Silver Supplement

Worldwide concerns in regard to the increasing bacterial resistance to antibiotics has led to a resurgence of interest in topical silver as a wound treatment and as a coating on urinary and intravenous catheters. Concerns have been voiced by scientists and clinicians about the best methods and therapeutic dosages for silver wound treatments and the risk of developing increased bacterial resistance to this metal. The 2nd World Union of Wound Healing Societies Conference, which was held in Paris in June 2004, facilitated company-sponsored symposia and debate amongst delegates, but many issues were left in dispute. Confusion in regard to the use of ever-increasing numbers and varieties of silver impregnated dressings is also of increasing concern to clinicians both nationally and internationally. Furthermore, the costs of silver impregnated products are considerably greater than other antimicrobial impregnated dressings and inappropriate use of these products has the potential to compromise cost-effective outcomes and increase health expenditure across all sectors.

In order to provide an interactive opportunity to address some of these concerns, Silver Chain Nursing Association in Western Australia proudly hosted the Inaugural Australian Silver Symposium, which was held in Perth on 7 September, 2005. The purpose of this event was to bring scientists, clinicians, manufacturers and other health professionals together as equal partners to discuss the relevant science, clinical and ethical implications of silver in clinical practice. Until then, other meetings had restricted their focus to individual products rather than adopt a universal approach. The aim was to achieve a preliminary consensus agreement amongst delegates in regard to issues concerning the use of topical silver in clinical practice and to disseminate the outcomes for further national and international debate. It is the ongoing goal of the organising committee that the legacy of the Silver Symposium will be the eventual development of clinical practice guidelines for the use of topical silver in clinical practice. Several papers presented at the Silver Symposium are reproduced in the supplement.

The symposium concluded with a panel discussion and a summary of the day's proceedings and discussions. Identified issues resulted in draft statements and these were put to the delegates for further debate, refinement and voting. As a result six consensus statements resulted (see Table 1). As previously stated, the aim is to disseminate these consensus statements via professional forums and journals such as *Primary Intention* for ongoing debate and the Editors welcome your comments and suggestions.

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Table 1. Silver Consensus Statements.

1. Selection of a silver product is preceded by comprehensive assessment of the person, their wound and their healing environment.
2. Silver product selection should be based on randomised controlled trials and demonstrate efficacy, efficiency and cost-effectiveness in use.
3. The silver product is selected for its ability to provide a balanced micro environment.
4. Appropriate wound hygiene and/or debridement precedes the application of silver products.
5. Silver products, like all antimicrobial agents, should be used prudently to provide infection control and/or inhibit inflammatory responses or critical colonisation in the wound.
6. Industry standards for silver product testing and reporting are required.

The articles contained in this supplement are based on presentations given at the Silver Symposium and have not been peer reviewed.

Reduced cellular toxicity of a new silver-containing antimicrobial dressing and its clinical performance in non-healing wounds

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Abstract

Normal wound healing may become disturbed by bacterial colonisation of the wound; this can give way to infection, which requires systemic intervention with antibiotics. As an antimicrobial agent, silver has a long tradition and has been used from the ancient past to today. In burn centres, topical silver preparations are used to prevent the entry of pathogenic micro-organisms into the burn wound and to reduce the risk of sepsis.

Silver-containing dressings were introduced in the 1970s and have received widespread attention recently regarding their use in wounds with impaired healing such as leg ulcers, decubitus and diabetic foot infections. Various silver dressings are available; however, cellular toxicity is a serious concern and the benefit of antimicrobial action needs to be carefully balanced against the cytotoxic harm silver can do.

With this rationale, we developed a new silver-containing tulle dressing, Atrauman Ag. Atrauman Ag effectively kills a panel of commensal and pathogenic bacterial strains while viability of HaCaT keratinocytes remained at 90%. In two separate studies, 86 and 624 patients with a variety of wounds with impaired healing were treated with Atrauman Ag in an office-based setting. After three dressing changes, evaluation scores improved in both studies. Physicians' and patients' rating also were very favourable, reporting that the dressing format was versatile and that dressings were easy to apply and less painful to remove. It can be concluded that Atrauman Ag has a superior profile of antimicrobial activity over cellular toxicity. The low silver ion release rate of Atrauman Ag may not cause harmful interference with wound healing mechanisms.

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Historical perspective

The use of silver as a preservative can be dated back to the ancient Greeks and Romans. The medicinal use of silver became widespread in the 19th century and continues to be used to this day. In addition, before the discovery of antibiotics, the antimicrobial properties of silver preparations were particularly appreciated. Silver nitrate (1% solution) has been used since 1884 in Crede's prophylaxis against gonococcal ophthalmia. Silver sulfadiazine (SSD), a preparation which avoids greyish discolouration to some extent, is still in use in burn units as a prophylaxis against the entry of micro-organisms and subsequent sepsis.

It is well known that silver and the active form ionic silver rapidly become inactivated in a biological environment. Silver has to be reapplied repeatedly to maintain antimicrobial activity, resulting in the application of high doses, yet, despite this, clinical signs of systemic toxicity are a rare event [1-3]. Nevertheless, careful analysis has shown that silver is readily absorbed through burn wounds and deposited throughout the body; there is evidence that the amount of silver absorbed correlates with the amount of silver applied and the surface area treated [2, 4]. Furthermore, in SSD cream, the sulphadiazine moiety is the cause of frequent sensitisation and development of allergies, excluding the further use of this silver preparation [5, 6].

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Silver in the treatment of wounds with impaired healing

As well as being used in burn patients, silver preparations have been applied to wounds with healing impairment such as venous leg ulcers [7]. A full range of silver-containing dressings have been formulated for convenience in order to avoid repeated ointment applications. These dressings differ with regard to the silver ion release into the wound area. Technically, this can be controlled by varying the amount of available silver in the dressing, the surface area of the silver particles and the chemical composition of the silver preparation.

The first commercially available silver dressing, Actisorb, was introduced almost 30 years ago by Johnson & Johnson. In combination with activated charcoal, silver ions were supposed to limit microbial growth and bind toxic substances such as endotoxin [8]. Recently, several new antimicrobial dressing preparations have become available [9], including a high silver-releasing nanocrystalline form [10]. These are presented in different formats, ranging from xerodressings to moist wound dressing formulations; the latter aspect merits special attention since this has major implications for the way in which non-healing wounds are treated and the associated total treatment costs. Xerodressings can be moistened with physiologic NaCl or Ringer's solution, whereas silver-containing foam or hydrocolloid dressings provide a moist wound environment in addition to the antimicrobial effects.

Whether or not heavily colonised or even infected wounds should be treated with occlusive dressings is a matter of debate and depends on the type of wound. For diabetic foot ulcers non-occlusive dressings are still mostly preferred, while, for the treatment of infected venous leg, ulcers occlusive silver-containing dressings might be an option. The dressing change intervals for heavily colonised or infected wounds are determined more by the state of the wound than by the potential of the dressing for staying in place for longer periods. The need for repeated wound evaluations may prevent leverage of the full potential of moist wound dressings to reduce total treatment costs.

Whilst for the treatment of burn patients empirical evidence points to silver-containing preparations as the best solution, as these release high amounts of silver to the wound bed, the situation in chronic wounds is less clear. In particular, the question of how much silver needs to be delivered to the wound bed of non-healing wounds is subject of an ongoing debate. Current estimations have been extrapolated from laboratory studies (minimal inhibitory concentration on bacterial growth) on wound healing [11]. Nevertheless, clinical evidence is still missing, despite the fact that sometimes firm statements are being made.

Further evidence comes from a clinical study on a high silver release dressing using nanocrystalline silver and quantitative bacterial counts in non-healing wounds [12]. In this study on 29 patients with chronic, non-healing wounds of different etiologies, patients were treated for 6 weeks, or a shorter time if healing occurred earlier, with a nanocrystalline silver dressing. Bacterial swabs and quantitative biopsies were performed throughout the study. While clinical improvement was reported in more than 70% of the patients, quantitative microbiological analysis in biopsies did not show any reduction of bacteria in the wound tissue. While bacteria were reduced in wound fluid, surprisingly, this parameter did not correlate with the biopsy results [12].

These findings are in line with and further support empirical clinical evidence suggesting that it is difficult or even impossible to sanitise contaminated chronic, non-healing wounds. Nevertheless, clinical improvement suggests that healing proceeded well despite the inability of the nanocrystalline silver-containing dressing to reduce bacterial contamination of the wound bed. Taken together, there are obvious differences between burn wounds and chronic non-healing wounds regarding the role of wound contamination and indication for silver preparations or dressings. Consequently, extrapolation from either class of wound to the other should be considered with great care.

Toxicity of topically applied silver preparations

While the exact requirements for silver ion delivery in non-healing wounds are not known, the side effects of silver ions on cells are well recognised [13]. Again, this knowledge comes from *in vitro* studies on cultured cells [14, 15], *ex vivo* models of cutaneous infection [16] or animal models [17, 18]. The toxic effects of silver ions in the clinical setting were also reported [19, 20]; outright toxicity is evident when therapeutically employed in hypergranulating wounds treated with silver nitrate stick preparations.

The toxicity of silver ions *in vitro* is very pronounced and dose dependent. It is important to stress that these tests are normally performed in serum-containing media to analyse the viability of cells as well as the inhibitory effects on cell proliferation. In animal models, Burrell, who is credited for discovering nanocrystalline silver-containing dressings,

showed that wound healing is not impaired even when high silver-releasing dressings are used. This included normally healing wounds [17] as well as normally healing wounds which were inoculated with pathogenic bacteria [18]. Both studies were using young animals, which may correlate very well with burn patients but only partially reflects the wound healing situation in aged organisms [21-23]. However, there are significant differences between wound healing in young and elderly subjects, which can be mostly attributed to concomitant underlying diseases [24].

When carefully analysing the effects of silver dressings on normally healing wounds in humans, somewhat conflicting findings were reported. One study found no evidence of toxicity for high silver-releasing wound dressings [20], while the other study showed a marked delay in wound healing of donor sites [19]. Demling *et al.* compared nanocrystalline, high silver-releasing dressings with a topical preparation of neomycin and polymyxin. They analysed 20 burn patients with deep burns of over 15% of total body surface area; one meshed skin graft area was treated with the antibiotic solution and the second with the silver dressing. Infections were not noted and, at Day 7, re-epithelialisation was complete in the silver dressing treated area, whereas only 55% of the neomycin/polymyxin treated area was closed, reaching closure at Day 10. In this context, it should be kept in mind that, for neomycin, an inhibition of angiogenic activity of fibroblast and epidermal growth factors was shown [25]. This might explain some of the findings, as both substances may have had some inhibitory activity.

A neutral control was used in a study by Innes *et al.* who compared nanocrystalline silver dressings to foam dressings. This showed a significant delay in wound healing in 15 patients (16 paired sites). The donor sites dressed with Allevyn foam dressing were re-epithelialised (>90%) after 9.1±1.6 days (mean) while the Acticoat treated sites required 14.5±6.7 days to achieve >90% wound re-epithelialisation ($p=0.004$). Furthermore, after 1 and 2 months, scar measurements were significantly worse in the Acticoat treated wound group, yet, this normalised at Month 3 [19].

Thus, there is clinical evidence that silver toxicity is indeed a relevant problem. The benefits of silver release need to be balanced against potential harmful effects when deciding on choosing suitable silver dressings for use on non-healing wounds. For burn patients, a high silver release rate may be desired; for non-healing wounds, the toxic side effects may even inhibit repair.

The need of biocompatible silver dressings for non-healing wounds

From long-standing empirical evidence, it is obvious that silver dressings have their place in treatment options and that patients with non-healing wounds can benefit from these dressings. As mentioned above, antimicrobial activity of silver dressings in non-healing wound tissue where bacteria have translocated is largely missing [12]; this is an area which requires further detailed analysis. However, observational studies have shown that non-healing wounds improve when treated with these dressings, which also appear to have additional effects such as anti-inflammatory properties. Moreover, the released silver ions were reported to decrease matrix metalloproteases [18]. These are highly elevated in non-healing wounds and normalise when the wounds improve and healing progresses [26]. Perhaps these mechanisms are underestimated currently and are far more important in the treatment of non-healing wounds with silver-containing dressings.

