Select ONE option only.

   A. Bright granulation tissue
   B. Clear, demarcated wound edges
   C. Increased exudate
   D. Lack of pain
   E. Lack of slough

5. A 73-year-old man has a diabetic foot ulcer, which has been difficult to treat due to excessive wound exudate. He is systemically well and afebrile with no signs of infection. A wound swab is negative.

   Which ONE of the following conditions is the MOST likely underlying cause? Select ONE option only.

   A. Ischaemic heart disease
   B. Non-alcohol fatty liver disease
   C. Osteomyelitis
   D. Peripheral arterial disease
   E. Venous hypertension

6. A 61-year-old woman developed a diabetic foot ulcer 3 weeks ago. At each dressing change, there has been very little evidence of wound exudate.

   Which ONE of the following conditions is the MOST likely underlying cause? Select ONE option only.

   A. Chronic renal failure
   B. Congestive cardiac failure
   C. Morbid obesity
   D. Osteomyelitis
   E. Peripheral arterial disease

7. Which ONE of the following descriptions of a wound exudate would be considered a NORMAL finding in diabetic foot ulcers? Select ONE option only.

   A. Green
   B. Haemorrhagic
   C. High viscosity
   D. Milky
   E. Serosanguinous

8. According to a 2015 Cochrane review, which ONE of the following wound dressings, if any, has clear evidence to support its first-line use in diabetic foot ulceration? Select ONE option only.

   A. Antimicrobial
   B. Iodine-impregnated
   C. Silver-containing
   D. Superabsorbent
   E. No clear evidence

9. A 56-year-old male smoker has type 2 diabetes, peripheral arterial disease, CKD3 and a chronic diabetic foot ulcer. The dorsal foot wound is dry with some necrotic tissue, but there is no evidence of infection.

   Which is the SINGLE MOST appropriate INITIAL management to PREVENT infection in this situation? Select ONE option only.

   A. Frequent emollient use
   B. Negative pressure wound therapy
   C. Offloading
   D. Regular debridement
   E. Stopping smoking

10. According to Lopez et al (2014), ELEVATED levels of which ONE of the following cell populations, if present in elevated levels in wound exudate at an early stage, is associated with useful prognostic indicators? Select ONE option only.

    A. Eosinophils
    B. Granulocytes
    C. Lymphocytes
    D. Macrophages
    E. Platelets