The use of maggots in canine, feline and equine wound care

Användning av fluglarver i sårvård för hundar, katter och hästar

Cecilia Berglund

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Djursjukskötarprogrammet

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Contents

Abstract

Maggots' abilities to aid in treatment of infected and necrotic wounds have been known for centuries. Larval therapy (LT) was used frequently in human patients in the first half of the 20th century, but usage declined with the introduction of antibiotics. It regained popularity only recently due to the emergence of antibiotic resistance. In veterinary patients though, the treatment is still rare, and clinical studies are few and of poor quality. The objective of this veterinary nursing under-graduate project is to assemble relevant literature on larval therapy to form a theoretical foundation from which further steps towards clinical use of LT in companion animals can be taken. Currently, maggots are used in humans primarily to treat chronic ulcers not responding to conventional treatment. Indications for use in small animals include pressure ulcers and traumatic wounds. In horses LT is most commonly used to treat different diseases of the hoof. Findings indicate that maggots are effective in debridement and disinfection of wounds, as well as promoting granulation tissue formation. Maggots are also effective in treating wounds colonised with MRSA. Adverse effects are few and infrequent, with pain being the most commonly mentioned. In practice, sterile larvae are applied to the wound either freely or contained in a biobag. Dressings are adapted to enclose maggots, to be absorbent of heavy exudation while still allowing oxygen to reach the maggots and to protect the peri wound skin from wound exudate and larval excretions/secretions. For clinical use in the veterinary field, further research is required in several areas, including establishing number of maggots needed for safe yet efficient treatment and determining which patients are likely to benefit from the therapy. Problems to overcome related to veterinary nursing are likely to be difficulties in dressing wounds, prevention and identification of pain and overcoming issues with owner acceptance of therapy.

Introduction

With the increasing problem of antibiotic resistance in the veterinary field, any alternative treatment which may lead to less use of antibiotics deserves further research. Larval therapy can potentially not only reduce antibiotic use, but also effectively disinfect wounds already colonised with resistant bacteria. The fact that maggot secretory and excretory products are also said to enhance wound healing makes the therapy all the more interesting. Additionally, developing LT for use in dogs, cats and horses will add one more treatment method to utilise in non-healing wounds before resorting to the final treatment option, euthanasia.

Larval therapy – a historical perspective

Maggots' favourable effects in wounds have been recognised since the 16th century (Goldstein, 1931). According to Goldstein (1931), the idea of purposefully breeding maggots for use in wound care was born in early 20th century. Several military surgeons observed the beneficial effect maggots of the green blowfly *Lucilia sericata* had on wounds during World War I (Baer, 1931; Goldstein, 1931). Treating two soldiers with compound fractures and large flesh wounds filled with maggots led one surgeon to believe that maggots could be of use in the prevention and curing of infection (Baer, 1931). The soldiers had been lying on the battlefield for a week with no access to food or water, yet they presented no fever and no evidence of septicaemia, and underneath the maggots their wounds had begun to heal. Baer (1931) later performed the first experimental voluntary use of maggots in wound care, and went on to treat several cases of osteomyelitis successfully.

Larval therapy (UK), or maggot debridement therapy (US), gained popularity in human medicine and was frequently used in hospitals in the first half of the 20th century, but fell out of favour when antibiotics were introduced (Courtenay *et al.*, 2000). LT made a comeback in the 1980s with the increasing occurrence of antibiotic resistance and since then improved methods using sterile larvae have been developed (Beasley & Hirst, 2004). In work animals, maggots have been used in folk medicine in treating infected wounds caused by chafing work equipment (Dar *et al*., 2013). Early reports in literature include potential use in the buffalo (Iversen, 1996), and the successful treatment of wounds not responding to conventional treatment in a donkey (Bell & Thomas, 2001). The use of maggots in companion animal wound care is still rare, but as antibiotic resistance is an issue in veterinary medicine as well, larval therapy is a treatment option for dogs, cats and horses that is worthy of more attention (Jones & Wall, 2007).

Antibiotic resistance

Resistance has developed due to several factors, one of the most important being the use and misuse of antibiotics (Boothe, 2006; EWMA, 2006). Acquired antimicrobial resistance is a significant problem in veterinary medicine (Loeffler *et al.* 2009; Weese & van Dujikeren, 2009), as well as a health risk for personnel due to the risk of zoonotic transmission (O'Mahony *et al*., 2005; Loeffler *et al.* 2009; Weese & van Dujikeren, 2009).

Methicillin-resistant *Staphylococcus aureus* (MRSA) and Methicillin-resistant *Staphylococcus pseudintermedius* (MRSP) are resistant to a broad range of important antimicrobials including penicillins, cephalosporins and carbapenems (Weese & van Dujikeren, 2009). *S. aureus* is the most commonly occurring bacteria in human wounds (Bexfield *et al*., 2004; Bexfield *et al*., 2008). In 1961, less than two years after the introduction of methicillin, *S. aureus* first acquired resistance it (Bexfield *et al*., 2004). In Sweden, MRSA was first confirmed in animals by SVA, the National Veterinary Institute, in 2006 (SVA, 2012). Between 2006 and 2011, a total of 45 cases were verified at SVA; 18 dogs, 5 cats and 17 horses. In other countries, MRSA can be found in 0-4% of healthy dogs and cats, in 9% of hospitalised dogs and in 0-10,9% of horses in various populations (Weese & van Dujikeren, 2009). There is a high prevalence of MRSA carriage, 7,5-12,3%, in veterinary staff and among pet owners in the UK (Loeffler *et al.* 2009). *S. pseudintermedius* is a part of the normal microflora of dogs and cats (Weese & van Dujikeren, 2009). The first case of MRSP verified in Sweden was in a healthy dog, screening for MRSA in 2006 (SVA, 2012). In 2011, 60 cases were confirmed by SVA; 59 dogs and one cat. Since 2006, MRSP has only been verified in two horses in Sweden. Internationally, MRSP carriage is 2-30% in hospitalised cats and dogs compared to 1,5-4% in healthy populations (Weese & van Dujikeren, 2009). Although MRSP has been isolated from humans, Weese & van Dujikeren (2009) conclude that it is uncommon even in individuals with frequent animal contact, making it a less important zoonotic pathogen than MRSA.

To prevent further spread of antibiotic resistance strategies include appropriate use of antimicrobials (Boothe, 2006; SVA, 2012) Antibiotic use should be limited to treatment of systemic infections and directed towards susceptible organisms, confirmed by cultures (EWMA, 2006; Hollis, 2011). Further strategies include implementation of hygiene routines (Boothe, 2006; SVA, 2012) and decrease length of hospital stay (Boothe, 2006).

Management of infected wounds

It is important to understand the phases of wound healing to effectively manage wounds (Chivers, 2010; O'Dwyer, 2012). Wound healing can be divided into three phases: the inflammatory phase, the proliferative phase and the remodelling phase (Hosgood, 2006). Inflammation is important in the healing process (Guo & DiPietro, 2010; Hollis, 2011). In the inflammatory phase leucocytes migrate into the wound; neutrophils remove bacteria and debris from the wound by phagocytosis and monocytes become wound macrophages that debride necrotic tissue, reducing bacteria and organic debris (Hosgood, 2006; Hollis, 2011). Proteolytic enzymes break down proteins into a liquid form that can be easily digested by macrophages (Hollis, 2011). As macrophages increase in numbers, debridement begins, marking the transition into the proliferative phase (Hosgood, 2006). In the proliferative phase new capillaries, fibroblasts and fibrous connective tissue become granulation tissue, which protects the wound, provides a barrier to infection and provides a surface for epithelisation, according to Hosgood (2006). The article explains that wound contraction is also a part of the proliferative phase; the wound reduces in size in response to fibroblastic invasion and changes in the tension of the wound and surrounding tissue. Wound contraction continues until the wound edges meet and the remodelling phase is initiated; connective tissue is remodelled and collagen bundles are rearranged to form a scar, as described by Hosgood (2006).