We therefore became interested in the formulation a silver-containing dressing which releases sufficient amounts of silver ions for strong antimicrobial activities, yet which avoids the pronounced cytotoxic activity of some of the silver dressings. The rationale was that, in the absence of exact data on how much ionised silver needs to be delivered, the potential damage of too much silver should be avoided.

A new silver dressing with strong antimicrobial activity and low cytotoxicity

We developed a newly formulated silver-containing ointment tulle dressing, Atrauman Ag. The format was chosen to allow unrestricted clinical use. It can be used with virtually any secondary dressing, allowing adaptation of the dressing technique to the special wound requirements. A polyamide tulle onto which silver is deposited serves as the dressing base. The ointment phase is composed of a lipid mixture which can be metabolised by the surrounding cells, thus avoiding vaseline remnants in the wound bed. Atrauman Ag effectively killed a panel of commensal skin and pathogenic bacterial strains, including a methicillin-resistant *Staphylococcus aureus* strain (MRSA) (Table 1).

The duration of antimicrobial efficacy is demonstrated in long-term experiments. When a fresh bacteria suspension was inoculated daily onto the same Atrauman Ag dressing for up to 9 days, the *S. aureus* and *Klebsiella pneumonia* cultures were killed efficiently – from $5x10^6$ colony forming units/ml (cfu) to less than 1 colony forming unit/ml after 9 days of seven repeated inoculations (Table 2). Thus, Atrauman Ag has strong, efficient and sustained antimicrobial activity.

Table 1. Bacterial strain (adapted [27]).

Bacterial strain	log_{10} reduction after 24 hours
Staphylococcus aureus	8.6
Staphylococcus aureus (MRSA)	6.3
Klebsiella pneumoniae	5.7
Pseudomonas aeruginosa	4.8
Escherichia coli	4.6
Bacillus subtilis	5.1

To test cellular cytotoxicity of Atrauman Ag, human HaCaT keratinocytes were used. Keratinocytes of the migrating tip of the epithelium were exposed to the highest concentrations of liberated silver ions in the wound bed. We compared Atrauman Ag with two other silver-containing dressings, Acticoat from Smith & Nephew and Actisorb 220 from Johnson & Johnson. Out of the three silver-containing dressings, Atrauman Ag had the lowest cytotoxic effects, with a viability of 90% (Table 3). Viability of keratinocytes with the Actisorb 220 dressing was slightly lower, with values of 80%, and Acticoat showed high cytotoxicity, with almost all cells being killed. It is important to note that these experiments were done in serum-containing media.

Our experiments are in line with a recent study examining the cytotoxic effects of high silver release nanocrystalline dressings in an animal burn model and transplanted skin equivalents. Within 1 day significant cytotoxicity was observed, but after 1 week *in vivo*, the skin equivalents recovered and the burn wounds healed [28]. Possibly it is the high initial silver dumping activity which causes toxicity; once this effect wears off, the lower silver ion levels become more compatible with cell survival.

Table 3. Viability (adapted [27]).

	Viability (%)
Atrauman Ag	90
Actisorb 220	80
Acticoat	1.6

Clinical evaluation of Atrauman Ag

Atrauman Ag was analysed in two separate prospective, multicentre observational studies in an outpatient setting. The first study involved 86 patients with traumatic as well as non-healing wounds of different aetiologies [27]. The second study analysed clinical performance of Atrauman Ag in 624 patients with predominantly chronic, non-healing wounds in an outpatient setting [29]. For both studies the aim was to test the clinical performance under circumstances which reflect daily practice as closely as possible and to avoid study conditions which analyse a very narrow, well-defined patient subgroup which is not representative of daily routine in an office based setting. For both studies, patients were treated with Atrauman Ag for three wound dressings; the clinical wound parameters were recorded before and after the study.

In the first study [27], the mean age was 73 years (±15 years) and 64% of the participants were female. Treatment with Atrauman Ag was for 9 days (±3.7 days), the interval between the three dressing changes was 3.1 days (±1.2 days), and all wounds had existed for 2 months (median) before the treatment with Atrauman Ag was initiated. Wound size at the start was 4 ± 3.2cm x 3.3 ± 3.4cm; 31% of the wounds were venous leg ulcers, 25% mixed leg ulcers and 18% traumatic wounds. The wound state was scored by the investigators; slough score was reduced from 59.2% to 35.8%, granulation tissue increased from 27% to 40%, and epithelialisation went up from 12.1% to 24%. Strongly exuding wounds decreased from 19.5% at the beginning to 2.3% at the end of the observation period.

Table 2. Bacterial inoculation load and viability (adapted [27]).

	24 hours	Day 2	Day 5	Day 6	Day 7	Day 8	Day 9
Bacterial inoculation load (cfu)	$1.8x10^7$	$2.1x10^6$	$5.7x10^6$	$1.3x10^7$	$6.3x10^6$	$1.5x10^7$	$1x10^6$
Bacterial viability (cfu)	<1	<1	<1	<1	<1	<1	<1
Inoculation number	1	2	3	4	5	6	7

Patient-reported pain sensation during dressing changes decreased from 78% to 45% in the course of the three dressing changes and 83% of the investigators reported that, in comparison to the initial examination, the condition of the wounds had improved.

In the second study [29], 624 patients were treated with Atrauman Ag again for the duration of three dressing changes. The demographic details and the most common underlying diseases are listed in Table 4. Before Atrauman Ag was evaluated, the patients were treated with ointment dressings (n=98), PU-foam dressings (n=68), hydrocolloids (n=66), other silver-containing dressings (n=60), and some were receiving concomitant systemic antibiotic treatment (n=110). In 364 patients, clinical signs of infection were recorded at the start of the study; *Staphylococcus* ssp. (n=60), *Pseudomonas* ssp. (n=25) and *Streptococcus* ssp. (n=17) were detected in wound swabs. Compression therapy for venous insufficiency was recorded in 270 patients. 27% of the patients had a reduced physical state due to underlying disease.

Treatment duration with Atrauman Ag was 23 days on average. Slough covered wounds were reduced from 35% at the beginning of the study to 3%. Likewise, the percentage of highly exuding wounds came down from 39% to less than 6%. Epithelialisation increased from 4.5% to 45% during the observation period. Signs of infection went down from 58% of the wounds to 20%, and patient-reported intermediate to strong pain sensation decreased from 40% to 6.5%. At the end of the study, 53.5% of patients reported no pain at all (from 17% at the beginning). Wound size decreased from 4.9cm (±3.8) x 3.3cm (±2.6), to 3.5cm (±3.6) x 2.4cm (±2.6) concomitant with improvement of the wound margins concerning inflammatory changes, oedema and maceration.

Table 4. Demographic variables and underlying pathology (adapted [29]).

Demographic variables	Values	
Subjects	624	
Male	61.4%	
Female	38.6%	
Age, mean (SD)	70 ± 16 years MaleMal	
Underlying pathology	**Duration**	**n**
Venous leg ulcers	1.57 ± 3.97 years	270
Arterial leg ulcers	1.2 ± 1.5 years	28
Mixed leg ulcer	3.0 ± 7.4 years	78
Diabetic foot ulcers	1.6 ± 1.5 years	57
Decubitus	5.96 ± 12 months	61
Other		139

Some patients had multiple underlying diseases

Investigators appreciated the versatility of Atrauman Ag; in particular it could be incorporated into any dressing protocol. Highly absorbent pads, compresses, PU foams, alginates and TenderWet were used without having to change dressing habits for a given wound and which were appropriate in the investigator's routine.

Both studies showed that wound healing improved (in an unselected panel of patients reflecting wound healing disorders most commonly encountered in daily practice). The wound condition improved after only three dressing changes and it appears that Atrauman Ag activated wounds which were senescent to progress into the next wound healing phase. Obviously the low cytotoxic profile was compatible with granulation tissue build-up and, most importantly, with epithelialisation.

Silver resistance development due to the use of silver dressings

Recently concerns were raised about the development of silver resistance due to silver exposure [30] or the widespread use of silver-containing dressings [11]. Silver resistance is compared to antibiotic resistance in some reviews, although these ignore the clinical implications. Antibiotics interfere with specific metabolic pathways in bacteria, limiting their growth or survival. Antibiotic resistance is naturally occurring – bacteria may not use the targeted metabolic pathway or resistance can be acquired through transfer of genetic information from one bacterium to the other, thus conferring resistance. Antibiotic resistance can be lost when selective pressure, i.e. antibiotic, treatment stops.

The main risk of antibiotic resistance for patients is the lack of response to antibiotic treatment when infection needs to be controlled such as in sepsis. Spread from one patient to the other occurs particularly in situations when hygienic precautions fail to control transmission of resistant bacteria. In the clinical setting, transmission of resistant bacteria from one patient to another is much more prevalent than

transmission of genetic elements conferring antibiotic resistance from one bacterium to another bacterial strain. Thus hygiene measures have an extremely high relevance in controlling the spread of antibiotic resistance in patients.

Silver, on the other hand, belongs to the group of antiseptics. The mode of action targets a much wider spectrum of metabolic pathways, hence resistance is more difficult to develop, although it may occur. Few clinical cases of silver resistance have been reported in the literature as a clinical problem.

One of the most prominent reports described antibiotic and silver resistance in three patients in a burn unit in 1973 [31]. Subsequently, the genetic elements conferring silver resistance have been isolated and analysed on the molecular level in detail [32-34]. When reviewing the patients' histories, the incident was traced back to one burn patient admitted with third and fourth degree electrical burns involving 30% of body-surface area. After surgical debridement, infection developed, despite topical silver nitrate (0.5%) use; systemic antibiotic treatment was commenced. Sepsis could not be controlled and hypotension and oliguria ensued, from which the patient did not recover.

Microbiologic examination revealed, among others, *S. typhimurium* with multiple antibiotic resistances as well as silver resistance on one piece of genetic information (plasmid). Interestingly, the bacteria harbouring this plasmid were detected in a stool sample, which suggests that the primary reservoir might have been in the digestive tract of this patient. In this patient, sepsis could not be controlled because of the antibiotic resistances.

The other two patients did not have direct contact with the first patient or with each other. They were also admitted to the same burn unit for third degree burn injuries of 35% and 80% respectively. They also developed sepsis which was not controllable by antibiotic treatment, and the same antibiotic and silver resistances were detected in microbiologic cultures. Despite thorough investigation, the mode of transmission between the patients could not be clarified and the burn unit was closed down [31].

Reports on silver resistance in patients with chronic, non-healing wounds are missing in the literature and it appears that this has not been identified as a clinical problem to date. This is surprising as the first silver dressings were introduced more than 30 years ago for non-healing wounds; when comparing this with antibiotic resistance development, this should have been ample time for silver resistance to develop and to become a clinical problem. One possible explanation why this is not the case is that silver preparations are used topically as an antiseptic but cannot be used systemically like antibiotics. Hence, if infection develops, systemic antibiotics and surgical debridement is the mainstay of therapy and whether silver resistance is present becomes irrelevant.

There are also no reports available which describe increasing systemic infections in patients with chronic non-healing wounds as a result of silver resistance development. From a clinical point of view, silver resistance has not become a major issue in patients with chronic non-healing wounds; these are mostly contaminated and, despite treatment with silver-containing dressings, cannot be sanitised [12].

The situation may be different in burn patients. Silver preparations are used to prevent infection and reduce the risk of sepsis. Either patients introduce bacteria with silver resistance into burn units (which probably is a rare event) or acquire silver resistant bacteria as nosocomial infection (which should prompt review of hygiene measures in a clinical setting). However, even in burn units where silver has been used for several decades, silver resistance has not been correlated to poorer outcomes or emerged as major clinical issue.

