Assessment, management and prevention of infected wounds

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For the patient, wound infection can lead to poor healing outcomes and has the potential to result in life-threatening sepsis. For healthcare services, additional expense can be incurred due to the need for remedial treatment and extra clinician time. Poor wound infection rates also attract negative publicity and damage the public’s perception of care standards. This article examines the essential roles played by prevention of infection, early diagnosis and the initiation of effective management strategies.

KEYWORDS:
Wound bioburden  Antimicrobial dressings  Infection risk factors

Contamination of a wound with organisms is inevitable and clinicians should recognise that no wound is truly sterile (Bowler, 2002). Despite this, the majority of wounds do heal (Gilchrist and Reid, 1989). However, in some cases wound contamination can progress to infection, which negatively impacts on healing and may pose a significant risk of systemic disruption or life-threatening sepsis unless adequately controlled. Such infections also increase healthcare expenditure due to the cost of treatment and the rise in the number of patients needing hospitalisation (Cook and Ousey, 2011).

The relationship between the patient (the host) and the microorganisms present in the wound (the wound bioburden) is dynamic — it is dependent on the numbers of bacteria present, the ability of the organisms to instigate a negative effect on the host (virulence), and the ability of the host to mount an effective defensive response (Heggies et al, 1992; Mertz and Ovington, 1993 Rumbaugh et al, 1999; Bowler, 2002).

There is no universal definitive volume of bioburden at which an infection can be said to occur, although a bacterial count of $10^5$ colony forming units per gram of tissue is considered sufficient to impede healing in most cases (Robson, 1997; Heggies, 1998).

While some organisms have little effect on the body — meaning that high concentrations are required to elicit changes in the local wound environment or produce systemic signs and symptoms — other organisms, such as haemolytic streptococci, are virulent, and can have a marked detrimental effect, even at low numbers (Robson et al, 1990).

In addition, pathogens work synergistically to develop an environment within the wound in which proliferation is more likely to occur (Bowler, 2003). From very low numbers of bacteria (contamination), the absence of adequate host defences will enable bacteria to multiply (colonisation) until they impact on the wound healing process (critical colonisation).

Eventually, if unchecked, bacterial numbers will increase to induce a state of localised infection or widespread systemic infection. Kingsley (2001) describes this direct relationship between wound bioburden and the signs of infection as the wound infection continuum.

Biofilms

Biofilms are complex microbial communities containing bacteria. As the bacteria and microorganisms in a wound multiply they eventually become attached, synthesise and secrete a protective matrix of sugars and proteins (Wolcott et al, 2008).

Biofilms may comprise single bacterial species, or more commonly, multiple diverse species, which continuously change and adapt to the surrounding conditions.

The protective matrix enhances the tolerance of microorganisms embedded in the matrix to the immune system, antimicrobials and environmental stresses, making them difficult to eliminate (Flemming et al, 2007). This may account for many of the chronic low-grade infections seen clinically (Wolcott et al, 2008).

RISK FACTORS

In general terms, any pre-existing condition that impairs the vascular perfusion of the wound or reduces the individual’s ability to mount an effective immune response will increase the likelihood of infection (McIntosh, 2007; World Union of Wound Healing Societies [WUWHS], 2008).

The risk of infection in the acute wound is increased by contamination, the presence of...
debris (foreign material and non-viable tissue) and delays in seeking appropriate medical attention (WUWHS, 2008).

By their very nature, chronic wounds remain open for prolonged periods of time, offering bacteria the opportunity to contaminate the wound and multiply to levels at which they have a negative impact on healing. Many patients with chronic wounds have underlying conditions, such as diabetes, which make tissue repair problematic and affect the individual’s ability to mount an effective defence against bacterial attack. In addition, the presence of high bioburden may in itself slow the repair process (Penhallow, 2005).

DIAGNOSIS OF WOUND INFECTION

The diagnosis of wound infection is based on the presenting clinical signs and symptoms (Patel, 2010; Cook and Ousey, 2011). The classic signs are considered to be (Cutting and Harding, 1994):

- New or increasing wound pain
- Erythema
- Local warmth
- Swelling
- Purulent discharge.

There may also be wound malodour and pyrexia (WUWHS, 2008). If infection spreads and systemic infection is present, pyrexia becomes more common and erythema may spread from the immediate wound area, tracking towards the proximal lymph nodes in particular. These, in turn, may become swollen (lymphangitis). An increase in wound size, wound breakdown and/or dehiscence is also likely to occur (WUWHS, 2008).

In chronic wounds, the presence of infection may be less obvious. Underlying conditions such as sensory neuropathy and altered immune-competence may mean that signs become muted or hidden, and systemic signs such as pyrexia may not be present until the infection is well-established (Ousey and McIntosh, 2009). As well as the more obvious signs, changes in wound odour, increased exudate volume and pain may all indicate localised infection.