The three phases are not always distinct; they can overlap as one phase leads on to the next (Chivers, 2012). If the wound is infected for instance, inflammation may be prolonged, making it difficult to determine the age of the wound (Hosgood, 2006; Guo & DiPietro, 2010). Failure in any phase will result in delayed healing, which if uncorrected will result in chronic non-healing wounds (O'Dwyer, 2012). Two of the most common factors resulting in delayed wound healing are infection (EWMA, 2006; Hosgood, 2006; Hollis, 2011; O'Dwyer, 2012) and necrotic tissue (O'Dwyer, 2012).

Infection inhibits all stages of wound healing (Hosgood, 2006); infected wounds always heal slower than non-infected wounds (O'Dwyer, 2012). Bacteria are the likely cause in most wound infections, but infection can also be caused by fungi, yeasts or viruses (Hollis, 2011). All wounds contain bacteria (EWMA, 2006; Hollis, 2011), but a wound is only acknowledged as infected when a reaction is initiated in the host (Hollis, 2011). Bacteria in infected wounds occur in the form of biofilms on the surface; a biofilm can act as a barrier preventing antibiotics from penetrating the wound (Guo & DiPietro, 2010; O'Dwyer, 2012). As biofilms mature, they become more resistant, possibly explaining why many chronic ulcers do not respond to antibiotic treatment (Guo & DiPietro, 2010). Aside from delayed wound healing, signs of infection include increased exudate with changed appearance, an unusual smell (Ramundo & Wells, 2000; Hollis, 2011), erythema, warmth and pain or tenderness (Ramundo & Wells, 2000).

Wound management strategies aim to accomplish wound healing rapidly by creating optimal healing conditions (EWMA, 2006). The wound is initially assessed; aetiology and level of contamination serve as indicators of required management and provide of a prognosis with expected length of treatment (Chivers, 2010; Hollis, 2011). To manage an infected wound, reduction of microbial load is of utmost importance (Ramundo & Wells, 2000; Hollis, 2011). Antibiotics alone will not achieve this, thus not removing the initial cause for infection (Hollis, 2011). Basic wound management techniques such as lavage and debridement are important in reducing bacterial load and thereby preventing establishment of biofilms (Hosgood, 2006; Hollis, 2011; O'Dwyer, 2012). Topical antimicrobials, including honey, iodine, silver and clorhexidine, can also be used to reduce bioburden (EWMA, 2006). The European Wound Management Association, EWMA (2006), recommends that antimicrobial agents must be used with caution to remain effective, as resistance to topical agents such as silver and iodine has been reported. EWMA (2006) recognises larval therapy as an alternative method of reducing microbial load that is not susceptible to resistance.

Debridement, removal of necrotic tissue, is thought to be one of the most important steps in wound management (Ramundo & Wells, 2000; Wolff & Hansson, 2003); especially in treatment of chronic wounds (Wollina *et al*., 2002). Debridement can be surgical, chemical or autolytic (Ramundo &

Wells, 2000; Chivers, 2010). In autolytic debridement, the wound is rehydrated using special dressing materials (Ramundo & Wells, 2000). Although the most selective method, it is slow and sometimes insufficient (Wolff & Hansson, 2003). Surgical debridement is faster and more effective, but painful and less selective as healthy tissue can be mistakenly resected (Ramundo & Wells, 2000; Wolff & Hansson, 2003). Chemical, or enzymatic, debridement is slower than surgical, but involves less pain and no loss of viable tissue (Ramundo & Wells, 2000). The use of maggots rates as chemical debridement, but is often referred to as biological debridement or biosurgery according to Ramundo & Wells (2000). The debridement process should be initiated by a physician, but the procedures, with the exception of surgical debridement, are generally performed by nurses (Ramundo & Wells, 2000; Chivers, 2010). Regardless of therapy chosen, the wound must be continuously reassessed, and the strategies reevaluated if the wound does not change for the better (EWMA, 2006). When bioburden has been reduced, healing becomes the goal of wound care (Ramundo & Wells, 2000).

Objective

The objective of this undergraduate examination project is to review the scientific evidence for larval therapy, to determine its potential usefulness in veterinary wound care, by answering the following questions:

Is LT an appropriate treatment method for companion animals?
Which mechanisms make maggots of beneficial in wound care?
How is LT carried out in practice?
Which veterinary nursing aspects are there of treating patients with LT?

The information will be assembled into a comprehensive student report that will hopefully raise interest in the use of maggots in companion animal wound care, as well as describe the basics of larval therapy for those interested in practicing it clinically.

Materials and method

This literature study was performed by searching for literature using different combinations of the search words maggot, larvae, *Lucilia sericata,* nursing, debridement, treatment, therapy, wound, healing, infection, biosurgery and antimicrobial. The search was initially narrowed by adding the words canine, dog, feline, cat, equine, horse, veterinary or small animal, but as very little material was found, the search was extended to cover human literature as well. The search covering human literature generated numerous results. To utilise the most recent research, articles used were limited to those published after the year 2000. Articles were found primarily through the search engine Google Scholar and by researching citations in relevant literature.

A total of 41 pieces of literature were used in this overview, not counting the 12 references used exclusively in the introduction. To achieve the result 33 texts were studied, of which a majority of 25 were original articles. Three review articles of veterinary origin were included due to shortage of clinical trials in the veterinary field. Two additional reviews were used as an alternative to original articles, to limit the extent of the work; one dealing with management of wound infection in humans and one compiling information on maggots’ effect on MRSA. Though not peer reviewed, one scientific book describing human wound care nursing and two veterinary nursing articles focusing on infected wounds were included to obtain information on basic nursing needs. An additional eight references were used in the discussion; six of which were original articles.

Result

Patient treatment options

The main indication for larval therapy in human patients is infected wounds with slough or necrotic tissue (Courtenay *et al.*, 2000; Steenvoorde *et al.*, 2007). It is used to treat chronic non-healing wounds (Ramundo & Wells, 2000; Steenvoorde *et al.*, 2007); ulcers (Wolff & Hansson, 2003; Bowling *et al.*, 2007) such as pressure ulcers and vascular ulcers are the primary cause of treatment (Courtenay *et al.*, 2000; Wollina *et al.*, 2002; Steenvoorde *et al.*, 2007). LT can also be used to treat wounds colonised with MRSA (Bowling *et al.*, 2007). Underlying cause for treatment in human medicine includes trauma (Steenvoorde & Jukema, 2004; Steenvoorde *et al.*, 2007), diabetes mellitus (Steenvoorde & Jukema, 2004; Bowling *et al.*, 2007; Steenvoorde *et al.*, 2007) and vascular insufficiency (Steenvoorde & Jukema, 2004).