Moreover, apart from direct medicinal use, silver is ubiquitously encountered in our environment. Silver- and antibiotic-resistant *Enterobacter cloacae* have been isolated from teeth [35], while silver-containing water filters are prominent examples of household exposure. It is possible that the development of silver resistance may evolve from these uses of silver or at sites of industrial silver release (as was shown in the case of mercury resistance in toxic waste contaminated environments [36, 37]). It may prove difficult to prevent non-medicinal use of silver and thus avoid emergence of silver resistance in the environment. This is a clear distinction from antibiotics which are largely confined to the medicinal setting.

Finally it should be noted that it is possible to generate silver resistant bacterial strains under experimental conditions. The underlying mechanisms of how resistance develops are of great scientific interest; nevertheless, extrapolation to the clinical setting and elaboration of frightening scenarios is inappropriate. The clinical consequences are far from clear and, when balancing against the benefits of silver preparations on chronic non-healing wounds versus the

potential of silver resistance, the benefits outweigh the potential risks by far. It must be stressed that silver resistance can not be equalled with antibiotic resistance from a clinical perspective, there are fundamental differences.

Conclusion

Silver-containing wound dressings have introduced new therapeutic options to treat chronic non-healing wounds. While it was shown that they can not sanitise contaminated or infected wounds, wounds do improve, inflammation is reduced and, if cellular toxicity is avoided, difficult to heal wounds may eventually progress to the next healing phase and close. We have observed additional mechanisms of how silver-containing dressings can help with non-healing wounds apart from the direct antimicrobial activity.

Editor's note

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References

1. Owens CJ, Yarbrough DR & Brackett NC. Nephrotic syndrome following topically applied sulfadiazine silver therapy. Arch Intern Med 1974; **134**:332-5.
2. Coombs CJ, Wan AT, Masterton JP, Conyers RA, Pedersen J & Chia YT. Do burn patients have a silver lining? Burns Incl Therm Inj 1992; **18**:179-84.
3. Jarrett F, Ellerbe S & Demling R. Acute leukopenia during topical burn therapy with silver sulfadiazine. Am J Surg 1978; **135**:818-9.
4. Wang XW, Wang NZ, Zhang OZ, Zapata-Sirvent RL & Davies JW. Tissue deposition of silver following topical use of silver sulphadiazine in extensive burns. Burns Incl Therm Inj 1985; **11**:197-201.
5. Kulick MI, Wong R, Okarma TB, Falces E & Berkowitz RL. Prospective study of side effects associated with the use of silver sulfadiazine in severely burned patients. Ann Plast Surg 1985; **14**:407-19.
6. Thomson PD, Moore NP, Rice TL & Prasad JK. Leukopenia in acute thermal injury: evidence against topical silver sulfadiazine as the causative agent. J Burn Care Rehabil 1989; **10**:418-20.
7. Maitre S, Jaber K, Perrot JL, Guy C & Cambazard F. Increased serum and urinary levels of silver during treatment with topical silver sulfadiazine. Ann Dermatol Venereol 2002; **129**:217-9.
8. Muller G, Winkler Y & Kramer A. Antibacterial activity and endotoxin-binding capacity of Actisorb Silver 220. J Hosp Infect 2003; **53**:211-4.
9. Thomas S & McCubbin P. A comparison of the antimicrobial effects of four silver-containing dressings on three organisms. J Wound Care 2003; **12**:101-7.
10. Dunn K & Edwards-Jones V. The role of Acticoat with nanocrystalline silver in the management of burns. Burns 2004; **30**:S1-S9.
11. Burrell RE. A scientific perspective on the use of topical silver preparations. Ostomy Wound Manage 2003; **49**:19-24.
12. Sibbald RG, Browne AC, Coutts P & Queen D. Screening evaluation of an ionized nanocrystalline silver dressing in chronic wound care. Ostomy Wound Manage 2001; **47**:38-43.
13. Hollinger MA. Toxicological aspects of topical silver pharmaceuticals. Crit Rev Toxicol 1996; **26**:255-60.
14. Lam PK, Chan ES, Ho WS & Liew CT. In vitro cytotoxicity testing of a nanocrystalline silver dressing (Acticoat) on cultured keratinocytes. Br J Biomed Sci 2004; **61**:125-7.
15. Poon VK & Burd A. In vitro cytotoxicity of silver: implication for clinical wound care. Burns 2004; **30**:140-7.
16. Schaller M, Laude J, Bodewaldt H, Hamm G & Korting HC. Toxicity and antimicrobial activity of a hydrocolloid dressing containing silver particles in an *ex vivo* model of cutaneous infection. Skin Pharmacol Physiol 2004; **17**:31-6.
17. Olson ME, Wright JB, Lam K & Burrell RE. Healing of porcine donor sites covered with silver-coated dressings. Eur J Surg 2000; **166**:486-9.
18. Wright JB, Lam K, Buret AG, Olson ME & Burrell RE. Early healing events in a porcine model of contaminated wounds: effects of nanocrystalline silver on matrix metalloproteinases, cell apoptosis, and healing. Wound Repair Regen 2002; **10**:141-51.
19. Innes ME, Umraw N, Fish JS, Gomez M & Cartotto RC. The use of silver coated dressings on donor site wounds: a prospective, controlled matched pair study. Burns 2001; **27**:621-7.
20. Demling RH & DeSanti L. The rate of re-epithelialization across meshed skin grafts is increased with exposure to silver. Burns 2002; **28**:264-6.
21. Swift ME, Kleinman HK & DiPietro LA. Impaired wound repair and delayed angiogenesis in aged mice. Lab Invest 1999; **79**:1479-87.
22. Swift ME, Burns AL, Gray KL & DiPietro LA. Age-related alterations in the inflammatory response to dermal injury. J Invest Dermatol 2001; **117**:1027-35.
23. Mogford JE, Sisco M, Bonomo SR, Robinson AM & Mustoe TA. Impact of aging on gene expression in a rat model of ischemic cutaneous wound healing. J Surg Res 2004; **118**:190-6.
24. Van de Kerkhof PC, Van Bergen B, Spruijt K & Kuiper JP. Age-related changes in wound healing. Clin Exp Dermatol 1994; **19**:369-74.
25. Hu GF. Neomycin inhibits the angiogenic activity of fibroblast and epidermal growth factors. Biochem Biophys Res Commun 2001; **287**:870-4.
26. Trengove NJ, Stacey MC, MacAuley S, Bennett N, Gibson J, Burslem F *et al.* Analysis of the acute and chronic wound environments: the role of proteases and their inhibitors. Wound Repair Regen 1999; **7**:442-52.
27. Ziegler *et al.* 2005. In press.
28. Supp AP, Neely AN, Supp DM, Warden GD & Boyce ST. Evaluation of cytotoxicity and antimicrobial activity of Acticoat burn dressing for management of microbial contamination in cultured skin substitutes grafted to athymic mice. J Burn Care Rehabil 2005; **26**:238-46.
29. Zoellner *et al.* 2005. In press.
30. Gupta A & Silver S. Silver as a biocide: will resistance become a problem? Nat Biotechnol 1998; **16**:888.
31. McHugh GL, Moellering RC, Hopkins CC & Swartz MN. *Salmonella typhimurium* resistant to silver nitrate, chloramphenicol and ampicillin. Lancet 1975; **1(7901)**:235-40.
32. Gupta A, Matsui K, Lo JF & Silver S. Molecular basis for resistance to silver cations in Salmonella. Nat Med 1999; **5**:183-8.
33. Gupta A, Phung LT, Taylor DE & Silver S. Diversity of silver resistance genes in IncH incompatibility group plasmids. Microbiology 2001; **147**:3393-402.
34. Li XZ, Nikaido H & Williams KE. Silver-resistant mutants of *Escherichia coli* display active efflux of Ag^+ and are deficient in porins. J Bacteriol 1997; **179**:6127-32.
35. Davis IJ, Richards H & Mullany P. Isolation of silver- and antibiotic-resistant *Enterobacter cloacae* from teeth. Oral Microbiol Immunol 2005; **20**:191-4.
36. Nakamura K & Silver S. Molecular analysis of mercury-resistant Bacillus isolates from sediment of Minamata Bay, Japan. Appl Environ Microbiol 1994; **60**:4596-9.
37. Filali BK, Taoufik J, Zeroual Y, Dzairi FZ, Talbi M & Blaghen M. Waste water bacterial isolates resistant to heavy metals and antibiotics. Curr Microbiol 2000; **41**:151-6.

Wounds with a silver lining

Rosalind Probert • Sarah Burston

Abstract

In our practice we have used wound management products that contain silver on pressure ulcers, donor sites, acute, chronic and malignant wounds. These initial applications have proved effective, providing positive anecdotal evidence. In this article four case studies are discussed; we will use these as a springboard to further explore the use of silver dressings and to collate evidence to support their use.

Luke sustained multiple fractures and friction burns as a result of a motorbike accident. Acticoat Ag® was used over the friction burns, resulting in complete re-epithelialisation in 5 days. Amanda, a wheelchair bound spina bifida patient, had Stage IV pressure ulceration on her buttocks and a complex care history. Aquacel Ag® and a VAC® were used to effectively manage Amanda. Daniel had spinal fusion and wound dehiscence following a fall in a mountain range and subsequent air retrieval. Daniel had a non-Methicillin-resistant *Staphylococcus aureus* (MRSA) infection in the wound. Aquacel Ag, foam and suction were applied to the wound to facilitate healing and allow transfer from the acute setting to the spinal rehabilitation programme.

Betty had an isolated limb infusion of chemotherapy for treatment of melanoma. Subsequent to discharge there was necrosis at some digits and ongoing inflammatory reaction. Admission was required to treat the wounds. We used Aquacel Ag, Alione®, Contreet Foam®, Polymem Ag® and Acticoat® at various stages of the healing process. Medical impatience dictated a change to silver sulphadiazine® (SSD) cream. Five days of treatment with SSD demonstrated deterioration in the wound and the medical decision at that time was to return to the previous dressing.

Probert R, Burston S. Wounds with a silver lining. Primary Intention 2005; 13(4): S10-S14.

Introduction

Silver dressings have been increasingly developed in a variety of formulations such as hydrofibre, polyurethane foam and in sheet form, utilising different methods of making the silver available in the dressing and at the wound bed. They differ in composition, presumed mechanism of action and rate of silver release [1]. We have used these products in wounds of differing aetiology such as pressure ulcers, donor sites, acute, chronic and malignant wounds.

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Case studies

Luke

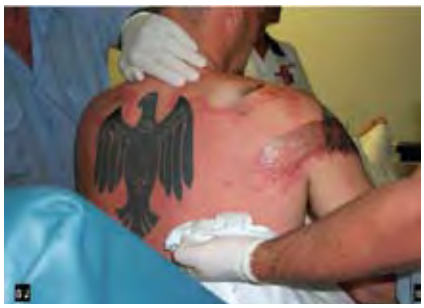
Luke sustained fractures and friction burns as a result of a motorbike accident in April 2002 and was taken to the operating theatre for management of his fractures. Twenty four hours later, we reviewed the friction burns to his shoulders which were causing significant pain upon movement, therefore impairing mobility and respiratory function. Luke sustained Stage II skin damage across his shoulders and upper back (Figure 1). Discolouration of the tissue occurred due to the epidermis burrowing into the dermal tissue – this was a result of friction as Luke's body skidded along the road.

Acticoat® was the dressing chosen as there was a potential for infection from the nature of the injury (the wound being superficial) and the wound required a reduced number of dressing changes (Figure 2). Exudry® was used as a secondary

dressing to absorb the volume of exudate secreted by the new abrasions. The dressing was anchored *in situ* with a semipermeable film.

The dressing was left intact for 3 days, then was changed in the operating theatre as part of another procedure. A film was noted to cover the surface of the wound at the time of the dressing change (Figure 3). The film was left in place and the new dressing applied. The next dressing change 2 days later revealed the wounds had re-epithelialised (Figure 4). This case study demonstrates the efficacy of Acticoat in an acute and potentially infected wound.

Figure 1.