Within the wound, tissues may become discoloured, more friable and likely to bleed and healing may be delayed or halted altogether. When granulation does occur, bridging (the formation of strands of granulation or epithelial tissue over non-healed tissue) and pocketing (non-healing tissue surrounded by active granulation) may be observed (European Wound Management Association [EWMA], 2006; WUWHS, 2008).

‘The diagnosis of wound infection is based on presenting signs and symptoms.’

While microbiological analysis (obtained from the culture of swab samples) is a useful tool in investigating the likely causative organism — and is an essential part of the clinician’s armoury in effectively managing infected wounds — it has its limitations. Cultures of any swab are likely to reveal a number of bacterial species, but whether these are responsible for the infection or are simply surface-colonising organisms is debatable (Gilchrist, 1996).

Although wound swabbing is the commonest investigation, it is not without error and care must be taken in interpreting its findings. If infection is suspected (by clinical signs in acute and chronic wounds and/or when chronic wound healing has stalled despite appropriate treatment), swabs should be taken after wound cleansing and removal of non-viable tissue (WUWHS, 2008). The sample should be sent to the laboratory accompanied by a full patient and wound history to aid analysis (WUWHS, 2008).

Despite the prevalence of swabbing, wound biopsy is a far more accurate method of determining infection status, but is rarely available in the general community setting (Dowsett et al, 2004). For patients displaying overt systemic signs of spreading infection, blood cultures should be obtained and urgent expert assistance sought (WUWHS, 2008).

PREVENTING INFECTION AND MANAGING INFECTED WOUNDS

Optimising the host reaction is a key component in the prevention and management of infection (WUWHS, 2008), and thus it is essential that the patient’s nutritional and hydration status is maintained.

Management of incontinence will help prevent contamination of the wound and any dressings with faecal debris — particularly significant when the wound is in the pelvic region or on the leg.

For patients with diabetes, the importance of tight glycaemic control should be explained and, if required, blood sugar levels should be monitored more frequently. This is particularly significant if infection is present, as blood sugar levels may become unstable.

Tissue oxygenation and vascular perfusion should be optimised (WUWHS, 2008), and to encourage blood flow patients with known vascular disease should be advised to exercise (within the limits of their condition). Where dependent oedema is present, elevation of the affected limb will reduce venous congestion and assist local perfusion by dispersing extracellular fluid.

Respiratory function and, therefore, tissue oxygenation can be improved by even moderate exercise and postural improvement, and patients that smoke should be given advice and support to reduce or stop.

LOCAL WOUND MEASURES

Steps should be taken to reduce contamination of the wound. Adhering to universal precautions when dressing the wound prevents inoculation with potential pathogens and, if infection has
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become established, helps to reduce the risk of microorganisms spreading to other patients. In the community, the patient and their informal carers will need to be trained, as many will have an active role in managing the wound.

Leakage of exudate through the dressing (strikethrough) provides a portal for the ingress of pathogens into the wound (Thomas, 2010; White, 2011). Clinicians should select dressings that are able to cope with elevated volumes of exudate and the frequency of dressing change should be increased (White, 2011). If soiling of the outer structure of the dressing has occurred, the dressing should be replaced.

Necrosis
The presence of necrotic material within the wound provides a nutrient–rich base for bacterial proliferation (EWMA, 2006; WUWHS, 2008) and a barrier to topical antimicrobials and antibiotics (Weir et al, 2011). This, therefore, should be debrided (WUWHS, 2008).

Similarly, the presence of high volumes of bacteria-rich exudate provides an environment for proliferation (Adderley, 2010). Wounds should be drained of this fluid to reduce bacterial numbers (WUWHS, 2008). Although it is recognised that wound bed cleansing is unnecessary at each dressing change, the exception is the infected wound, where cleansing at dressing change may be beneficial (Cutting, 2010). This also offers the opportunity for gentle debridement of the wound bed, which, through its mechanical action, reduces necrotic burden within the wound and may disrupt biofilms.

**REDUCING BIOBURDEN**
Reduction in wound bioburden is a key element in the management of the colonised or infected wound.

This is an excellent article highlighting the clinical challenges faced by community nurses in the assessment and prevention of wound infection. It clearly demonstrates the complexities of wound management while outlining the multiple levels of knowledge and clinical judgement required to prevent and treat wound infection in clinical practice.

Changing demographics and the increased likelihood of patients presenting with comorbidities can negatively influence the natural healing process. From a clinical perspective, the section on dressings offers practical information to enable effective decision-making.

The article emphasises the need for clinicians to recognise the difference between acute and chronic infection. It is essential that community nurses are able to interpret wound bed changes accurately. This knowledge will determine the need for swab collection if infection is suspected.