In companion animals, LT has been used to assist in healing of chronic wounds where conventional therapies have failed, to effect debridement and to control infection (Sherman *et al.*, 2007a; Sherman *et al.*, 2007b). Durations and sizes of wounds prior to therapy vary in veterinary studies (Tab. 1). In small animals, wounds have been located to limbs (Kočišová *et al.*, 2003; Sherman *et al.*, 2007b), paws, back and perineum (Sherman *et al.*, 2007b). Wound aetiology includes pressure ulcers such as bedsores (Kočišová *et al.*, 2003; Sherman *et al.*, 2007b) and traumatic wounds, such as bite and scratch wounds (Sherman *et al.*, 2007b). In horses, treatment of diseases in the foot such as abscesses (Sherman *et al.*, 2007a), septic navicular bursitis (Lepage *et al.*, 2012), chronic laminitis (Sherman *et al.*, 2007a; Morrison, 2007) and coffin bone osteomyelitis appears to be most common (Morrison, 2007). Other treated podiatric conditions include chronic distal interphalangeal joint sepsis, canker, acute caudal coffin bone rotation, non-healing foot ulcers and necrosis of collateral cartilage (Morrison, 2007). Additionally, treatments of traumatic wounds, chronic ulcers (Sherman *et al.*, 2007a), soft tissue abscesses and MRSA infected wounds are reported in horses (Lepage *et al.*, 2012).

Table 1: wound characteristics prior to treatment in companion animals receiving LT

Patients		**Duration of wound, days**		**Size of wound, cm²**		**Reference**
Species	**Number**	**Average**	**Range**	**Average**	**Range**	**Author(s), year**
Equids (horses, ponies, donkeys)	41 (35, 2, 4)	-	2-56	-	-	Lepage *et al.*, 2012
Horses	13	36	2-90	-	10-1800	Sherman *et al.*, 2007a
Small animals (dogs, cats, rabbit)	7 (2, 3, 1)	28	4-119	28	2-63	Sherman *et al.*, 2007b

Patients with rapidly advancing infection (Jones & Wall, 2007) and sepsis should not initially be treated with larval therapy (Steenvoorde *et al.*, 2007). Other contraindications include wounds where maggots may become irretrievable (Beasley & Hirst, 2004); this includes fistulae (Jones & Wall, 2007; Dar *et al.*, 2013), wounds that may connect with body cavities or sinuses (Beasley & Hirst, 2004; Jones & Wall, 2007; Dar *et al.*, 2013), and wounds close to the brain (Courtenay, 2000). Maggots abrading small blood vessels can cause bleeding (Jones & Wall, 2007), making wound proximity to large vessels a contraindication (Courtenay, 2000; Jones & Wall, 2007; Dar *et al.*, 2013). Heavily exudative (Jones & Wall, 2007) or hemorrhagic wounds will cause maggots to drown (Jones & Wall, 2007; Dar *et al.*, 2013), or at the very least cause dilution of the maggots proteolytic enzymes, resulting in ineffective therapy (Jones & Wall, 2007). Dry necrotic wounds are not suitable for LT either, as maggots may dry out (Jones & Wall, 2007; Dar *et al.*, 2013).

Results of larval therapy in clinical studies

In human patients, debridement by maggots has been found to be very effective; both fast and precise (Wollina *et al*., 2002; Wolff & Hansson, 2003). In one study, 43% (n=70) of wounds were debrided fully and 29% partially after the treatment period; area of necrotic tissue was reduced by an average of 68% (Courtenay *et al*., 2000). In other studies, 100% (n=13) of wounds were fully debrided (Bowling *et al*., 2007), and 80% (n=74) of wounds were ultimately debrided by 66-100% (Wolff & Hansson, 2003). Other results of LT in humans include improved granulation and wound healing (Wollina *et al*., 2002). An average wound size reduction of 5% and granulation tissue increase of 26% has been reported (Courtenay *et al*., 2000). Granulation tissue increased in all patients (n=13) in a study of wounds colonised with MRSA (Bowling *et al*., 2007). In the study, maggots successfully removed infection in an average of three weeks, without MRSA specific antibiotic treatment. Compared to the average duration of conventional MRSA treatment, reported as 28 weeks, Bowling *et al*. (2007) conclude that LT appears to be a superior alternative. Malodour was also reduced in 81% (n=70) (Courtenay *et al*., 2000) and 58% (n=31) of the wounds (Wolff & Hansson, 2003). Furthermore, no patients required antibiotic treatment after completion of LT in one of the studies (Courtenay *et al*., 2000).

Maggots accomplish successful debridement of necrotic wounds (Kočišová *et al*., 2003; Sherman *et al*., 2007b; Lepage *et al*., 2012) and treatment of infection in companion animals as well (Morrison, 2007). Promotion of granulation tissue formation is also seen in animals, and has been observed in studies after three days of treatment (Kočišová *et al*., 2003; Lepage *et al*., 2012). Although LT was found successful, treatments such as surgery, casting and special shoeing were crucial for a positive outcome in horses (Morrison, 2007). Also, light surgical debridement was performed prior to LT in many equine cases to remove debris and dry necrotic tissue (Morrison, 2007; Lepage *et al*., 2012). The therapy appeared to be well tolerated by patients (Kočišová *et al*., 2003).

In studies of small animals and horses receiving LT, patient outcomes range from full recovery to euthanasia (Tab. 2). Prior to treatment, euthanasia or death was the expected outcome in five small animal patients (n=7) (Sherman *et al*., 2007b) and six horses (n=13) (Sherman *et al*., 2007a). Two small animals were expected to require amputation; in one of these patients the limb was ultimately saved after LT (Sherman *et al*., 2007b). Death or euthanasia was due to severity of pre-existing diseases, and was not associated with treatment failure (Morrison, 2007; Sherman *et al*., 2007b).

Table 2: Results of larval therapy in companion animals

Patients		Result				Reference
Species	**Number**	**Full recovery**	**Complete healing, but inability to return to intended use**	**Incomplete healing**	**Death or euthanasia**	**Author(s), year**
Rabbits	3	100%	-	-	-	Kočišová *et al*., 2003
Equids (horses, ponies, donkeys)	41 (35, 2, 4)	93%	-	5%	2%	Lepage *et al*., 2012
Horses	108	68%	11%	-	21%	Morrison, 2007
Horses	13	46%	38%	8%	8%	Sherman *et al*., 2007a
Small animals (dogs, cats, rabbit)	7 (2, 3, 1)	57%	-	14%	28%	Sherman *et al*., 2007b

Pain is the most commonly mentioned side effect in humans (Tab. 3). Most human patients experienced mild pain (Wollina *et al*., 2002; Courtenay *et al*., 2000), severe pain was only reported in one study, in 9% (n=70) of the patients (Courtenay *et al*., 2000). The pain was considered temporary (Wollina *et al*., 2002) and usually appeared 2-3 days after initiation of therapy (Courtenay *et al*., 2000). Pain may be ascribed to the use of free range maggots, as in one study none of the patients treated with the biobag technique experienced any pain (Steenvoorde & Jukema, 2004). Other possible explanations are changes in wound pH or the sensation of maggots crawling in the wound (Jones & Wall, 2007). It should be noted that during treatment in two studies 25% (n=61) (Wolff & Hansson, 2003) and 69% (n=70) of patients experienced less pain than before (Courtenay *et al.*, 2000). Other adverse effects of larval therapy reported in humans (Tab. 3) are rare and normally uncomplicated (Beasley & Hirst, 2004).