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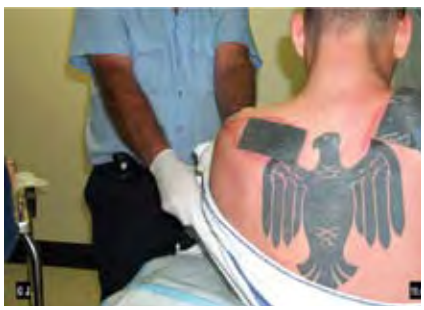

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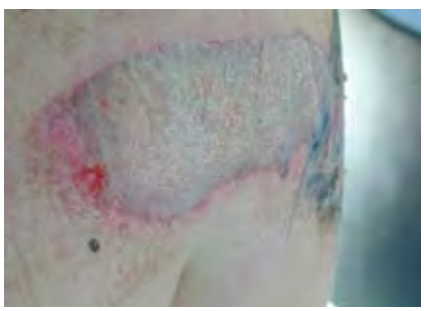

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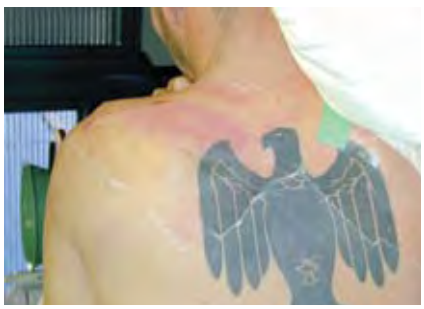


Amanda

Amanda was a 20 year old who had spina bifida and was mobilised in a wheelchair. She had developed a Stage IV pressure ulcer on her sacrum. Amanda had had Harrington rods inserted and was previously admitted in 2003 when the wound, which had never healed following insertion of the rods, deteriorated. Movement of the rods, pressure and non-compliance with pressure area care and hygiene had contributed to the deterioration. Saline packs and negative pressure dressings (KCI VAC®) were used. The wound improved and Amanda was discharged with the wound almost healed.

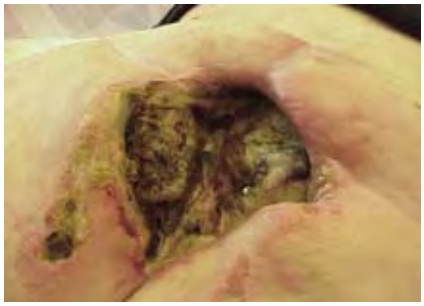
Subsequently, Amanda was readmitted in March 2004 with further deterioration of the wound. Amanda was unaware of the size of the wound as she had never visualised it. Using a digital camera, a photograph was taken and this was shown to Amanda. As a result, compliance to treatment improved as Amanda now understood the extent of the problem. The wound was necrotic with the rods exposed and, following surgical debridement, exposed bone was visible (Figure 5).

Saline packs were then used for 6 weeks to promote a clean wound bed. Amanda had no sensation in the wound area. Once the wound was clear of slough, a negative pressure dressing was applied. The wound continued to progress and healthy granulation tissue was visible in the wound. It was noticed that, from Week 12, the healing improved at a slower rate and the wound appeared static. Reassessment of the wound revealed a granulating cavity wound. Wound culture revealed colonisation of the wound with *Proteus* sp and *E. faecalis.*

The negative pressure dressing was felt to be helpful as it sealed the wound, reducing the risk of faecal contamination. Therefore it was decided to use a silver product underneath the VAC dressing to assist with the wound colonisation. Aquacel Ag® was chosen as it delivered silver in the form of a hydrofibre so that it was easily applied to a cavity wound (Figure 6).

After 3 weeks of the Aquacel Ag and VAC dressing, increased granulation and a reduction in wound size could be seen and the wound continued to progress up to discharge. Amanda was discharged on this treatment regime and continues to heal (Figure 7).

Figure 5.



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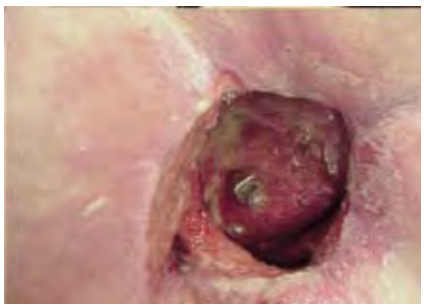

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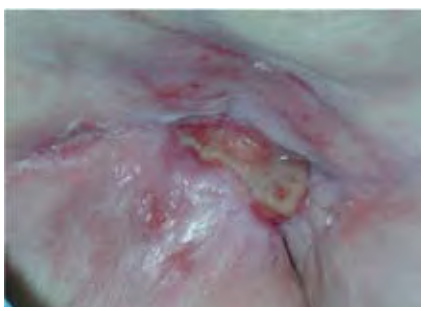


Daniel

Daniel fell 20 metres while climbing and sustained a traumatic brain injury and spinal cord injury, resulting in paraplegia, visual loss and endocrine disturbances. Spinal fusion was performed to stabilise Daniel's spinal injury.

The wound dehisced and, on review, non-Methicillin-resistant *Staphylococcus aureus* (MRSA) had been cultured. The wound was located on the thoracic spine and was 22x5x3.5cm, with a creamy green wound bed and malodorous exudate. A metal pin was on view in the wound bed.

Neurosurgeons had been taking Daniel to theatre second daily for washouts of the wound but felt there was slow improvement in the wound status with this high cost management plan. Review was requested 3 months post initial injury with the view of improved management and outcome for Daniel.

The treatment plan implemented was an Aquacel Ag dressing to the wound bed. A suction dressing using layers of polyurethane foam and redivac tubing covered with a semi permeable film and connected to low wall suction was applied. Aquacel Ag was selected for the documented antimicrobial properties[2]. The subsequent dressing change revealed a clean, red and granulating wound bed (Figures 8, 9 & 10).

This treatment was continued for 5 weeks, at which time the wound had contracted in size and looked clean. We decided to cease the suction dressing and the Aquacel Ag to the wound bed and use Aquacel® with a polyurethane foam dressing and semipermeable cover. Review of the wound 3 days later was disappointing, as the creamy green exudate and malodour had returned. The wound at this time was 12cm long x 1cm wide and superficial.

Acticoat was selected as the dressing because the wound was superficial, low exudating and the dressing had a higher concentration of available silver. The wound healed with this regime, allowing Daniel to be transferred to the spinal injuries unit for rehabilitation 4 weeks later (Figure 11).

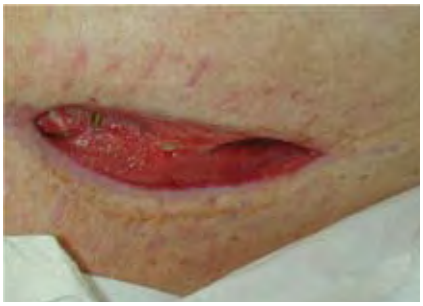
The Aquacel Ag in this case study would appear to have maintained a bacteriostatic action in the wound bed but, when ceased, colonisation returned. Introduction of Acticoat to the wound bed facilitated healing without further exacerbation of colonisation.

Betty

Betty had an isolated limb infusion of chemotherapy for treatment of melanoma. Subsequent to discharge there was necrosis at some digits and ongoing inflammatory reaction. Admission was required to treat the wounds. We used Aquacel Ag, absorbent dressings, Contreet Foam®, Polymem Ag® and Acticoat at various stages of the healing process on the multiple wounds. Medical impatience dictated a change to silver sulphadiazine® (SSD) cream. Five days of treatment with SSD demonstrated deterioration in the wound and the medical decision at that time was to return to the previous dressing.

Assessment of the right foot revealed a large blister, erythema, oedema, vascular compromise, open wounds and pain (Figures 12, 13 & 14). There was also ulceration of the medial and lateral shin above the malleolus where previous excision of melanoma and skin grafting had been performed. Aquacel Ag was chosen for its antimicrobial, formation of a gel on the wound bed and vertical wicking properties. Exudate was managed with Alione® high absorbent waterproof dressing. This dressing was applied to all wounds (Figures 15 & 16).

Figure 8.



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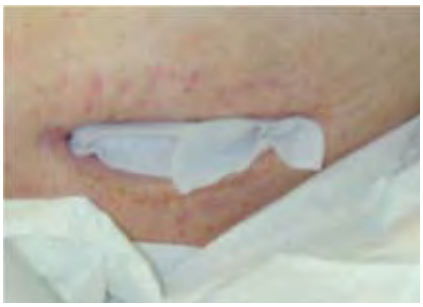

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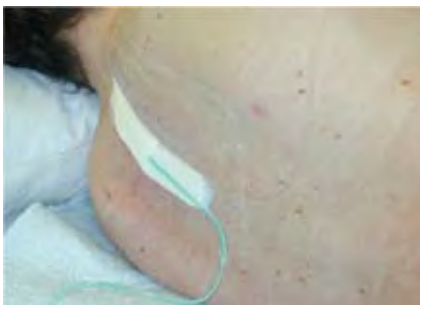

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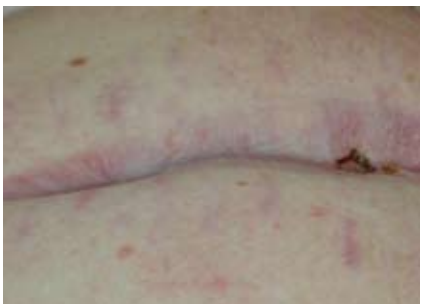

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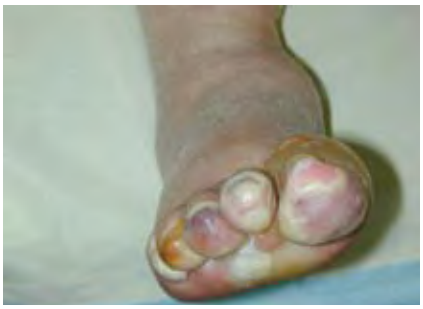

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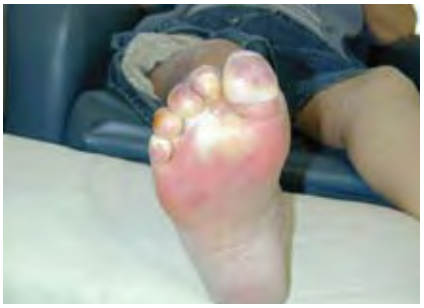

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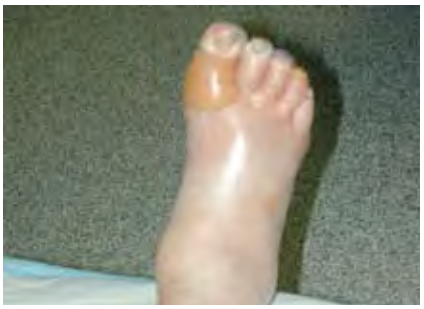

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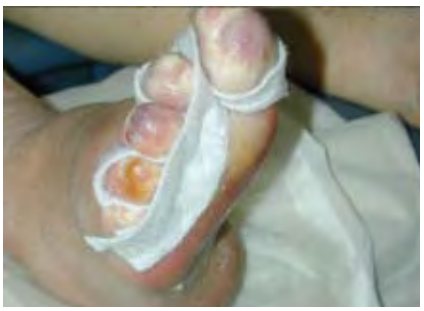

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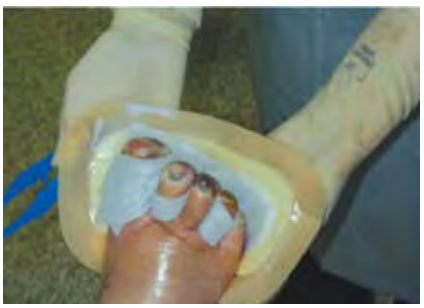


Reassessment after 14 days found the wounds healing but with ongoing waves of inflammatory reaction occurring. Aquacel Ag was continued on the foot wound and Contreet Foam added to assist in exudate management and control any colonisation of the wound. The medial graft remained sloughy, therefore a hypertonic saline dressing was implemented, and found to be effective (Figures 17, 18, 19 & 20). Two weeks later, Betty's right leg became increasingly

oedematous and wound progress stagnated. We decided to trial Polymem Ag to observe if there was a difference in the efficacy of the silver dressings. The Polymem Ag was unable to manage the exudate and caused significant maceration of the surrounding skin and wound. Acticoat and polyurethane foam were implemented to manage the wound. Persistent leg oedema impeded healing of the wounds.