In my experience, the fact that wound swabs need collecting post-cleansing should be emphasised. Also, the importance of providing a detailed history on the request form ensures that pertinent information, including symptoms and current medication, will be routinely reported. This allows lab technicians to perform informed microculture and sensitivity lab testing.

This article is clear, concise and provides an excellent reference for community nurses attempting to minimise wound infection and promote healing in their practice.

Guidelines on the management of wound infection (EWMA, 2006; WUWHS, 2008) have suggested that topical antimicrobial dressings may be useful in reducing wound bioburden. Some have active agents that disrupt bacterial proliferation or are toxic to cells, whereas others contain substances that bind bacteria to the dressing.

In addition, the structure and function of some dressings’ base materials means that they are able to effectively manage the negative sequelae of wound infection (White, 2011). For example, absorbent agents such as alginates, hydrofibres and foam-based dressings can help to reduce exudate volume, while offensive odours may be neutralised by charcoal-based products (Williams, 2001).

Products based on the antimicrobial agents iodine, silver, honey and latterly polyhexamethylene biguanide (PHMB) are considered by many to be the first line of treatment in the management of bioburden, particularly in chronic wound care, as they have the following benefits:

- Provide a high antimicrobial concentration at the site of infection (White et al, 2001; Cooper, 2004)
- Have bactericidal effects against multiresistant organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA) (Lawrence, 1998; Sibbald et al, 2001)
- Do not interfere with the protective bacterial flora in other parts of the body
- Are less likely to produce an allergic reaction.

**Silver**
Silver-based products have been particularly successful in burns (Klasen, 2000a; Klasen, 2000b; Demling and DeSanti, 2001), and as an antimicrobial in general wound care (Armstrong, 2002; Clarke, 2003) with skin discouloration (argyria) being the only visible side-effect (Wright et al, 1998).

Silver ions are highly reactive and affect multiple sites within bacterial cells, ultimately causing...
bacterial cell death. They bind to bacterial cell membranes, causing disruption of the bacterial cell wall and cell leakage. Once transported into the cell, silver ions interrupt the cell’s function by binding to proteins and interfering with energy production, enzyme function and cell replication (Lansdown, 2002; Hermans, 2007).

Silver ions are active against a broad range of bacteria, fungi and viruses, including many antibiotic-resistant bacteria, such as MRSA and vancomycin-resistant Enterococci (VRE) (Parsons et al., 2005). Studies have suggested that silver may reduce bacterial adhesion and destabilise the biofilm matrix (Chaw et al., 2005), as well as killing bacteria within the matrix. Silver dressings represent one in seven of all wound dressing prescriptions in the UK (Iheanacho, 2010).

**Iodine**

Iodine-based products have been used in wound care for many years. Exposure of bacteria to iodine causes changes in cells’ walls, membranes and cytoplasm, resulting in rapid death (Gottardi, 1983) through leakage of cellular materials (Schreier et al., 1997).

Povidone-iodine is not as effective as some other biocides in eradicating *Staphylococcus epidermidis* within *in-vitro* biofilms (Presterl et al., 2007), but cadexomer iodine provides enough iodine for biofilm suppression while not causing significant host damage (Akiyama et al., 2004; Rhoads et al., 2008).

**Honey**

The antibacterial action of honey is due to its high osmolarity, which inhibits microbial growth (Molan, 2001), and the action of intrinsic enzymes, which release hydrogen peroxide into the wound (Molan and Betts, 2004). Some honeys, particularly the manuka honeys, have been found to retain their bactericidal properties even without the presence of hydrogen peroxide, and are effective against both antibiotic-sensitive and antibiotic-resistant organisms (Cooper et al., 2002a; 2002b).

**PHMB**

Although the use of PHMB is widespread in German-speaking Europe and the US, these dressings are a relatively new development in the UK’s wound management armoury. PHMB is a fast-acting biguanide compound composed of a synthetic mixture of polymers. It has a broad spectrum of activity against bacteria, viruses and fungi, inducing cell death by disrupting cell membrane integrity (Moore and Gray, 2007).

However, PHMB does not interfere with the proteins that make up animal cell membranes and has an effect on both planktonic bacteria and those in biofilms (Seipp et al., 2005; Pietsch and Kraft, 2006; Harbs and Siebert, 2007). A significant body of evidence is now emerging to support PHMB’s use in the management and eradication of wound bioburden (Butcher, 2012).

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**Dialkyl carbamoyl chloride**

An alternative approach to bioburden management is offered by products containing dialkyl carbamoyl chloride (DACC) technology. DACC is a fatty acid derivative, which is applied to dressing materials during manufacture. It provides the dressing with strongly hydrophobic properties — bacteria become irreversibly bound to the wound dressing itself, preventing them from proliferating or releasing harmful exotoxins. At each dressing change inert bacteria are removed from the wound bed along with the dressing product, thus reducing the bacterial load (Cutting and Butcher, 2011).

