Original Research

Silver Antimicrobial Dressings in Wound Management: A Comparison of Antibacterial, Physical, and Chemical Characteristics

David Parsons, PhD; Philip G. Bowler, MPhil; Viv Myles, MSc; Samantha Jones, BSc

From ConvaTec Ltd, Flintshire, United Kingdom

Abstract: Silver-containing dressings are widely used to assist with management of infected wounds and those at risk of infection. However, such dressings have varied responses in clinical use due to technological differences in the nature of their silver content and release and in properties of the dressings themselves. This study examines the relationship between silver content, rate of silver release, and antibacterial activity in a simulated wound fluid model against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. The study also looks at other important measures for the clinical performance of dressings including fluid-handling properties and dressing pH. Seven proprietary silver-containing dressings (AQUACEL® Ag [Hydrofiber®; "nonwoven A"], Acticoat™ Absorbent [alginate; "nonwoven B"], SILVERCEL™ [alginate-carboxymethylcellulose nylon blended fibers; "nonwoven C"], Contreet® Foam [nonadhesive; "foam A"], PolyMem® Silver ["foam B"], Urgotul® S.Ag ["gauze"], and SilvaSorb® ["hydrogel"]) were assessed. No direct correlation between silver content, silver release, and antibacterial activity was found. Dressings with the highest silver content were nonwoven B and nonwoven C, while the lowest levels were found in nonwoven A and hydrogel. Nonwoven A, gauze, and nonwoven B were most effective against *S. aureus* and *P. aeruginosa*; however, their silver release rates differed widely. Free fluid absorption was greatest for the 2 foam dressings and least for gauze. However, nonwoven A and nonwoven B showed the best fluid retention under conditions of compression, while nonwoven A demonstrated the lowest level of capillary wicking. Dressing choice is a vital part of the successful management of infected wounds and those wounds at risk for infection. This study suggests that dressing selection should be based on the overall properties of the dressing clinically relevant to the wound type and condition.

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Critical colonization and infection of wounds present a dual problem for clinicians. First, there is the possibility of delayed wound healing, particularly in the presence of a compromised immune system or where the wound is grossly contaminated or poorly perfused.[1] Second, colonized and infected wounds are a potential source for cross-infection—a particular concern as the spread of antibiotic-resistant species continues. For patients, an infected wound can have additional consequences including increased pain and discomfort, a delay in return to normal activities, and the possibility of a life-threatening illness. For healthcare providers, there are increases in treatment costs and nursing time to consider.[1,2]

Address correspondence to:
David Parsons, PhD, ConvaTec Wound Therapeutics Global Development Centre
Deeside, Flintshire CH5 2NU United Kingdom
Phone: 44 1244 584349; E-mail: dave.parsons@bms.com

Until recently, local wound infection has been a challenge with few management options. However, the advent of advanced wound dressings containing topical antimicrobial agents, such as silver, has provided a new approach to the control of wound pathogens.[3,4]

Silver has proven antimicrobial activity that includes antibiotic-resistant bacteria, such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE).[4] Its role as an antimicrobial agent is particularly attractive, as it has a broad spectrum of antimicrobial activity[5,6] with minimal toxicity toward mammalian cells at low concentrations[7] and has a less likely tendency than antibiotics to induce resistance due to its activity at multiple bacterial target sites.[8]

Topical creams or solutions containing silver (eg, silver sulfadiazine) have long been used as a mainstay of wound management in burn patients who are especially susceptible to infection.[1] However, disadvantages to their use include staining the skin and toxicity.[3] In addition, the need for frequent removal and reapplication of silver sulfadiazine due to the development of pseudoeschar is both time consuming for professionals and painful for patients.[3,9] A range of antimicrobial dressings containing silver either incorporated within or applied to the dressing are now available for clinical use.[10] This new class of dressings is designed to provide the antimicrobial activity of topical silver in a more convenient application. However, the dressings themselves differ considerably in the nature of their silver content and in their physical and chemical properties.

This study compares the *in-vitro* antibacterial activity of 7 such dressings against 2 common wound pathogens, *Staphylococcus aureus* and *Pseudomonas aeruginosa*. The correlation between silver content and/or silver release from each dressing and its antibacterial effect is examined, and factors relating to the provision of an optimal environment for wound healing are compared to provide a basis for an overall assessment of the clinically valuable properties of each dressing.