The medical officers at that time were disappointed that the wound had stagnated and decided to use SSD dressing. The SSD was not effective and there was an increase in slough in all wound areas (Figure 21).

Reintroduction of Acticoat and polyurethane foam decreased slough on the wound bed. Betty was discharged home using Acticoat and polyurethane foam. The wounds continued to progress and healed within 4 weeks.

Outcomes

The case reports suggest several outcomes when wound management products containing silver are used. They:

- Assist in the reduction of bacterial loading and control colonisation.
- Protect from secondary infection.
- Reduce pain – due to fewer dressing changes and non adherence.
- Accelerate healing (some of the silver containing products).
- Are cost effective due to the reduction in visits to operating theatre

These outcomes are generalisations from the case reports and may not be applicable to all scenarios. They also require further investigation to substantiate.

Conclusion

Now that we have gained experience with several of the wound management products containing silver, we need to progress to looking more closely at the differences in effectiveness between the dressings and their applications.

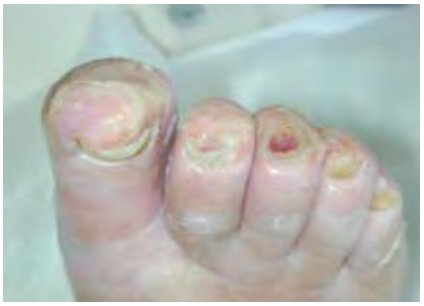
Editor's note

This article was submitted to *Primary Intention* on request following the Silver Symposium, Perth Western Australia in September 2005.

References

1. Lansdown A. A review of the use of silver in wound care: facts and fallacies. Br J Nurs (Tissue Viability Supplement) 2004; **13(6)**:S6- S19.
2. ConvaTec. What makes Aquacel Ag the unique antimicrobial dressing? 2005.

Figure 17.



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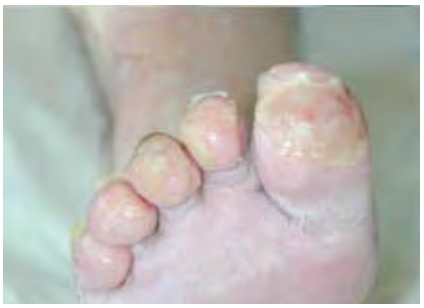

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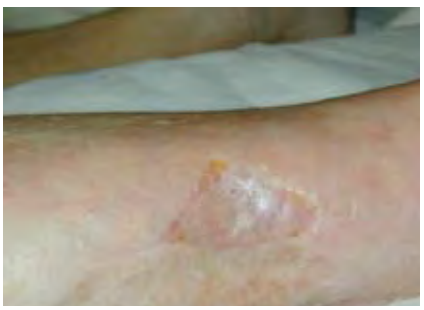

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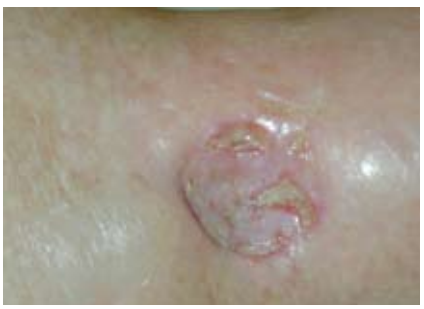

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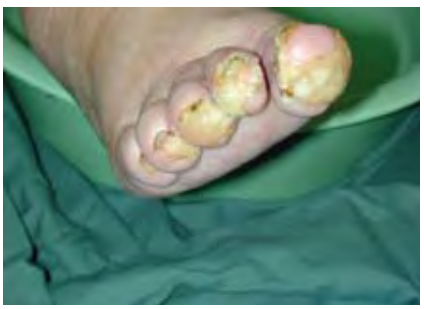

The use of silver products in the management of burn wounds: change in practice for the burn unit at Royal Perth Hospital

Joy Fong

Abstract

The aim of this paper is to describe and discuss the properties and applications of silver in the management of burn wounds. Recent renewed interest in silver has resulted in the development of new silver delivery systems. Silver is a broad spectrum antibiotic with antiseptic, antimicrobial, anti-inflammatory and pro-healing properties. Free silver cations released in a wound have a potent antimicrobial effect, destroying bacteria by the process of cell replication inhibition, blocking cellular respiration and cell functional structure. Research indicates that the effectiveness of the silver dressing is related to the bacterial burden in the wound and the delivery of silver must be at the right concentration over an appropriate time. Research into silver toxicity reveals low mammalian toxicity; 'agyria' is the most common side effect.

There is limited documentation on silver bacterial resistance. Burn wounds are susceptible to infection, often exacerbated by immuno-suppression associated with burn injury. Burn wound infections remain the main cause of mortality and morbidity for patients with burn injuries.

The common silver products used in burn wound management are silver sulphadiazine cream (SSD), Flammercerium, silver nitrate 0.5% solution, Acticoat™, Acticoat Absorbent, Aquacel Ag and silver hydrocolloids such as ContreetH. Several investigations found that Acticoat is more effective than other silver dressings. The burn unit at Royal Perth Hospital, after conducting patient care audits to evaluate the effectiveness of Acticoat as compared to Silvazine™, found Acticoat more effective and cost effective. The unit subsequently changed their practice of early burn wound management to Acticoat dressings for all partial to full thickness burn admissions.

Fong J. The use of silver products in the management of burn wounds: change in practice for the burn unit at Royal Perth Hospital. Primary Intention 2005; 13(4): S16-S22.

Introduction

This paper aims to describe the properties and applications of silver in the management of burn wounds. In recent years, the interest in silver as a topical agent for treating wounds has resurged. Silver was used historically for treating maladies and diseases, although the actual healing mechanism of silver was not scientifically known at that time as empirical science was not practised till much later [1]. Since ancient times, silver has been used for disinfecting stored water or liquids; both the ancient Greeks and early American settlers used silver for this purpose [2]. Before the 1800s, silver nitrate was used for treating epilepsy, venereal infections, acne and leg ulcers. Silver foil applied to surgical wounds improved healing and reduced post-operative infections, whilst silver pencils were used to remove warts and debride ulcers [1, 2].

In the late 19th century, Crede discovered that instilling 1% silver nitrate solution into conjunctiva sacs reduced post-partum eye infections. By the early 1900s it was discovered that silver nitrate could release silver ions to form soluble silver albuminates [1].

Recently, the concept of biological burden or bacterial burden has generated considerable interest for clinicians. A biological burden is placed on the wound not only by the bacteria

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present in the wound but also by the chemical substances they produce [3]. Bacterial cells produce and secrete a variety of enzymes and toxins into the wound which may impede wound healing. One reason for the renewed interest in silver products is its ability to reduce the biological burden of the wound [3]. Research indicates that the effectiveness of the silver dressing is related to the bacterial burden in the wound; the delivery of silver must be at the right concentration over an appropriate time.

Another reason for further research into the use of silver is that silver cations does not incur resistance and are effective against a wide range of micro-organisms [3-5]. Silver is therefore used to treat infections or as a prophylaxis on various wounds such as burns, chronic wounds, leg or pressure ulcers and bladder infections.

Action of silver

Silver has antiseptic, antimicrobial, anti-inflammatory properties and is a broad spectrum antibiotic [1-3]. In recent years, new silver delivery systems have been developed which include silver salts, silver complexes and silver coatings. These products deliver silver as foams, films, alginates, hydrocolloids, hydrogels, fabrics and wound contact layers [3].

Silver cation is the active ingredient of silver. Free silver cations have a potent antimicrobial effect and can destroy micro-organisms immediately by blocking the cellular respiration and the function of bacterial cell membranes. This occurs when silver cations bind to tissue proteins, causing structural changes in the bacterial cell membranes which in turn cause cell death [1, 3, 4]. Silver cations also bind and denature the bacterial DNA and RNA, thus inhibiting cell replication [1-3, 5-8].

Silver toxicity and resistance

Research into the toxicity of silver shows that absorbed silver will interact with other metals and tissue proteins; however, no proven permanent harmful effects to the body are established [1, 2, 8-11]. The most common side effect seen, especially with excessive oral intake of silver, is 'agyria' which is a process of silver granule deposition in the skin leading to a grey blue brown discolouration. Agyria can occur in bodily organs but no toxicity has yet been identified. There is evidence that silver is also absorbed systemically and is excreted in urine [1, 8, 11-13].

In some instances, silver sulphadiazine (SSD) has been found to cause stinging, burning or a rash. This may be attributed to the sulphadiazine component rather than the silver component. In addition, transient leucopenia has been observed in people treated with SSD. Experimental animal studies indicated SSD suppresses lymphocytic and T-cell activity and is toxic to bone marrow progenitor cells, thus inhibiting wound healing through immunosuppression [3, 9, 12, 14-17,20].

Whilst one investigation found that a sustained released silver dressing can delay epithelialisation in donor sites, other investigations revealed that silver cations are more toxic to mammalian cells with low bacteria burden than those with a high bacteria burden. Cells with a low bacteria burden are cells that move in a monlayer manner (epithelial cells), whilst cells with a high bacteria burden are cells with a three dimensional association (fibroblasts) [3, 18].

Literature indicates that there is a development of bacterial resistant species in burn patients treated with SSD or silver nitrate over the years [3, 12]. New silver delivery products have not been used in the treatment of burn wounds for long. Whilst nothing yet has emerged in literature regarding resistant strains to these dressings, Orvington, in 2004, stated that at least one *in vitro* study revealed the culture of a resistant Pseudomonas strain beneath silver products, but it seemed to be a temporary resistance [3]. It is clear that more research into silver toxicity and resistant strains is to be conducted for clearer understanding into this area.

Burn wound infections and sepsis

Burn wounds are susceptible to infection due to the impairment of skin integrity and reduction in cell mediated immunity [12, 19-23]. Once skin integrity is breeched, wound colonisation and invasion of bacteria can occur. Infection or sepsis is present in a burn wound when deposition and multiplication of bacteria in the tissue is associated with host reaction or invasion of nearby healthy tissue and a bacterial count of $10^5 g^{-1}$ of tissue [19, 22-23].

Burn injury results in tissue destruction; the presence of an avascular burn eschar provides an environment for infection that can progress to septicaemia [1, 24]. Infection is exacerbated by immuno-suppression often associated with burn injury [25]. The rate of infection depends on the extent of the burn injury, general wound care and various host factors such as nutritional state, age, immune status and any co-morbidity factors. In addition to the increasing number of burn wound infections, the emergence of Methicillin Resistant *Staphylococcus aureus* (MRSA) and Multi-resistant *Pseudomonas aeruginosa* concerns clinicians as the control of

burn wound sepsis is vital to survival of the patient [5, 23-25]. Burn wound infections remain as the main cause of morbidity and mortality for patients with burn injuries.

Silver products used in burn management

The common silver products used in burn wound management are SSD cream, Flammercerium, silver nitrate 0.5% solution, Acticoat, Acticoat Absorbent, Aquacel Silver and silver hydrocolloids such as ContreetH.

Silver sulphadiazine cream (SSD)

Prior to the invention of SSD cream, there was a high mortality from sepsis in those with burn injuries. Up to until the 1960s, burn wounds were allowed to dessicate or dry, often causing pain when the burn eschar contracted.

In the late 1960s, Fox introduced SSD cream to treat burn wounds [12, 14]. SSD cream is a white, highly insoluble compound made from silver nitrate and sodium sulphadiazine. The cream is available in 1% w/w silver concentration in a water-soluble cream. It has an *in vitro* activity against a wide range of organisms including *S. aureus, Escherichia coli, Klebsiella* species, *P. aeruginosa, Proteus* and *Candida albicans.*

The precise action of the active ingredients in SSD cream remains unclear; particularly the cream's penetration of the eschar is poor. One potential explanation for the effectiveness of SSD cream as an antibacterial is the strong bonding of the silver cation to DNA. This bonding differs from that seen in silver nitrate or other silver salts. Another possible reason is that SSD modifies the cell membranes of bacteria by creating structural changes that weaken the cell wall. The effectiveness of SSD depends on the slow, continuous reaction with serum and other sodium chloride containing body fluids, leading to a slow continuous release of silver ions in the wound [12, 14, 23].