**CONCERNS REGARDING TOPICAL ANTIMICROBIAL DRESSINGS**

Recently, concern has been raised regarding the cost and cost-effectiveness of topical antimicrobial dressings (Bergin and Wraith, 2006; Chaby et al., 2007; Michaels et al., 2009), and their safety in respect to the systemic absorption of antimicrobial elements and potential for systemic toxicity (Wan et al., 1991; Parsons et al., 2005; Burd et al., 2007; Denyer, 2009; Wang et al., 2009).

The results of studies such as the VULCAN trial (Michaels, 2009), which appear to indicate that silver-based antimicrobial products are not cost-effective, have added to this controversy, although alleged methodological flaws in this particular study have led to widespread criticism of its recommendations (Calderon et al., 2007; Gottrup and Apelqvist, 2010; Loaper and Drake, 2010; White et al., 2010).

To date, however, there has been no conclusive evidence that, when used appropriately, topical antimicrobial dressings pose a significant risk. Thus, to aid clinicians a number of recommendations for safe use have been developed (Bowler et al., 2001; EWMA, 2006; Best Practice Statement, 2011; International Consensus, 2012).

Most importantly, antimicrobial use should be targeted to those at most risk or in whom wound infection has been diagnosed. Treatment should also be measured and time-limited — widespread, inappropriate use increases healthcare costs with no outcome gain.

Once initiated, if the signs of infection subside and the patient shows no signs of systemic infection, the antimicrobial agent may be discontinued. If the wound continues to show signs of infection, a systemic antibiotic should be considered (EWMA, 2006). Similarly, a lack of a noticeable healing response within two weeks may necessitate the use of other topical or systemic agents (Bowler et al., 2001; Best Practice Statement, 2011).

The prophylactic use of antimicrobial preparations is
Antibiotics: are problems with the use of species or strains. However, there needed to treat particular bacteria with particular antibiotics being narrow band of effectiveness, (Sabundayo, 2007). Most have a growth processes (Calderon and Costerton and Stewart, 2001). Resistance to antibiotics has become a serious problem for those involved in wound care (White et al, 2001). Easterbrook (1998) suggested that widespread and often indiscriminate use of antibiotics is a major factor in the emergence of drug-resistant bacteria.

This means antibiotics can enable the resistant species to proliferate and dominate the wound micro-flora (Huovinen et al, 1994). Resistance to antibiotics has become a serious problem for those involved in wound care (White et al, 2001). Easterbrook (1998) suggested that widespread and often indiscriminate use of antibiotics is a major factor in the emergence of drug-resistant bacteria.

The use of antibiotics can select for resistant bacterial strains as antibiotics eliminate species that are sensitive to their specific action, while leaving unaffected those in which genetic modification has enabled the evolution of defence mechanisms. This means antibiotics can enable the resistant species to proliferate and dominate the wound micro-flora (Huovinen et al, 1994). Resistance to antibiotics has become a serious problem for those involved in wound care (White et al, 2001). Easterbrook (1998) suggested that widespread and often indiscriminate use of antibiotics is a major factor in the emergence of drug-resistant bacteria.

The emergence of bacterial resistance has reduced the treatment options for many systemic infections. It is, therefore, important that new antibiotic options are developed if the medical world is to have new weapons to treat disease. Currently, there are no new antibiotic preparations in development and no new products on the horizon. This is, therefore, a potential time-bomb in emerging nations and the developed world.

Systemic antibiotics have limited effect on biofilm colonies (Moss et al, 1990; Marr et al, 1997; Costerton and Stewart, 2001).

Thus, due to the limited efficacy of systemic antibiotics and the need to reserve them for serious infections they are not recommended for wounds that only show signs of local infection (Bowler et al, 2001). In addition, topical antibiotics are linked to the development of bacterial resistance and can provoke delayed hypersensitivity reactions (Zaki et al, 1994), and so are neither recommended nor have a role in the management of chronic wounds (WUWHS, 2008).

CONCLUSION

Wound infection occurs when...
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the body is unable to mount a sufficiently robust defence to control the burden of bacteria within a wound or when defence mechanisms are overwhelmed by the numbers and virulence of the pathogens present.

While the clinician must accept that some degree of contamination of the wound with environmental microorganisms is inevitable, the escalation of this to a state of infection should be avoided. Identifying those factors which increase the likelihood of infection becoming a problem, taking preventative actions to control them, and maximising the patient’s natural defences, are all essential steps in preventing infection.

However, if infection occurs it is important that the clinician is able to identify the signs and symptoms and initiate speedy and appropriate treatment to control and reduce bacterial numbers and re-establish an equilibrium within the wound, which will support the repair process. Judicious use of topical antimicrobial wound dressings has proven to be an effective method of reducing bioburden, enabling clinicians to reserve the use of antibiotics just for those patients in greatest need.

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