Table 3: adverse effects experienced during larval therapy

Patients		**Adverse effects**					**Reference**
Species	**Number**	**Pain**	**Discom-fort**	**Bleeding**	**Pyrexia or influensa-like symptoms**	**Maggot related anxiety**	**Author(s), year**
Humans	13	-	-	-	-	-	Bowling *et al.*, 2007
Humans	70	33%		34%	16%	-	Courtenay *et al.*, 2000
Equids (horses, ponies, donkeys)	41 (35, 2, 4)	-	17%	-	-	-	Lepage *et al.*, 2012
Small animals (dogs, cats, rabbit)	7 (2, 3, 1)	-	-	-	-	-	Sherman *et al.*, 2007b
Humans	16	19%	-	-	-	-	Steenvoorde & Jukema, 2004
Humans	61	34 %	-	-	-	5%	Wolff & Hansson, 2003
Humans	30	40%	-	-	-	-	Wollina *et al.*, 2002

In horses, discomfort has been reported as the most common adverse effect (Tab. 3) of larval therapy (Morrison, 2007; Sherman 2007a) affecting animals 2-3 days into the treatment (Lepage *et al.*, 2012). This can be demonstrated by moving or stomping the limb and repeatedly rubbing the bandage (Morrison, 2010; Lepage *et al.*, 2012). No adverse effects have been identified in small animals (Tab. 3).

Mechanisms of biosurgery

Biosurgery is the procedure in which maggots are applied to necrotic or sloughy wounds to perform debridement (Horobin *et al.*, 2005). Maggots of the green bottle fly *Lucilia sericata* are the most preferable for larval therapy; they are necrophagus (Wolff & Hansson, 2005) and feed relatively superficially (Jones & Wall, 2007). The species is common in Europe and North America (Wolff & Hansson, 2005). Maggots enhance wound healing in three ways; by debriding necrotic tissue, promoting granulation tissue formation and helping to disinfect the wound (Horobin *et al.*, 2005).

Debridement

Lacking teeth, the maggots have a pair of mouth-hooks they use to break down their food source (Beasley & Hirst, 2004; Jones & Wall, 2007). The maggots secrete proteolytic enzymes that dissolve necrotic tissue from the wound surface, making it into a fluid suitable for ingestion (Chambers *et al.*, 2003). The liquefied food is then sucked into their alimentary tract via their powerful pharynx (Jones & Wall, 2007). Proteolytic enzymes in secretions are mainly serine proteinases of two different subclasses; trypsin-like and chymotrypsin-like proteinases (Chambers *et al.*, 2003). The maggots ingest necrotic tissue on a microscopic scale, and they cause minimal disruption to viable tissue (Beasley & Hirst, 2004).

Disinfection

According to previous theories, animals respond to movement and irritation of maggots by producing large quantities of serous exudate, promoting continuous wound lavage and dilution of bacterial concentration (Beasley & Hirst, 2004; Jones & Wall, 2007). However, more recent studies suggest that the mechanical crawling effect is of very little importance (Blake *et al*., 2007). Disinfection of the wound is now thought to be achieved in two ways; by destruction of bacteria through ingestion and by secretion of antibacterial compounds (Beasley & Hirst, 2004).

Antibacterial substances are continuously being produced in the maggots' saliva; following ingestion, bacteria are killed as they pass through the digestive tract (Jones & Wall, 2007). This has been determined by feeding green fluorescent protein-producing *Escherichia coli* to sterile maggots; most of the bacteria were destroyed in the anterior part of the hindgut, and close to the anus there were practically no viable bacteria left (Mumcuoglu *et al*., 2001).

Secretions of sterile larvae exhibit antibacterial activity against a range of bacteria (Kerridge *et* al., 2005). Growth of Gram-positive bacteria has been shown by Kerridge *et al.* (2005) to be inhibited, whereas growth of Gram-negative bacteria is only slowed down. The antibacterial mechanism has been identified as a defensin called lucifensin, which is active in vitro against G+ bacterial strains, but not against G- bacteria (Andersen *et al*., 2010). Similar results were found by analysing wound cultures prior to and after maggot treatment in a clinical study (Steenvoorde & Jukema, 2004). The analysis indicated that larval removal of G+ bacteria was more efficient than that of G-. However, in another study growth of both G+ and G- bacteria were inhibited by antibacterial factors in the larval excretions/secretions (ES) (Bexfield *et al*., 2004). Larval ES exhibits significant antibacterial activity against a range of clinically relevant MRSA strains (Bexfield *et al*., 2004; Kerridge *et* al., 2005; Bexfield *et al*., 2008). This is also reflected in a clinical study, where MRSA colonisation was eliminated in 92% (n=13) of human chronic diabetic foot ulcers (Bowling *et al*., 2007).

Further antibacterial actions include alkalinising wounds through maggots' excretions of ammonia (Chambers *et al*., 2003; Arora *et al*., 2011), allantoin and urea (Jones & Wall, 2007), making the wound an unsuitable environment for many bacterial species (Arora *et al*., 2011). The pH of larval ES is high (Chambers *et al*., 2003; Arora *et al*., 2011), in the range of 8,6-8,7 (Arora *et al*., 2011). Rising pH is also said to provide optimal conditions for proteolytic enzyme activity (Chambers *et al*., 2003).

Promotion of granulation tissue formation

A possible mechanism by which granulation tissue formation is enhanced has been found by investigating the effects of *L. sericata* ES products on behaviour of fibroblasts; ES significantly reduced fibroblast adhesion and promoted spreading across protein surfaces, while keeping cells viable (Horobin *et al*., 2003). Results were verified in a later study, where it was found that fibroblast motility was promoted, resulting in a wider distribution of viable fibroblasts in a chronic wound (Horobin *et al*., 2005). Chymotrypsin-like serine proteinases in larval secretions can, in addition to removing necrotic tissue, also promote wound healing by aiding in the remodelling of provisional extra cellular matrix to granulation tissue (Chambers *et al*., 2003; Horobin *et al*., 2003). It has also been suggested that secretions of substances such as allantoin, create an optimal environment for wound healing (Beasley & Hirst, 2004).

Larval therapy in practice

Number of maggots required

Current recommendation in human medicine is 5-10 maggots per cm² of wound base (Wolff & Hansson, 2003; Bowling *et al*., 2007; Jones & Wall, 2007). In veterinary medicine, use of 5-10

(Sherman *et al.,* 2007a; Lepage *et al.*, 2012) and 8-12 maggots/cm² has been reported (Kočišová *et al*., 2003). The number of maggots needed depends on amount of necrotic tissue (Jones & Wall, 2007). A standard dose of 100 maggots can debride 50 grams of necrotic tissue during one treatment cycle, when taking larval death in the wound into account (Blake *et al*., 2007). Wound depth may also need to be considered; when the wound was deeper than 2 cm, the surface area was multiplied by the depth of the wound in a study on equids (Lepage *et al*., 2012). As larval removal of Gram-negative bacteria appears less efficient (Steenvoorde & Jukema, 2004), a greater number of maggots might be required for a wound infected with G- bacteria (EWMA, 2006). Ordering more maggots than estimated may need to be considered, as for example only half of the maggots were alive and able to debride on delivery after a two day transport (Lepage *et al*., 2012). It is also more cost effective to apply a large number of maggots for a short period of time, rather than small number for more extended period (Jones & Wall, 2007). More exact predictions of number of maggots needed will lead to economical use, which is of increasing importance (Blake *et al*., 2007).

Sterile maggots are prepared in a laboratory, where eggs from *L. sericata* flies are collected and sterilised by being rinsed several times in chloramine solution 0, 25% (Wolff & Hansson, 2005). Eggs are placed in a transportation flask where the larvae hatch during the first day; the flasks are stored at room temperature whilst waiting for results of a disinfection control. As claimed by Wolff & Hansson (2005), larvae are always microbiologically tested before use, to certify that no infection will be induced by larval therapy. The number of maggots needed for therapy are estimated and ordered (Lepage *et al*., 2012). In Sweden, larvae are distributed by Sahlgrenska University Hospital, department of dermatology (Wolff & Hansson, 2005). The maggots are shipped in a temperature controlled package (Dar *et al*., 2013). When the maggots arrive they are approximately one day old (Wolff & Hansson, 2003). They should be used as soon as possible, but if necessary maturation can be delayed by storing in a refrigerator at 4-8° for two (Blake *et al*., 2007; Dar *et al*., 2013) to five days (Wolff & Hansson, 2005).