After wound cleansing, the cream is applied once or twice daily, providing a moist wound-healing environment. A pseudo-eschar often forms over the burn wound surface, promoting wound healing as well as protecting the wound bed. However, wound assessment can be made difficult due to the presence of the pseudo-eschar. An advantage of SSD cream application is that the pseudo-eschar serves to reduce pain at the wound bed. However, since the inception of SSD cream for burn wound treatment, burn infection and sepsis have decreased, and there has been an improvement in burn mortality (Figures 1-3).

Figure 1. SSD cream product.

Figure 2. Burn wound for SSD cream.

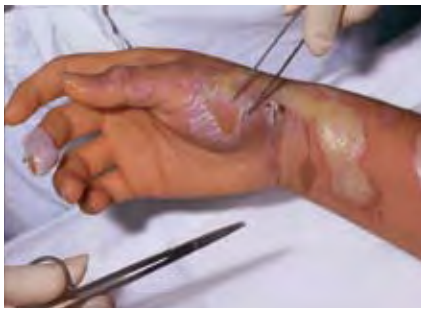
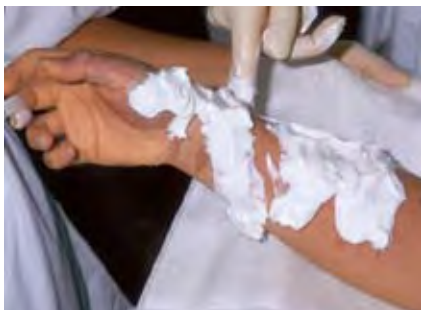


Figure 3. Application of SSD cream.



Flammercerium

This is a white sterile hydrophilic cream composing of SSD 1% w/w and cerium nitrate 2.2% w/w. Its action is similar to SSD, yet it has the added effect of suppression of cell mediated immunity in people with severe burns. Flammercerium forms a hard crusty layer over the burn wound. The method of application is similar to that of SSD. However, a dressing change once every 3-4 days is required, compared to daily or twice daily when using SSD cream [12, 14, 23]. This is useful in the management of severe burn patients who are haemodynamically unstable and may not be able to tolerate the activities during dressing changes. Less frequent dressing changes results in less pain for the patients.

Silver nitrate 0.5% solution

This was introduced in the 1960s as a topical agent for burn wounds. It is effective against *Staphylococcus* and *Pseudomonas*

strains and many Gram-negative aerobes. The exact mechanism of silver nitrate solution as an antibacterial is unclear. The main complication is the reduction of blood sodium and chlorine levels during the use of silver nitrate for major burns; this causes hyponatraemia and staining of skin and any object it comes in contact with. It is painless to apply. Gauze wet with silver nitrate 0.5% solution is applied directly on the wound and secured with bandages or a stockinet. This dressing is re-moistened every few hours and should be changed daily [1, 14, 23] (Figure 4).

Acticoat™

Acticoat is a three-layered dressing constructing of a silver-coated mesh applied to either side of a rayon/polyester core. It contains nanocrystalline silver which releases clusters of highly reactive silver cations which then cause electron transport, inactivation of DNA, cell membrane damage and binding of insoluble complexes in micro-organisms [1, 23, 26, 27]. Research has indicated that sustained released silver products have a bactericidal action and provide effective management of odour and exudate [1, 8, 26, 27].

The antimicrobial barrier property becomes effective when moistened with sterile water. Moistening Acticoat has a two fold benefit: it unleashes the antimicrobial power of nanocrystalline silver and assists in maintaining a moist wound environment for faster healing [28]. *In vitro* studies into Acticoat compared to other delivery systems of silver indicated that the nanocrystalline silver achieved a more rapid delivery of silver and a significantly faster kill rate of bacteria than the other agents [4, 6, 18, 23, 26-28]. Acticoat destroys MRSA, Vancomycin-resistant enterococcus, candida and more than 150 types of pathogens [3, 6, 8, 12, 26-28] and protects the wound from further bacterial contamination. Sustained release of nanocrystalline silver cations provides an antimicrobial barrier, reducing the risk of colonisation and infection [4, 5].

Tredget *et al.* conducted a matched paired randomised controlled investigation of 30 burn patients treated with Acticoat or 0.5% silver nitrate solution dressings. The investigators found the frequency of burn wound sepsis (>10^5 organism/g tissue) was less in Acticoat treated wounds than those treated with silver nitrate 0.5% solution dressings. There was a less frequent occurrence of secondary bacteraemia from within the Acticoat group [8]. Three other experimental investigations comparing Acticoat with various other silver dressings demonstrated that Acticoat performed better and destroyed bacteria faster than the other silver dressings [4, 6, 7].

Figure 4. Silver nitrate 0.5% solution.

The reduction in burn wound cellulitis could also be attributed to the ability of Acticoat to reduce inflammation. Research reveals that Acticoat has an anti-inflammatory effect through metalloproteinases; this has a role in the degradation of extra-cellular proteins in wound sites, allowing optimal re-epithelialisation [1, 2, 10].

Following cleansing of the burn wound, Acticoat is moistened with sterile water prior to application; this is followed by a compress of water, dry gauze and securing with a bandage. Acticoat can be left on for 3 days. The compress dressing is re-moistened twice daily and the dressing changed daily (Figures 5 & 6).

Acticoat Absorbent

This dressing is an alginate impregnated with nanocrystalline silver. It has an absorbent property and, when in contact with wound exudates, it forms a gel, creating a moist environment for wound healing. Nanocrystalline silver ions are released when the dressing comes in contact with wound exudate. It will absorb exudate and sustained release silver cations onto the wound. Its antibacterial action is similar to Acticoat [29].

Acticoat Absorbent is applied dry onto the burn wound and secured with a retention dressing or bandage. It should be kept dry and should be changed daily or as required. This

Table 1. Comparing silvery delivery methods [2, 30, 31].

Silver product	Ag concentration after 24 hrs	Log reduction Pseudo-monas
Silver nitrate 0.5%	Ag+ 3180mcg/mL$H_2$0	2
Silver sulphadiazine 1%	Ag+ 3030mcg/mL$H_2$0	2
Silver delivery (Acticoat)	Ag+100mcg/mL$H_2$0	>6
Aquacel	Ag+6mcg/mLH_2O	>2

Figure 5. Acticoat product.

Figure 6. Application of Acticoat.

dressing may be used in the acute as well as the community setting (Figure 7).

Aquacel Silver

There is ionic silver in this hydrofibre, which is composed of 100% sodium carboxymethyl cellulose. This dressing has a high fluid affinity which is capable of drawing moisture; silver ions are then released. This enables the dressing to exert significant antimicrobial activity over time. It is excellent for moderate to high exudative burn wounds [7].

It is applied dry onto the wound bed and secured with a secondary dressing. It should be kept dry. This dressing is ideal for use in the community setting (Figures 8-10).

ContreetH

This is a hydrocolloid incorporated with a silver complex which, when in contact with the wound, dissociates and releases silver cations on to the wound bed. This may be used for partial or full thickness burns and changed every 3 days or as required. This dressing is ideal in both acute and community settings.

An *in vitro* study comparing Acticoat with four other dressings, including Contreet H, indicated that Contreet H has a marked antimicrobial effect on bacteria (although Acticoat has a more rapid onset of action and performed better in the microbial challenge test) [6, 7]. However, the authors of the above study

Figure 7. Acticoat Absorbent product.

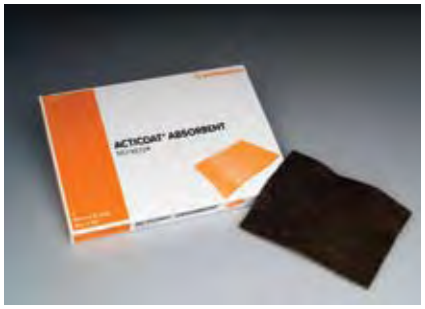


Figure 8. Aquacel AG product.

Figure 9. Burn wound for Aquacel AG.

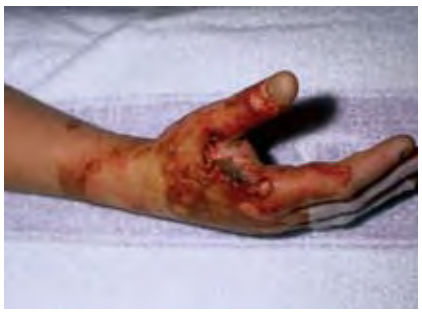
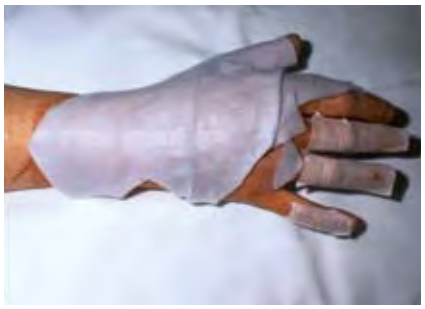


Figure 10. Application of Aquacel AG.



cautioned the extrapolation of results from *in vitro* studies to clinical practice (Table 1).

Change in practice for the burn unit at Royal Perth Hospital

An investigation conducted by Fong *et al.* [19] provides some evidence that Acticoat is the dressing of choice post burn admission and results in reduced rates of burn wound cellulitis and antibiotic usage.

In 2000 and 2002, the burn unit at Royal Perth Hospital, Western Australia, conducted two 'before and after' patient care audits comparing the effectiveness and cost of Silvazine™ (SSD and chlorhexidine digluconate cream) and Acticoat, a new dressing product for management of early burn wounds. The main outcome variables were burn wound cellulitis, antibiotic use and cost treatment. Two patient care audits and a comparative sample were used. The two regimes audited were:

- A 'standard treatment' of twice daily showers or washes with chlorhexidine 4% soap and the application of Silvazine cream as topical dressing (2000, n=51)
- A 'new treatment' of daily showers or washes of the burn wound with chlorhexidine 4% soap and the application of Acticoat dressing (2002, n=19).

In 2002, costs were also examined using a sample of matched pairs (n=8) of current and previous patients.

The main findings were that, when using Acticoat, the incidence of infection and antibiotic use fell from 55% (28/51) and 57% (29/51) in 2000 to 10.5% (2/19) and 5.2% (1/19) in 2002. The total costs (excluding antibiotics, staffing and surgery) for those treated with Silvazine were $109,357 and for those treated with Acticoat they were $78,907, demonstrating a saving of $30,450 with the new treatment. The average length of stay in hospital was 17.25 days for the Silvazine group and 12.5 days for the Acticoat group – a difference of 4.75 days [19].

Staff working with the previous standard of wound care regime (Silvazine cream) and the new method of Acticoat made subjective observations that patient comfort improved with the new method (Acticoat) as patients now only required once daily or third daily treatments instead of twice daily treatments. This led to verbalisation of improved feeling of well being, with patients requiring less analgesia and experiencing improved mobility and increased participation in activities of daily living and therapy.

These audits demonstrate that the use of Acticoat results in reduced incidence of burn wound cellulitis, antibiotic use and the overall cost compared to Silvazine in the treatment of early burn wounds. As a result of this investigation, the burn unit at RPH changed their practice of early burn wound treatment from using Silvazine to Acticoat dressings for the first 3 days post admission [19].

Conclusion

New silver delivery systems dominate in the management of burn wounds. These silver dressings contain and release different amounts of silver cations at different rates. Sustained release silver products are preferred as they seem to be more superior to those that are not sustained release. The effectiveness of the silver dressing is related to the bacterial burden in the wound and the delivery of silver must be at the right concentration over an appropriate time.

Research into silver toxicity is not well documented, but SSD cream has been shown to cause transient leucopenia. Reports of toxicity are low and often not permanent; little has been documented in *in vivo* or *in vitro* research on bacterial resistance to recent silver delivery systems. Further research into the negative effects of silver in burn wound management is therefore required to assist clinicians in their decision making as to which is the most appropriate silver dressing for the patient with a burn wound in the acute setting or in the community setting.