Methods

This study assessed the characteristics of 7 proprietary silver-containing antimicrobial dressings: 3 fibrous dressings—AQUACEL® Ag (ConvaTec, Skillman, NJ, USA; referred to throughout this article as nonwoven A), Acticoat™ Absorbent (Smith & Nephew, London, UK; referred to throughout this article as nonwoven B), and SILVERCEL™ (Johnson & Johnson Wound Management, Somerville, NJ, USA; referred to throughout this article as nonwoven C); 2 foam dressings—Contreet® Foam (Coloplast, Holtedam, Denmark; referred to throughout this article as foam A) and PolyMem® Silver (Ferris, Burr Ridge, Ill, USA; referred to throughout this article as foam B); a gauze dressing—Urgotul® S.Ag (Laboratoires Urgo, Chenôve, France; referred to throughout this article as gauze); and a nonadhesive polymer hydrogel sheet—SilvaSorb® (AcryMed/Medline, Mundelein, Ill, USA; referred to throughout this article as hydrogel).

While all 7 dressings contain silver, they vary in their components and structures (Table 1). The dressings ranged in weight from 1.05 g to 6.93 g for a 10 cm x 10 cm piece.

Bacteria. The dressings were tested against 2 common wound pathogens, namely *Staphylococcus aureus* NCIMB 9518 (gram positive) and *Pseudomonas aeruginosa* NCIMB 8626 (gram negative).

Measurement of antibacterial activity. Antibacterial activity was assessed in repeat-challenge assays over a period of 7 days for each of the 7 silver-containing dressings (SCD) and for a nonsilver-containing control dressing (NSCD, AQUACEL®, ConvaTec).

To best reproduce the clinical conditions in which these dressings are used while providing a consistent and reproducible environment across all the dressings tested, a simulated wound fluid was prepared consisting of 50% fetal calf serum (First Link [UK] Ltd, mycoplasma tested) and 50% maximum recovery diluent (MRD, LABM, UK; 0.1% w/v peptone [beef protein extract] and 0.9% w/v sodium chloride).

Bacteria were inoculated into simulated wound fluid (SWF) such that the final volume was 10 mL, and the population density was approximately 1 x 10^6 cfu/mL. Due to the higher free swell absorption capacity of the foam dressings, a 20 mL volume was used to enable serial samples to be taken without distorting the dressings; however, to provide an equivalent bacterial challenge, the bacterial popula-

Table 1. Typical weight of a 10 cm x 10 cm dressing

Dressing	Dressing Type	Weight (g)
	Fibrous nonwoven felt	
Nonwoven A (AQUACEL® Ag)	Hydrofiber®22 with 1.2% w/w ionic silver	1.05
Nonwoven B (Acticoat™ Absorbent)	Metallic nanocrystalline silver-coated calcium alginate	1.51
Nonwoven C (SILVERCEL™)	Calcium alginate-carboxymethylcellulose fiber blended with metallic silver-coated nylon fiber	1.65
	Foam	
Foam A (Contreet® Foam)	Silver-impregnated polyurethane foam	6.93
Foam B (PolyMem® Silver)	Silver-impregnated polyurethane foam	6.48
	Gauze	
Gauze (Urgotul® S.Ag)	Gauze dressing coated in a Vaseline™ paste containing hydrocolloid and silver sulfadiazine particles	1.72
	Hydrogel	
Hydrogel (SilvaSorb®)	Microlattice synthetic hydrogel matrix containing silver chloride	6.67

tion density was halved. A 5 cm x 5 cm square of SCD or NSCD control was transferred to the inoculum, and tubes were incubated at 35°C. Samples (100 µl) were removed for total viable counts at 4, 24, 48, 72, and 96 hours and on Day 7. At the 48-hour time point, each test sample was re-inoculated with approximately 1 x 10^6 cfu/mL of the original challenge organism. Each test was performed on 4 separate occasions.

Chemical assays. *Measurement of total silver content.* Samples were digested by heating in a mixture of concentrated sulfuric and nitric acids to break down the dressing matrix and to release and dissolve all of the silver present. The digest was then filtered and diluted with deionized water as required to enable quantification of the silver by atomic absorption spectrophotometry. Determinations were performed in triplicate.

Measurement of dressing pH. Three samples from each dressing were suspended in deionized water at a ratio of 1:100 (w/v) and were roller mixed at room temperature for 3 hours to ensure the samples had reached equilibrium. The pH was measured using a pH meter with a combination pH electrode, calibrated at pH 4 and 7 or pH 7 and 10, as appropriate to the pH of the sample being measured.

Measurement of silver release into water over time. A weighed portion (in duplicate) from each dressing was suspended in deionized water at a ratio of 1:100 (w/v), and the samples were placed into a temperature-controlled environment (37 ± 3°C) for 7 days. During this period, aliquots were removed at timed intervals, and the liquid was replaced to maintain a constant volume. Samples were filtered, diluted as appropriate, and analyzed by atomic absorption spectrometry.