Application techniques; biobag or free range

There are two methods of larval application (Steenvoorde & Jukema, 2004; Jones & Wall, 2007). In the direct contact technique maggots are put freely in the wound, in direct contact with the wound surface (Steenvoorde & Jukema, 2004). Alternatively, maggots can be placed in a heat-sealed biobag, a small porous bag made of nylon mesh (Jones & Wall, 2007) or polyvinylalcohol (Steenvoorde & Jukema, 2004). The structure of the mesh enables the proteolytic secretions to reach the necrotic tissue, and maggots can still aid in debridement (Jones & Wall, 2007).

Application of maggots in a biobag is less complicated; it requires less experience and can be performed by a single nurse, saving time and resources during dressing changes (Blake *et al*., 2007). Another advantage is that treatment using the biobag has been perceived as less painful than free range maggots by human patients (Steenvoorde & Jukema, 2004).The biobag may be more preferable if the owner of the animal is unwilling to accept the use of maggots in veterinary wound care (Jones & Wall, 2007). A study investigating patient acceptability shows that human patients would consider maggots in a biobag as an equal alternative to autolytic debridement using a hydrogel (Petherick *et al*. 2006). However, treatment would need to be a mean of three weeks shorter than autolytic debridement for patients participating in the study to consider LT with free range maggots. According to the findings of another study, a majority of patients with leg ulcers would consider the use of larval therapy, regardless of method used (Spilsbury *et al*., 2008). The participants refusing larval therapy were also distributed equally between the two application methods.

One disadvantage of the biobag is that maggot debridement is only effective in its direct vicinity, making the biobag ineffective in irregularly shaped wounds (Blake *et al*., 2007). It can still be used according to Blake *et al*., (2007), although one cycle of free range maggots may be needed. It has been described as likely that debridement is less effective as the maggots cannot use mouth hooks through the biobag (Jones & Wall, 2007). Use of the biobag has been found to be one of the factors that have a significant negative impact on successful outcome of LT (Steenvoorde *et al*., 2007). In contrast, another study comparing the two techniques reveals that debridement efficiency appears to be similar (Blake *et al*., 2007). Statistical analysis revealed no difference between the use of freely crawling maggots and maggots in a biobag regarding total amount of debrided tissue after 3 or 4 days of treatment.

Dressing a wound for larval therapy

Although wound dressings used in larval therapy differ depending on location of the wound, some principles need to be followed for treatment to be successful (Sherman *et al*., 2007b; Dar *et al*., 2013). Both studies recount that dressings must be permeable; maggots are oxygen-dependent, so air must be allowed to reach the maggots. A drain can be placed to ensure a constant open entrance for the larvae to be sufficiently supplied with oxygen in deep, closed or heavily exuding wounds (Jones & Wall, 2007; Morrison, 2007). In necrotic cavities an opening can be created to ensure drainage and oxygen supply (Dar *et al*., 2013). Exudate and liquefied necrotic tissue must be able to drain freely out of the wound (Sherman *et al*., 2007b; Dar *et al*., 2013). The surrounding healthy skin must be protected as well (Jones & Wall, 2007; Dar *et al*., 2013). The skin must be protected from maceration due to excessive exudation and from damage to healthy tissue caused by proteolytic enzymes secreted by larvae; preventing the maggots from crawling on healthy skin may also lessen the feeling of discomfort experienced by the patient (Ramundo & Wells, 2000).

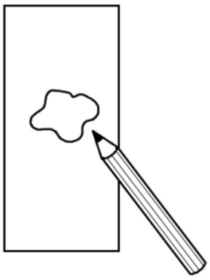

Figure 1: tracing the wound on a plastic sheet
Illustration: Berglund, C., 2013

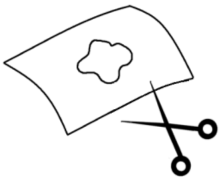

Figure 2: cutting a hole in a hydrocolloid dressing
Illustration: Berglund, C., 2013

To prepare for larval therapy, a wide area around the wound is clipped (Sherman *et al*., 2007b; Chivers, 2010), with a sterile water soluble jelly applied in the wound to prevent hair contamination (Chivers, 2010; Dar *et al*., 2013). Non-sterile single use gloves are worn at all times during wound management (Chivers, 2010). Prior to placing maggots, the wound is cleaned with 0, 9% saline to remove any topical wound agents (Dar *et al*., 2013). The patient is protected from lavage fluid with incontinence sheets (Chivers, 2010). Special care should be taken in the lavage process when products including propylene glycol have been used, since it can negatively affect maggot viability (Dar *et al*., 2013). In horses, if acrylic or urethane is used in the gluing process of a shoe application, at least 24 hours need to pass before larval application, as vapours from adhesives can be fatal to maggots (Morrison, 2010). The surrounding healthy skin is cleaned, dried and disinfected (Dar *et al*., 2013). The wound is traced on a sheet of sterile plastic (Fig. 1). This is used to help in calculating a more exact number of maggots needed for therapy (Jones & Wall, 2007).

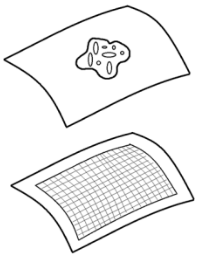

Figure 3: placing free range maggots in the wound, and covering with a net
Illustration: Berglund, C., 2013

The most common way to dress a wound for larval therapy is a cage like dressing (Jones & Wall, 2007; Dar *et al*., 2013). The primary layer in direct contact with the wound (Chivers, 2010) is formed by a hydrocolloid dressing with a hole cut in the shape of the wound; the shape is taken from the plastic sheet used to calculate number of maggots (Fig. 2). The hydrocolloid dressing protects surrounding skin as well as provides a base on which additional dressings can be securely fixed (Jones & Wall, 2007; Dar *et al*., 2013). It also serves to relieve pressure to prevent crushing of the maggots (Bowling *et al*.,

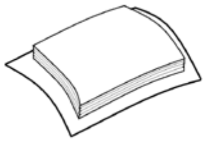

Figure 4: attaching an absorbent dressing to the hydrocolloid frame Illustration: Berglund, C., 2013

2007). A deeper wound can be created by using an additional layer of hydrocolloid dressing in areas exposed to pressure (Wolff & Hansson, 2003). Free range maggots are placed in the wound and covered by a porous sheet or net (Fig. 3). The net is fixed securely to the hydrocolloid frame using a waterproof adhesive, creating a cage with the maggots inside (Dar *et al*., 2013). Alternatively, a biobag is inserted and fastened to the primary hydrocolloid dressing (Jones & Wall, 2007; Sherman *et al*., 2007b). This is subsequently covered with a secondary layer; an absorbent dressing, such as a gauze pad (Fig. 4), to absorb necrotic drainage (Jones & Wall, 2007; Sherman *et al*., 2007b; Chivers, 2010).

Maggot dressings are individually adapted in veterinary medicine (Sherman *et al*., 2007b; Lepage *et al*., 2012). Different dressings for horses, depending on location of the wound, have been described (Morrison, 2010; Lepage *et al*., 2012). For treatment in the hoof, a temporary non-occlusive bandage (Lepage *et al*., 2012) or full foot cast can be applied; if a cast is used, a window is cut in the cast to enable maggots to be placed inside (Morrison, 2010). Wounds located to difficult positions on the body or upper limbs can be treated by fastening a biobag to the skin with sutures (Sherman *et al*., 2007a; Lepage *et al*., 2012). In lower limbs, elastic adhesive bandages can be placed proximal and distal to the wound (Lepage *et al*., 2012). A net is placed around the limb, taped down on either side of the wound, and sealed to the lower bandage, as described by Lepage *et al*. (2012). The maggots are then poured into the sleeve created by the net, and the net is fixed to the top bandage.