Acknowledgements

Thanks to to Mrs Bess Fowler and Professor Fiona Wood.

Editor's note

This article was submitted to *Primary Intention* on request following the Silver Symposium, Perth Western Australia in September 2005.

References

1. Landsdown A. Silver 1: its antibacterial properties and mechanism of action. J Wound Care 2002; **11(4)**:125-130.
2. Demling R & DeSanti L. The role of silver technology in wound healing: Part 1: Effects of silver on wound management. Wounds. A Compendium Clinical Res and Pract. Suppl A 2001; **13(1)**:4-15.
3. Orvington L. The truth about silver. Ostomy Wound Management 2004; **50(Suppl.9A)**:1S-10S.
4. Yin H, Langford R & Burrell R. Comparative evaluation of the antimicrobial action of Acticoat: antimicrobial barrier dressing. J Burn Care Rehabil 1999; **20(3)**:195-199.
5. Wright J, Lam K & Burrell R. Wound management in an era of increasing bacterial antibiotic resistance: a role for topical silver treatment. Am J Infect Control 1998; **26**:572-577.
6. Thomas S & McCubbin P. A comparison of the antimicrobial effects of four silver-containing dressings on three organisms. J Wound Care 2003; **12(3)**:101-107.

7. Thomas S & McCubbin P. An *in vitro* analysis of the antimicrobial properties of 10 silver-containing dressings. J Wound Care 2003; **12(8)**:305-309.
8. Tredget E, Shankovsky R, Groenveld A & Burrell R. A matched-pair, randomised study evaluating the efficacy and safety of Acticoat silver-coated dressing for the treatment of burn wounds. J Burn Care Rehabil 1998; **19(6)**:531-537.
9. Poon V & Burd A. *In vitro* cytotoxicity of silver: implication for clinical wound care. Burns 2004; **30(2)**:140-7.
10. Landsdown A & Williams A. How safe is silver in wound care? J Wound Care 2004; **13**:131-135.
11. Precht R & Burrell R. A comparative analysis of the anti-microbial efficacy of a novel silver coated dressing, a silver sulfadiazine and silver nitrate. J Burn Care Rehabil 1997;**18(suppl)**:S:178.
12. Hoffman S. Silver sulfadiazine: an antibacterial agent for topical use in burns. Scand J Plast Reconstr Surgery 1984; **18**:119-126.
13. Landsdown A. Silver 2: toxicity in mammals and how its products aid wound repair. J Wound Care 2002; **11(5)**:173-177.
14. Klasen H. A historical review of the use of silver in the treatment of burns. II. Renewed interest for silver. Burns 2000; **26**:131-138.
15. Jarrett F, Ellerbe S & Demling R. Acute leucopenia during topical burn therapy with silver sulphadiazine. Am J Surgery 1978; **13:**6,818-819.
16. Fuller F & Engler P. Leukopenia in non-septic patients receiving 1% silver sulphadiazine cream treatment: a survey. J Burn Care Rehabil 1989;**9**:606-609.
17. Lockhart S, Rushworth A, Azmy A & Raine P. Topical silver sulphadiazine: side effects and urinary excretion. Burns 1983; **10**:9-12.
18. Innes M, Umraw N, Fish J, Gomez M & Cartotto R. The use of silver coated dressings on donor site wounds: a prospective, controlled matched pair study. Burns 2001; **27**:621-7.
19. Fong J, Wood F & Fowler B. A silver coated dressing reduces the incidence of early burn wound cellulites and associated costs of inpatient treatment: Comparative patient care audits. Burns 2005; **31**:562-567.
20. Barlow Y. T lymphocytes, immunosuppression in the burned patient: a review. Burns 1994; **20(6)**:487-470.
21. Miller M. How do I diagnose and treat wound infection. Br J Nurs 1998; **7(6)**:335-338
22. Ayton M. Wounds that won't heal. Nurs Times 1985; **81(46)**:S:16-19.
23. Heggers J, Hawkins H, Edgar P, Villareal C & Herndon D. Treatment of infection in burns. In: Herndon DN (Ed). Total Burn Care (2nd ed). London: Saunders, 2002, p120-169.
24. Kumar G, Rameshwar L, Suhas C, Eiman M & Abdul R. *Pseudomonas aeruginosa* septicaemia in burns. Burns 1999; **25**:611-616.
25. Cook N. Methicillin resistant *Staphylococcus aureus* versus the burned patient. Burns 1998; **24**:91-98.
26. Deitch E, Marin A, Malakanov V & Albright J. Silver nylon cloth: *in vivo* and *in vitro* evaluation of antimicrobial activity. J Trauma 1987; **27**:301-304.
27. Orvington L. The role of silver technology in wound healing: Part 2 why is nanocrystalline silver superior? Wounds. A Compendium Clinical Research and Practice 2001; **13(2)(Suppl.B)**:5-10.
28. Dynamic silver release rapid destruction, sustained protection. Acticoat with silvercryst. Smith and Nephew Pty Ltd 2003 Product information.
29. Together at last. Dynamic silver and super-powered absorbency. Acticoat absorbent. Smith and Nephew Pty Ltd 2004 Product information.
30. Orvington L. Nanocrystalline silver: where the old and familiar meets a new frontier. Wounds 2001; **13(Suppl B)**:5-10.
31. Burrell R. The science of silver and its impact on wound healing 2002. Lecture notes.

Australian Wound Management Association Inc (SA)

Notification of the Annual General Meeting of the Australian Wound Management Association Inc (SA)

The Annual General Meeting of the Association will be held in accordance with the Constitution of the Association.

Date: Thursday 16 March 2006 **Time**: 1545-1800 hours

Venue: National Convention Centre,
31 Constitution Avenue, Canberra ACT 2600

See Directory in foyer for allocated Meeting Room. Entrance to the Meeting not permitted after 1545 hours.

Order of Business

The ordinary business of the Annual General Meeting will be conducted according to Rule 6 of the Constitution.

Special Business

Any other business than that identified under Rule 6 i-vi) shall be deemed Special Business. No Special Business will be considered at the Annual General Meeting unless written notification of the business or the relevant motion(s) is received by the AWMA Secretary by 5pm, Friday 27 January, 2006.

Please forward any Special Business to:

Judith Manning, Secretary AWMA, 37 Recreation Parade, Semaphore Park, South Australia, 5019

The Australian silver product tour

Geoff Sussman

Sussman G. The Australian silver product tour. Primary Intention 2005; 13(4): S23-S25.

Silver is one of the oldest elements known to man. It is found naturally and is also associated with copper and gold or as the ore argentite.

Metallic silver exists as two isotopes and is inert in this form. In presence of fluid, silver ions are present as charged ions – Ag^{+}, Ag^{++}, Ag^{+++} – and can form some soluble and mostly insoluble compounds. Silver is used in an elemental form as nanocrystalline silver or foil, or inorganic compounds such as silver oxide and silver nitrate, and as organic complexes. A number of these forms are used in silver dressings and contrast with silver sulphadiazine (SSD) delivered as a cream or a tulle. A decreased size of silver particles leads to an increased proportion of surface atoms compared with internal atoms. It is believed that a nanocrystalline structure is associated with a rapid and long lasting action of silver.

Silver has been used for many years, in particular in the treatment of burns as a SSD cream. This cream has also been applied to other types of wounds. The cream, however, is formulated to be applied to intact skin. When applied to a wound, it encourages the development of mucilageneous slough. The Australian formulation of SSD cream differs from that used in other countries: the Australian formula is SSD 1% and chlorhexidine digluconate 0.2% in an oil in water hydrophilic emulsion. The overseas formulations, such as Flamazine, do not contain chlorhexidine and are less prone to form this slough.

There is a relationship between silver content and antimicrobial content. There are also other factors, according to Thomas *et al.* [1, 2], that influence a dressing's ability to kill micro-organisms. These include:

- Distribution of silver in the dressing.
- The chemical and physical form of the silver – metallic, bound or ionic.
- The dressing's affinity for moisture.

The level of silver contained in the various dressings varies greatly. The mode of action also varies. Some release the silver into the wound, some partly release the silver and hold some silver in the dressing and some keep the silver entirely within the dressing. Dressings with the silver content concentrated on the surface or those with the silver in ionic form have performed well in tests. Sodium and chloride ions can influence the antimicrobial activity of dressings.

The Australian market has available a range of dressings incorporating silver. These are further described in Table 1.

Conclusion

The decision to use or not to use a silver dressing will depend on the wound itself; for example, the clear presence of high levels of colonisation or a clinically infected wound warrant consideration of a silver dressing. Silver should not be the automatic choice in all wounds. Further, the decision of product type, once silver has been chosen as a treatment modality, must reflect the wound environment as well as the tissue, wound depth and level of exudate.

References

1. Thomas S & McCubbin P. An *in vitro* analysis of the antimicrobial properties of 10 silver-containing dressings. J Wound Care 2003 Sep; **12(8)**:305-8.
2. Thomas S, McCubbin P & Nielsen PS. Silver dressings: the debate continues. J Wound Care 2003 Nov; **12(10)**:420.

Editor's note

This article was submitted to Primary Intention on request following the Silver Symposium, Perth, Western Australia, in September 2005.

Geoff Sussman
Director, Research Wound Foundation of Australia
Monash University, Melbourne

Table 1. Silver products available in Australia.

Product name, type / manufacturer	Silver type/content	Method of use	Freq. of changing	Contraindications	Warnings	Uses
Acticoat 3 & 7 High density polyethylene *Smith & Nephew*	Nanocrystalline silver Acticoat 107mg/100cm^2 Acticoat 7 120mg/100cm^2 held in two layers of polyethylene mesh enclosing a single layer of rayon. Polyester silver is released into the wound. Acticoat 7 has an additional layer of silver coated polyethylene mesh silver. Released silver 24hrs 60PPM	Before application moisten with water (must not be saline – this will react with the silver). Dressing trimmed to wound size; darker blue surface is placed in contact with the wound. Cover with a secondary dressing, depending on the level of exudate	Every 3 days (A-3); max. of 7 days (A-7)	Patients with known hypersensitivity	Do not use with oil based products or topical anti-microbials. If applied to lightly exudating wounds, may need to be re-moistened with water	Partial and full thickness wounds e.g. burns, donor sites, ulcers covered with a secondary dressing
Acticoat Absorbent High density polyethylene *Smith & Nephew*	Calcium alginate coated with nanocrystaline silver 144mg/100cm^2 Released silver at 24hrs 60PPM. As exudate is absorbed into the dressing, silver is released into the wound	Applied to moderate to high exudating surface or cavity wounds covered with a secondary dressing, depending on the level of exudate	Every 3 days	Patients with known hypersensitivity	Do not use in cavity wound where there are sinuses present	Partial and full thickness moderate to highly exudating wounds
Contreet-H Hydrocolloid *Coloplast*	Silver complex 32mg/100cm^2 30% of the silver is released within 7 days. The silver is released into the wound	Applied to light to moderately exudating surface wounds	Every 4-7 days	Patients with known hypersensitivity Use with caution on arterial, diabetic lower leg/foot wounds that need review daily	Potential allergic reaction to adhesive or components. Must be removed prior to radiotherapy	Partial thickness wounds e.g. burns, donor sites, ulcers, pressure sores
Contreet Hydroactive *Coloplast*	Silver complex 47mg/100cm^2 on contact with exudate provides sustained release of the silver. 70% of the silver is released within 7 days. The silver is released into the wound	Applied on and around surface wounds and lightly packed into cavity wounds	Up to 7 days	Patients with known hypersensitivity. Should not be used with hydrogen peroxide or hypochlorite solutions or over exposed muscle or bone	May cause transient discolouration of wound bed. Should be removed prior to radiation therapy, x-rays etc	Partial and full thickness wounds e.g. burns, donor sites, ulcers, pressure sores. Use in moderate to high exudating wounds
Polymem Silver Hydroactive *Ferris*	Nanocrystalline silver 12.4mg/100cm^2. Released silver at 48hrs 50mcg/100cm^2. Silver is released into the wound, though mostly held in the dressing	Apply to the surface or lightly packed (no more than 80%) into moderate to high exudating wounds	Every 3 days	Patients with known hypersensitivity	None provided	Partial thickness or cavity lightly exudating wounds