Absorption testing (fluid handling properties). *Measurement of fluid absorption under various applied pressures.* A 5 cm x 5 cm square sample of each dressing was weighed (W_1), placed onto a perforated stainless steel plate, and covered with a flat Perspex plate slightly larger than the dressing. The desired compressive pressure was applied by placing weights on top of the Perspex plate. The entire arrangement was then immersed into a tray of solution A (sodium chloride and calcium chloride solution, 0.142 mol l^{-1} and 0.0025 mol l^{-1}, respectively) at a temperature of 20°C for 20 seconds so that the dressing material was completely covered. The sample was removed and placed onto a double layer of absorbent paper towel to remove freely draining fluid then reweighed (W_2). The weight of fluid absorbed and retained per gram was calculated by $(W_2 - W_1)/W_1$.

Measurement of vertical wicking. Vertical wicking distance was measured for the fibrous dressings only, as this method is unsuitable for freely draining foams and gauzes and solid hydrogel products.

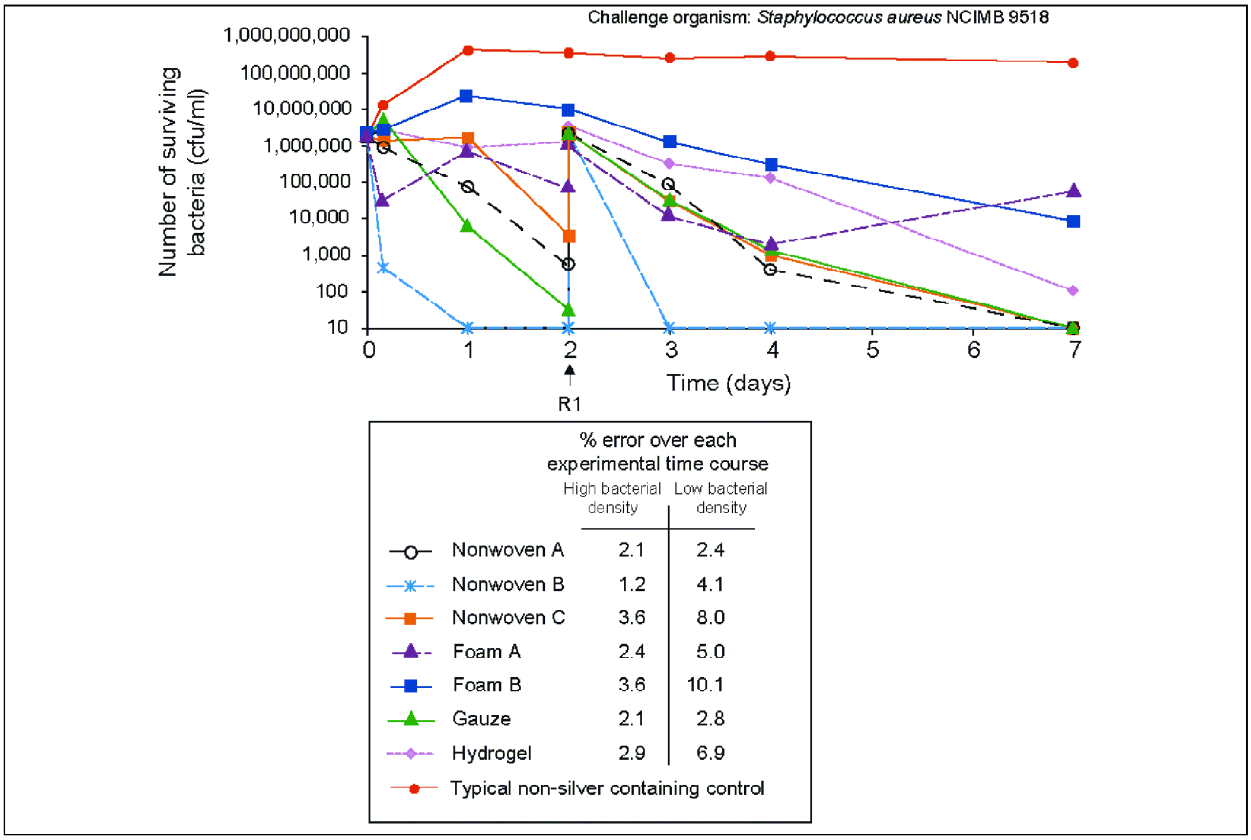

Figure 1. *The antibacterial efficacy of silver-containing dressings against* S. aureus *over a 7-day period (re-inoculation occurred at 48 hours). Simulated wound fluid 10 mL volume (re-inoculation at approximately 2.1 x 10^6 cfu/mL [R1]). For foam A and foam B, a 20 mL volume was used (re-inoculation at approximately 1.4 x 10^6 cfu/mL).*

A strip of dressing 15 mm wide and 100 mm long was lowered vertically into a bath of solution A containing a red dye (0.25 g/L eosin) until 10 mm of the length was submerged. After 60 seconds, the vertical liquid movement (in mm) up the dressing above the surface of the liquid was measured.