The absorbing layer of the dressing gets soiled quickly as maggot debrided wounds are heavily exudative (EWMA, 2006). The outer dressing is changed daily in clinical studies (Morrison, 2010; Lepage *et al*., 2012). The top layers may need to be lifted twice daily to sufficiently aerate the maggots (Wolff & Hansson, 2003). To prevent maggots drying out, the maggots can be watered by applying fresh gauze moistened with saline over the net after the first day of treatment (Wolff & Hansson, 2003; Dar *et al*., 2013).

Table 4: Length of maggot application cycles in studies

Patients	Cycles	Reference
Species, number	**Length, days**	**Author(s), year**
Humans, 13	4	Bowling *et al*., 2007
Humans, 70	2-3	Courtenay *et al*., 2000
Rabbits, 3	3-6	Kočišová *et al*., 2003
Equids (horses, ponies, donkeys), 41 (35, 2, 4)	3	Lepage *et al*., 2012
Horses, 13	5-7	Morrison, 2010
Horses, 13	2-3	Sherman *et al*., 2007a
Small animals (dogs, cats, rabbit) 7 (2, 3, 1)	2-3	Sherman *et al*., 2007b
Humans, 101	3-4	Steenvoorde *et al*., 2007
Humans, 74	1-3	Wolff & Hansson, 2003
Humans, 30	1-4	Wollina *et al*., 2002

The maggots are removed from the wound when they are fully grown (Wolff & Hansson, 2003; Dar *et al*., 2013). The maggots are typically 1-3 mm long when they are applied to the wound (Jones & Wall, 2007), and 10 mm long when they are removed (Wolff & Hansson, 2003). In nature, fully grown maggots would leave the wound to pupate in the surrounding environment (Jones & Wall, 2007). The outer dressings are detached (Jones & Wall, 2007), while the hydrocolloid frame may be left in place (Dar *et al*., 2013). Free range maggots are removed by hand or using forceps (Dar *et al*., 2013). Any deep crawling maggots may be carefully removed by irrigating the wound with saline or sterile water (Jones & Wall, 2007; Dar *et al*., 2013). Maggot and dressings are disposed of as clinical waste (Lepage *et al*., 2012).

In clinical studies, the length of time each application of maggots is left in the wound varies (Tab. 4). It has been suggested that as maggots become less active after 48 hours, they are less useful in the wound and should be removed after two days (Paul *et al*. 2009). On the other hand, maggots have been shown to metabolise a significantly higher mass of tissue after four days than after three, why it should be attempted to leave maggots in the wound for at least four days (Blake *et al*., 2007).

After removal of maggots, the wound is reassessed to determine whether further larval therapy is required or not (Dar *et al*., 2013). The effects of cycle length and frequency of dressing changes need to be assessed throughout treatment (O'Dwyer, 2012). It is important to keep accurate records of dressing changes for management to be consistent; including condition of dressing, materials used (Chivers, 2010), pain score on removal of dressings (O'Dwyer, 2012) and method of analgesia or sedation (Chivers, 2010).

If the wound deteriorates (Ramundo & Wells, 2000), if there is no sign of improvement within 10 days of treatment or if the patients' status changes for the worse, the treatment may need to be reconsidered (EWMA, 2006).

Length of treatment

Maggots are applied in cycles until complete debridement is achieved (Morrison, 2007; Steenvoorde *et al.*, 2007; Dar *et al*., 2013), granulation tissue is observed and there are no signs of infection (Dar *et al*., 2013). Treatment time and number of applications needed until wounds were fully debrided differ in clinical studies (Tab. 5). In deep visually inaccessible wounds, such as puncture wounds of the hoof, therapy can proceed until the patient walks soundly for a week (Morrison, 2007).

After therapy is discontinued, the wound should be managed using moist wound healing, according to local protocol (EWMA, 2006).

Table 5: Number of maggot cycles applied and length of treatment

Patients	Applications	Length of treatment	Reference
Species, number	**Average (range), number**	**Average (range), days**	**Author(s), year**
Humans, 13	3 (n/a)	19 (7-45)	Bowling *et al.*, 2007
Humans, 70	3 (n/a)	n/a	Courtenay *et al.*, 2000
Rabbits, 3	1,3 (1-2)	n/a	Kočišová *et al.*, 2003
Equids (horses, ponies, donkeys), 41 (35, 2, 4)	1,1 (1-2)	n/a	Lepage *et al.*, 2012
Horses, 13	9 (1-20)	n/a	Sherman *et al.*, 2007a
Small animals (dogs, cats, rabbit) 7 (2, 3, 1)	2,1 (1-5)	n/a	Sherman *et al.*, 2007b
Humans, 16	7 (3-21)	27 (12-83)	Steenvoorde & Jukema, 2004
Humans, 101	2,4 (1-11)	7 (n/a)	Steenvoorde *et al.*, 2007
Humans, 74	1,4 (1-4)	7 (n/a)	Wolff & Hansson, 2003
Humans, 30	1,1 (1-2)	n/a	Wollina *et al.*, 2002

Veterinary nursing aspects

The wound and surrounding tissues will require continuous reassessment throughout the wound management process (EWMA, 2006; O'Dwyer, 2012). The wound must be closely monitored to ensure that debridement proceeds as expected (Ramundo & Wells, 2000). Detailed accurate records should be kept at every dressing change, so reassessment can be made by different members of staff if necessary (O'Dwyer, 2012). Records need to describe the wound dimensions, appearance, exudate (Ramundo & Wells, 2000; O'Dwyer, 2012) and odour, as well as condition of the surrounding skin (Ramundo & Wells, 2000) and general health of the patient (O'Dwyer, 2012). An increase in wound size can be observed as necrotic tissue is removed, which should not be interpreted as treatment failure (Ramundo & Wells, 2000). Photographs can be taken to make changes in the wound more easily identifiable and to encourage owners by showing them progression of wound healing (Chivers, 2010). The patient needs to be closely monitored for signs of spreading or systemic infection (EWMA, 2006).

Management of wounds can be painful and prolonged (Chivers, 2010). The pain can originate from the wound, but also from the choice of debridement (Ramundo & Wells, 2000). Pain can cause animals to interfere with dressings and cause further damage to the wound (Chivers, 2010). Signs of discomfort such as change in behaviour should be recognised so pain can be relieved rapidly by administering analgesia or removing maggots (Jones & Wall, 2007). Daily analgesia may be indicated throughout treatment for adequate pain management (Chivers, 2010). Pain can be reduced by ensuring the hydrocolloid dressings are protecting the margins of the wound sufficiently, as eroded wound margins may be a cause of pain, or by stabilising the wounded area (Ramundo & Wells, 2000). On dressing changes, additional analgesia is required (Ramundo & Wells, 2000; Chivers, 2010). Ideally, the analgesic is administered, and dressing change timed to when the peak effect occurs (Ramundo & Wells, 2000). Dressing changes can be very stressful to the patient, and it may be necessary to anaesthetise the patient (Chivers, 2010).