Aquacel Ag Hydrofibre *ConvaTec*	Sodium carboxymethylcellulose containing silver 8.3mg/100cm^2. Released silver at 24 hrs 20PPM. Silver is released into the wound	Apply to the surface or lightly packed (no more than 80%) into moderate to high exudating wounds	Depending on the wound, may need to be daily or every third day or up to 14 days in burns	Patients with known hypersensitivity. Little value in lightly exudating or dry wounds	Should not be used with other wound care products	Partial and full thickness wounds e.g. burns, donor sites, ulcers and covered with a secondary dressing depending on the level of exudate
Avance Foam *SSL*	Silver virconium phosphate 1.59mg/100cm^2. Released silver at 24hrs 0 PPM silver is held in the dressing	The foam is applied on and around the surface in light to moderate exudating wounds	Every 3 days	Patients with known hypersensitivity	Should not be applied to wounds covered with dry scab or hard black necrotic tissue. Do not cover with occlusive film as this reduces water vapour loss	Partial and full thickness wounds e.g. burns, donor sites, ulcers
Atrauman Ag Tulle *Hartmann* sites,	Metallic silver 35mg/100cm^2. Released silver at 48hrs 100mcg/100cm^2. Silver is released into the wound, though mostly held in the dressing	Apply to the wound and peri-skin covered with a secondary dressing, depending on the level of exudate	Every 3-7 days	Patients with known hypersensitivity	Should not be used in combination with paraffin containing dressings or ointments	Complementary use in infected or contaminated partial thickness wounds e.g. burns, donor ulcers
Urgotul SSD* *Not yet approved by TGA Tulle *Urgo Lipocolloidal*	Silver sulphadiazine 3.75% = 70mgm/100cm^2. The SSD is held in a lipido-colloid suspension that absorbs moisture and forms a gel. Released silver 50mcg/100cm^2. Silver is released into the wound, though partly held in the dressing	Apply to the wound and peri-skin covered with a secondary dressing, depending on the level of exudate	Every 1 or 2 days	Patients with known hypersensitivity. Contraindicated in renal, hepatic insufficiency, pregnancy or in neonates	When used on a large surface area and/or for a prolonged period consideration of systemic effects of the SSD. Should not be used with any other local treatments	Partial and full thickness wounds e.g. burns, donor sites, ulcers
Actisorb Plus Silver impregnated activated charcoal *Johnson & Johnson*	Silver 2.43-2.95mg/100cm^2. Released silver 24hrs 0 PPM silver is held in the dressing	Apply to the wound and peri-skin covered with a secondary dressing, depending on the level of exudate	Up to 7 days	Patients with known hypersensitivity. Lightly exudating wounds	Must be used intact. Do not cut. Should not be used in conjunction with topical preparations or paraffin containing products	Used to reduce bacterial colonisation in partial and full thickness chronic wounds
Arglase Impregnated film *Unomedical*	Polymer silver. Silver 100mcg/100cm^2. Released silver 24hrs 8PPM	Film dressing is applied to the intact skin or to the wound. The film is adhesive and will stick to the periskin	Up to 7 days	Patients with known hypersensitivity. Greater than lightly exudating wounds	Should be used on dry or lightly exudating wounds only	Post op sutures lines, securing IV lines

Flights of fancy: the use of silver dressings to treat a trauma wound in a wild cockatoo

Simone Vitali • Karen Payne • Paul Eden

Abstract

This case report illustrates the application of nanocrystalline silver dressings in the second intention healing of an open wound in a wild cockatoo. The challenges of managing these non-compliant patients are discussed.

Vitali S, Payne K . Flights of fancy: the use of silver dressings to treat a trauma wound in a wild cockatoo. Primary Intention 2005; 13(4): S26-S29.

Introduction

There are three species of black cockatoo endemic to Western Australia - Baudin's cockatoo (*Calyptorhynchus baudinii*), Carnaby's cockatoo (*C. latirostris*) and the red-tailed black cockatoo (*C. banksii*). All three species are highly endangered [1].

The Perth Zoo veterinary department provides veterinary care to sick and injured black cockatoos on behalf of the WA Department of Conservation and Land Management (CALM). Over 70% of all admissions are suffering from trauma, and there is a high incidence of motor vehicle and shotgun injuries [1]. Open fractures are commonly encountered, often in association with chronic, contaminated wounds. This case report illustrates the application of nanocrystalline silver dressings (Acticoat®) in the second intention healing of an open wound in a cockatoo. Challenges of managing these non-compliant patients are discussed.

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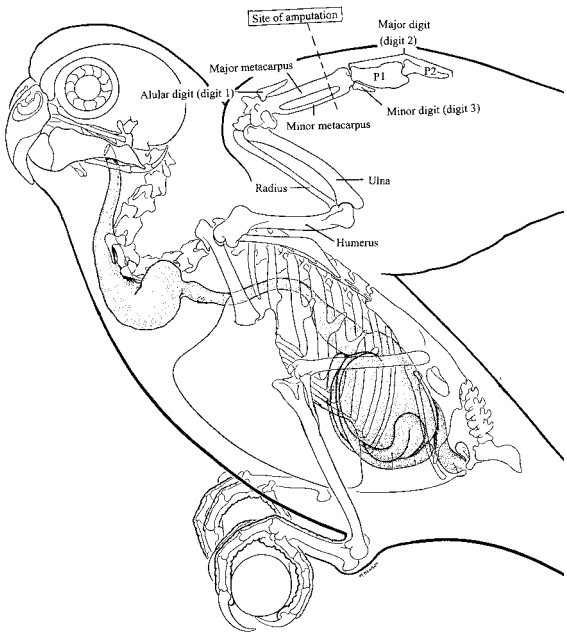
Case report

An adult female Carnaby's cockatoo (Figure 1) was presented with an open fracture of the distal metacarpi of the left wing. Although this bird's injuries precluded its release back into the wild, treatment of the injury was warranted because of its conservation value as a participant in captive breeding programmes.

The wing tip was severely injured, necessitating amputation at the level of the distal metacarpi (Figure 2). The resultant 4cm x 1.5cm wound was not amenable to complete primary closure, and therefore required management using second intention healing methods. All wound assessments and treatments took place with the bird under general anaesthesia.

Figure 1. Carnaby's cockatoo.

Figure 2. Anatomy of the bird wing, showing site of amputation[4].



Day 4

The bird was anaesthetised for amputation of the wing tip (Figure 3). The resultant wound bed was dressed with cadexomer iodine powder (Iodosorb®) and a hydrofibre (Aquacel®). Adhesive bandage (Hypafix®) was applied as a secondary dressing.

Day 11

Some contracture and epithelialisation of the wound had occurred. However, the surface of the wound had become dehydrated and fungated (Figure 4). There was a small area of exposed metacarpal bone, which appeared devitalised. The primary wound dressing was changed to nanocrystalline silver (Acticoat®). Due to the slightly cavitated nature of the wound bed, foam (Lyofoam®) was applied as a secondary dressing. Adhesive strips (Fixomull®) and adhesive film (Opsite®) were used as secondary and tertiary dressings (Figure 5).

Day 15

A substantial improvement in the healing process was observed (Figure 6). There was no longer any evidence of bone exposure or fungation. A healthy granulation bed was establishing, and the wound was continuing to epithelialise. Dressings remained the same as on Day 11.

Day 19

The granulation bed was looking healthy, and the wound was contracting (Figure 7). The primary dressing was changed from Acticoat® to a foam product (Curafoam®), since there was no longer any evidence of bacterial or fungal colonisation.

Day 26

There was some slough accumulation present in the central wound area (Figure 8). Although granulation tissue was present, it appeared not to be progressing satisfactorily in the centre of the wound. This raised the possibility that low level bacterial or fungal colonisation was inhibiting further healing.

Figure 3. Day 4 – wound site post-amputation.

Figure 4. Day 11 – white fungal overgrowth visible, centred on exposed bone.

Figure 5. Day 11 – application of secondary and tertiary dressings.

With this in mind, Acticoat® was reinstated as the primary dressing, with foam being used as a secondary dressing.

Day 32

There was a significant improvement in the appearance of the wound, with granulation tissue now covering the entire wound surface (now approximately 1cm diameter). Wound dressings remained the same as on Day 26.

Day 40 onwards

By Day 40, the wound was almost fully healed (Figure 9). By Day 54, the bird was sufficiently recovered to be transferred to an experienced cockatoo carer, appointed by the Department of CALM, for further rehabilitation in a more naturalistic environment.

Figure 6. Day 15 – 4 days after initiation of Acticoat dressings, no fungation is evident, and granulation is progressing well.

Figure 7. Day 19 – improved granulation and epithelialisation.

Figure 8. Day 26 – note slough deposition centrally.

Figure 9. Day 40 – almost fully healed.

Discussion

Injured wild cockatoos present unique compliance issues which complicate effective wound management. They are aggressive birds, whose strong beaks can easily injure inexperienced handlers. Consequently, most procedures, including dressing changes, must be conducted with the bird under general anaesthesia.

On presentation, injured cockatoos are often underweight, inappetant and dehydrated. Septicaemia is commonly encountered. Many birds will refuse to eat when hospitalised, necessitating tube feeding twice a day in addition to other stressful medical treatments [1]. Stress-related infections, particularly *Aspergillus* (both respiratory and disseminated infections), are a common, and often fatal, complication of confinement and hospitalisation.

Wing wound management in birds is further complicated by the nature of the avian integument and musculoskeletal system. The epithelium is very thin, only 10 cells thick in the domestic chicken [2], and the dermis is likewise very thin. These anatomical features limit the holding power of skin sutures and the opportunities for primary closure. Furthermore, soft tissue mass is minimal in the wings of flighted birds [3], reflecting the streamlining necessary to achieve flight. This reduction in soft tissue elements over the wing bones renders them particularly susceptible to impact injuries and open fractures [3]. Fungation and critical colonisation are common complications of the management of these wound sites.

In spite of special anatomical considerations and complications such as these, many of the principles and practices familiar to human wound management are directly applicable to non-human patients. For example, the detrimental effects of long-

term hospitalisation on a wild cockatoo's prospects for release have driven continued experimentation with modern wound healing products at Perth Zoo in order to find the quickest and most effective means of achieving wound healing. The sooner healing occurs, the quicker the bird can be transferred to a rehabilitation facility, and the better its chances for a full recovery and release back into the wild.

The introduction of silver dressings in this case caused a dramatic and rapid improvement in the healing process. This reflects the potent antibacterial and antifungal effects of these products. The dressings were well tolerated by the bird, another critical factor in promoting rapid wound healing in non-compliant animals.

Silver dressings are being used more frequently for wound management at Perth Zoo, particularly in reptiles and birds where wound healing is commonly hampered by difficulties with primary closure, a propensity for desiccation and slough formation, and a high incidence of secondary infections with commensal organisms (e.g. *Pseudomonas* and *Aeromonas* spp. in reptiles). This case illustrates the growing importance of modern wound products, and their relevance to wound management, in the veterinary field.

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Editor's note

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References

1. Rouffignac M & Joy R. A collaborative medical and husbandry approach to the conservation of black cockatoos in Western Australia. Proceedings of the Australian Society of Zookeepers National Conference; 2005 April 29-May 1; Melbourne.
2. Orosz S. Anatomy of the integument. In: Altman RB, Clubb SL, Dorrestein GM & Quesenberry K (Eds). Avian Medicine and Surgery. Philadelphia: Saunders, 1997:540-545.
3. Martin H & Ritchie BW. Orthopedic surgical techniques. In: Ritchie BW, Harrison GJ & Harrison LR (Eds). Avian Medicine: Principles and Application. Florida: Wingers Publishing, 1994:1137-1169.
4. Evans HE. Anatomy of the budgerigar and other birds. In: Rosskopf W & Woerpel R (eds). Diseases of Cage and Aviary Birds (3rd ed). Baltimore: Lea and Febiger, 1996:79-162.

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References

1. Disability Online – Latex Allergy. www.disability.vic.gov.au