Measurement of dehydration rate. A 5 cm x 5 cm square sample of each dressing was weighed and then submerged in an excess volume of solution A at 37°C for 30 minutes. Samples were then removed, suspended by a corner for 30 seconds to remove freely draining liquid, and then reweighed. The hydrated samples were laid on dry Petri dishes without lids and placed in an incubator at 37°C. The weight loss of each sample was measured hourly and the rate of weight loss calculated.

Results

Antibacterial activity. The antibacterial activity of the 7 SCDs against *S. aureus* (Figure 1) and *P. aeruginosa* are as shown (Figure 2).

Nonwoven A, nonwoven B, nonwoven C, and gauze demonstrated the greatest overall antibacterial activity, reducing bacterial counts for both *S. aureus* and *P. aeruginosa* from more than 1 million colony-forming units per mL fluid (cfu/mL) to less than 500 cfu/mL within 48 hours. Nonwoven B reduced the *S. aureus* count below the limit of detection (less than 10 cfu/mL) by 24 hours. Nonwoven A and nonwoven B were both highly effective against *P. aeruginosa*, reducing the viable microbial count below the limit of detection by 24 hours. Upon rechallenge with a high concentration of bacteria 48 hours after the start of the test, both nonwoven A and nonwoven B remained highly effective against both test organisms. Gauze (which contains silver sulfadiazine) and nonwoven C also showed continuing efficacy against both organisms but were less effective