Discussion

Larval therapy is rare in veterinary wound care. No prospective randomised case controlled trials on LT in companion animals have been performed. The studies currently available by Sherman *et al.* (2007a; 2007b) and Lepage *et al.* (2012) are retrospective surveys. They are neither prospective nor controlled, and should not be interpreted as such. The study on rabbits by Kočišová *et al.* (2003) is prospective, but there is no comparison to conventional therapy, and it involves only three animals, limiting the significance of the results. The Morrison (2007) study involves a greater number of patients, but it is not case controlled. Still, the studies represent examples of current use in companion animals, and if nothing else they serve to evoke interest in the LT as a treatment option.

While studies on LT in humans generally are of better quality, they often lack a placebo group or comparison to conventional treatment, making the actual effectiveness of treatment hard to assess. It is often studied on patients where all other treatments have failed, which may lead to LT appearing superior to conventional methods of debridement, without actual evidence of that being the case. There are a few studies comparing LT to conventional treatments though. In two studies by Sherman (2002; 2003) LT was found to be more effective in debridement and promoted faster wound healing than the control group in treating non-healing ulcers. In the 2002 study, 92 patients were included. Complete debridement was shown by 80% of LT patients and 48% of controls within 5 weeks. Average wound reduction was 84% in LT wounds and 37% in the control group. In the 2003 study, 18 patients were treated. After 4 weeks LT wounds were completely debrided, and conventionally treated wounds were still covered in an average of 37% necrotic tissue. Granulation tissue covered an average of 56% of the test group wounds, and 15% of the control group. A third study by Paul *et al.* (2009) showed no significant difference in the wound outcome of the different treatments in 54 patients with diabetic foot ulcers, however patients receiving LT were hospitalised for a significantly shorter length of time.

There are some issues to consider before using larval therapy on canine, feline or equine patients. Appropriate number of maggots per cm^2, for example, must be researched before initiating treatment on small animal patients. Sherman *et al.* (2007b) and Jones & Wall (2007) state that maggot therapy can theoretically cause the same adverse effects as myiasis, maggot infestation in nature. Myiasis can cause ammonia toxicity affecting the kidneys and heart, according to Jones & Wall (2007), with potentially fatal consequences. Dogs suffering from myiasis can present symptoms such as depression, anorexia and pyrexia, as noted by Orfanou *et al.* (2011). Some dogs also exhibited lameness due to local pain caused by maggots infesting limb wounds. Additional symptoms, from observations in sheep by Elkington *et al*. (2009), include tachycardia and tachypnoea. As Jones & Wall (2007) describe the condition as associated with a large number of maggots, the patients' size relative to the size of the wound is a risk factor for iatrogenic ammonia toxicity. The standard dose of 5-10 maggots/cm² may be unsuitable for a small animal with a large wound. Small animals in general should be treated with caution and monitored more closely during treatment. Further studies are required to be able to more exactly calculate a safe number of maggots for treatment on small animals.

Another aspect relating to the different species in veterinary wound care is the differences in wound healing. These differences have been described by Bohling & Henderson (2006). Cats' wounds heal slower than dogs'; contraction and epithelisation are slower, as well as production of granulation tissue. Granulation has been completed 2, 5 times faster in dogs than in cats in identically created wounds. In dogs granulation tissue appears simultaneously from the entire wound surface, whereas in cats it originates from the wound edges and advances towards the middle. Feline wound breaking strength is also significantly lower: after a week of healing only half of that in dogs. Bohling & Henderson (2006) also recount the differences in wound healing between horses and ponies. Horses have a tendency for persisting inflammation due to a weak inflammatory response. It often leads to excess amounts of granulation tissue, especially on the distal limbs, resulting in chronic non-healing wounds. Ponies have a stronger inflammatory response, which normally leads to wound healing progressing with fewer complications than in horses. The physiology of wound repair in different species is important to remember in any wound care situation, especially when problems with treatment arise. However, the importance of these findings to the use of larval therapy in companion animals is yet uncertain.

A considerable problem in treating animals according to Sherman *et al*. (2007b) is applying the dressing in a way that stops the animal from removing it. In conventional wound dressings, the secondary layer consists of soft orthopaedic wool to hold the primary layer in position and ensure even pressure across the dressing, as described by Chivers (2010). This is covered by gauze. A tertiary layer, typically consisting of a self-adherent elastic dressing, is added to protect the underlying layers from soaking and soiling according to Chivers (2010). The maggots' need of oxygen however, may limit the possibilities of using these additional dressing layers. They could also prove to apply too much pressure, effectively killing the maggots. If the wound is located to a lower limb, a waterproof sock or boot can be used for outside exercise to protect the underlying layers. This will not solve the problem of dressings not staying in place though. Moreover, any supporting layers used must be uncomplicated to change, as the owner will need to be able to perform this at home due to the heavy exudation of LT wounds. No mention of this has been made in literature, possibly due to the fact that secondary and tertiary layers are not as important in laying lasting dressings in human wound care.

Dressings' not keeping in place is not the only challenge in dressing maggot wounds. Dressings are elaborate and typically difficult to apply. Dressing changes are carried out in two parts. The maggots are removed and the wound evaluated. If further therapy is needed, Sherman (2002; 2003) recommends covering the wound with saline-moistened gauze while waiting for the next batch to arrive and maggots can be reapplied. As maggots and dressings are removed, the first visit is likely to involve more pain. The second visit, though less painful, requires a certain composure of the patient as reapplication of dressings and maggots is rather intricate. Depending on personality of the patient, sedation or general anaesthesia may be required at either dressing change. Only experience or further studies can help to ascertain whether sedation or anaesthesia will be required to a greater extent with LT than with other treatment methods.

Larval therapy appears to be the most effective of the non-surgical debridement options according to Sherman (2002). Steenvoorde *et al.* (2007) found that ASA classification of the human patient is not a factor that influences outcome of LT. This opens up possibilities for treating animals too ill or too high risk for anaesthesia, providing methods for dressing applications can be developed enough to perform dressing changes while the patient is awake.

The study by Steenvoorde *et al.* (2007) also showed that location or size of the wound does not influence outcome. Factors that did have a negative impact on outcome of LT in the study included older age of the patient, wound duration over three months, non-traumatic origin of wound, septic arthritis and deep wounds with visible tendon, muscle or bone. The cost of therapy is always a concern in veterinary medicine, and choosing patients likely to have a successful outcome of the treatment will enable a more economical use of the owners' resources.

It has been suggested by Sherman *et al*. (2007b) that LT is less expensive than surgery or prolonged antibiotic treatment. A randomised controlled trial measuring cost effectiveness of maggot therapy compared to autolytic debridement using hydrogel dressings has been conducted by Wayman *et al*. (2010). It was found that cost of LT per patient was 42% less than conventional therapy in human medicine. In dogs, cats and horses though, considering the possible need for sedation or anaesthesia and the added cost accompanying frequent hospital visits for dressing removal and application, it is unlikely that the cost effectiveness in human wound care will be reflected in companion animals.

The possible development of wound care products using larval ES has been investigated to utilise the positive properties of secretions without using actual maggots in wounds. After treating larval ES with heat in the study by Horobin *et al*. (2003), the secretions were still active, albeit significantly less active than before. Kerridge *et al.* (2005) found that larval secretory products could endure lyophilisation (freeze-drying) and long term storage at various temperatures. The products proved to be only slightly less active against MRSA after four months of storage at 4°. While a wound dressing with maggot secretions cannot replace the ingestion of bacteria and necrotic tissue performed by the maggots, it will be much more user friendly and may prove to be a good alternative to LT in the future.

There are scarcely any nursing studies on human patients receiving larval therapy, and certainly none on animal patients. There are several veterinary nursing aspects of larval therapy that necessitates further investigation, but as LT is a rare treatment form and a veterinary nursing is a new science, studies have yet to be undertaken.

One nursing specific aspect in humans is concerning patient perception of treatment. Acceptability is considered a problem both by patients and practitioners. However, in the previously mentioned studies by Petherick *et al*. (2006) and Spilsbury *et al*. (2008), no extensive aversion to the use of maggots was found. Similar results were found by Steenvoorde *et al.* (2005). None of the patients (n=37) refused LT, and 89% were willing to undergo treatment again. Even if humans are not the ones receiving treatment in the veterinary field, problems with containment of maggots may still be an issue that negatively influences the acceptance of LT. In the study by Steenvoorde *et al.* (2005), maggots escaped the wound of 43% of the patients at some point during treatment. The escape rate was 12% for all free range applications. As dogs and cats typically live indoors, the owner may be deterred by the idea of escaping larvae. Owner acceptability is probably less of a problem with use of LT in horses due to the difference in living environments. Regardless of patient, any potential acceptability issues will hopefully be resolved by open communication with the owner. The veterinary nurse is likely the one to help the owner understand the treatment procedure.

Pain evaluation and management is an important nursing aspect. The most commonly mentioned adverse effect in human patients is pain, and in animals patients it is discomfort. As no pain scores were used during the veterinary studies, it is plausible to believe that these are in fact one and the same. Discomfort can be caused by irritation or itching, but it can also mean that the patient is experiencing pain, a fact which should not be overlooked. Pain evaluation is important when treating wounds with maggots, but not only to keep the patient pain free. In the studies by Courtenay *et al*. (2000) and Wolff & Hansson (2003) patients actually experienced less pain than prior to treatment, which may lead to unnecessary medication if analgesia is given without assessment.

Nursing models can be used to identify and attend to veterinary nursing related problems in larval therapy. Bale & Jones (2006) describe nursing models as aids to relate nursing theory to clinical practice. The nursing role of care is emphasised, rather than the medical, and the patients' needs are central in the decision making process. A simple care plan based on problem, goal and intervention can be implemented to ease management of LT. A care plan is patient specific, and problems can be marked as potential or actual. For instance, a problem can be dressings not staying in place. The goal is then to minimise disturbance of dressings, and intervention can be to evaluate pain and analgesia, and to check owner compliance of use of Elizabethan collar. Another potential problem is owner experiencing maggot-related anxiety. The goal is to reduce anxiety to allow treatment to proceed. This can be achieved by allowing the owners to communicate their anxieties, by discouraging owners from being present at dressing changes, or by minimising risk of maggots escaping by appropriate wound dressings.

Conclusion

Despite the lack of material, the chosen method of a literature study was successful in achieving the objective of this student report. While it would be interesting to learn to which extent LT is used in companion animals in Sweden, if at all, the unusualness of the treatment makes a survey difficult to perform. Based on the knowledge obtained by engaging in this project, some experimental studies could be performed within the limits of an undergraduate project. For instance, investigating if any of the dressing materials commonly used in companion animals are compatible with larval therapy, with focus on larval survival in the wound. However, the need for potential experiments such as this one would not have been recognised without the foundation laid by this literature study.

How LT in companion animal wound care compares to conventional therapies remains to be seen. As LT can be used to successfully treat MRSA, it is definitely a treatment option that deserves more attention. One of the most commonly mentioned disadvantages in human wound care is patient acceptability. While owners' perceptions of the therapy potentially present a problem, the patient itself is unlikely to suffer from maggot-related anxiety. The disadvantage of more frequent dressing changes in the hospital setting must be weighed against the possibility of restoring the animal to health faster, and thus shortening the total length of treatment. Maggot wounds are difficult to dress, and the patients may require anaesthesia or sedation to a greater extent than in conventional wound dressings, although this is so far only speculation. The dressing changes are likely to be easier with growing experience of the veterinary nurse. If dressing changes could be performed without anaesthesia, this would be a major advantage, as the therapy appears to be effective with patients too ill for surgery.

Further clinical studies are needed, not only to ensure the safety and efficiency of the treatment, but also to increase awareness and encourage more veterinary nurses and physicians to take the first steps towards using larval therapy in our dogs, cats and horses.

Populärvetenskaplig sammanfattning (popular science summary)

Att fluglarver kan användas för att behandla sår med infektion eller död vävnad har varit känt sedan länge. Sårvård med fluglarver var vanligt under 1940-talet, men när antibiotikan introducerades avtog behandlingens popularitet. När antibiotikaresistens började spridas väcktes intresse för larvterapi igen, nu med förbättrade metoder med sterila larver.

Larverna som används är från guldflugan *Lucilia sericata*, en typ av spyfluga som är vanligt förekommande i Europa. Larver från guldflugan är lämpliga eftersom de bara livnär sig på död vävnad, och de äter ytligt. Dessutom lägger guldflugan ägg, vilket gör steriliseringsprocessen lättare. Sterila larver beställs från ett laboratorium.

Larver avlägsnar effektivt död vävnad och bakterier, och påskyndar dessutom sårläkningsprocessen. Hos människor används larver framförallt för att behandla sår som inte läker med konventionella metoder, såsom liggsår och fotsår orsakade av diabetes. Användning hos våra sällskapsdjur är fortfarande ovanlig. Det finns exempel på larvterapi hos hundar och katter för att behandla trycksår och traumatiska sår som riv- och bitsår. Hos häst förefaller behandlingen vanligare, då används larver främst för att behandla sjukdomstillstånd i hoven såsom fång eller djupa sticksår. Larvterapi är också effektivt mot sår infekterade med resistenta bakterier som MRSA.

Smärta i samband med terapi är förhållandevis vanligt, varför en viktig omvårdnadsaspekt är att identifiera och förebygga smärta. Övriga biverkningar är få och milda.

Vid leverans är larverna ungefär en dag gamla och 3 mm långa. Larverna kan placeras direkt i såret, eller indirekt i en påse gjord av finmaskigt nät, en så kallad biopåse. Förutsatt att inga biverkningar uppträder kan larverna vara kvar i såret i runt fyra dagar. Då är de fullvuxna, ungefär 10 mm långa. I naturen skulle larverna lämna såret i det här skedet för att bli puppor. Det är väldigt osannolikt att detta skulle hända i såret. Avlägsnade larver hanteras som kliniskt avfall. Efter utvärdering av såret kan en ny omgång påbörjas; larver appliceras i cykler tills det inte finns någon infektion eller död vävnad kvar. Efter avslutad behandling återupptas konventionell sårvård med fokus på sårläkning.

Bandagen som används i larvterapi består av flera delar som tillsammans skyddar omkringliggande hud från sårvätska och larvernas sekretioner, håller larverna instängda och absorberar sårvätska samtidigt som larverna får tillgång till syre. Det är inte lätt att lägga förband för larvterapi, och en utmaning för djursjukskötaren kommer att vara att få förbanden att hållas på plats.

Ett möjligt problem är att djurägaren känner obehag för larverna. Information från djursjukskötaren om terapin kommer troligen att vara en viktig del i djurägarens acceptans av behandlingen.

Fler studier krävs inom larvterapi för våra sällskapsdjur. Vilken mängd larver som är både säker och effektiv att använda för smådjur behöver undersökas. Hur olika bandagematerial påverkar larvernas syretillförsel är också viktigt att ta reda på, för att underlätta bandageläggning och minska kostnaden för misslyckad behandling för djurägaren. Kliniska studier kommer också att öka medvetenheten om behandlingen bland djursjukskötare och veterinärer, vilket förhoppningsvis leder till att larvterapi börjar användas i större utsträckning.

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