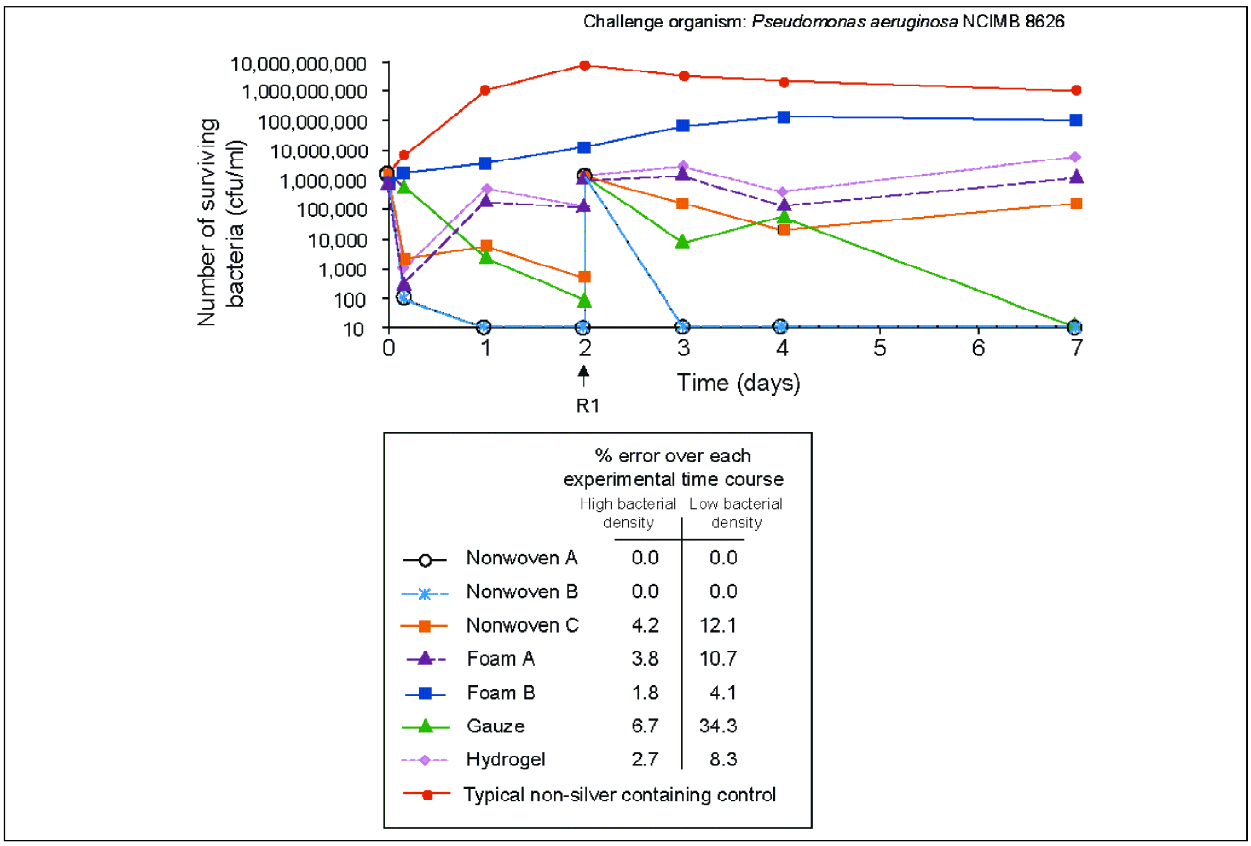

Figure 2. *The antibacterial efficacy of silver-containing dressings against* P. aeruginosa *over a 7-day period (re-inoculation occurred at 48 hours). Simulated wound fluid 10 mL volume (re-inoculation at approximately 1.3 x 10^6 cfu/mL [R1]). For foam A and foam B, a 20 mL volume was used (re-inoculation at approximately 8.6 x 10^5 cfu/mL).*

against *P. aeruginosa* following rechallenge. Foam A, foam B, and hydrogel showed only limited antibacterial activity against these organisms.

Silver content and silver release. The measured total silver content of the dressings ranged from 6 mg to 113 mg for a 10 cm x 10 cm sample. Content was greatest for nonwoven B and nonwoven C and least for nonwoven A and hydrogel (Table 2). The amount of silver released into purified water also varied extensively ranging from 17 to 111 µg/10 cm x 10 cm of dressing for the majority of dressings after 48 hours and rising to a little over 3,000 µg/10 cm x 10 cm for nonwoven B (1 mg = 1,000 µg). There was no correlation between silver release and silver content (Figure 3). For example, nonwoven B and nonwoven C have very similar total silver content, but the amount of silver released after 48 hours was approximately 50-fold greater for nonwoven B compared with nonwoven C.

Comparison of the antibacterial activity for the different dressings also revealed no correlation between antibacterial effect (as measured in a SWF model) and either silver content of the dressings (Figure 4) or total silver released into water (Figure 5). In particular, silver content was found not to be a predictor of antibacterial activity. For example, there was approximately a 10-fold difference in silver content between nonwoven A and nonwoven B, 2 dressings with very similar antibacterial effects. Conversely, while the silver content of nonwoven A, gauze, and hydrogel was broadly similar, antibacterial activity differed significantly between the dressings (Figure 4). It is important to note, however, that the technique used in this study measures the total amount of silver in solution and cannot differentiate between antibacterially active forms of soluble silver (silver ions, Ag^+) and inactive forms, such as metallic silver (Ag^0).

Nonwoven B showed the most rapid release of large amounts of silver into water (all values relate to a 10 cm x 10 cm dressing; 3,011 µg by 48 hours, 3,116 µg by 7 days) and had good antibacterial activity. Nonwoven A showed a much lower release of silver (17 µg by 48 hours, 27 µg by 7 days); however, this was associated with equivalent activity against *P. aeruginosa* and only marginally reduced activity against *S. aureus*. Gauze, which was marginally less effective against *P. aeruginosa* than nonwoven A and nonwoven B, had a slightly greater rate of silver release than nonwoven A (49 µg by 48 hours, 79 µg by 7 days). Hydrogel showed a more rapid rate of silver release than gauze (111 µg by 48 hours) and reached a level of 179 µg by day 7. Hydrogel showed less antibacterial activity than nonwoven A, nonwoven B, or gauze. A summary of silver content, rate of silver release, and antibacterial activity for all dressings is shown in Table 2.

Table 2. A comparison of silver content, rate of silver release, and antibacterial activity

	Ag Content (mg/10 cm x 10 cm)	Silver Release into Deionized Water (µg/10 cm x 10 cm)		Antibacterial Activity in SWF 48 h After Rechallenge
		After 3 h	After 48 h	
Nonwoven A	9	3.2	17	+++
Nonwoven B	104	555	3,011	+++
Nonwoven C	113	0.07	64	++
Foam A	77	4.6	102	+
Foam B	13	0.00	70	+
Gauze	14	0.53	49	++
Hydrogel	6	5.4	111	+

Excellent	+++
Good (consistent bacterial reduction)	++
Positive behavior (or bacterial control)	+
Ineffective	–

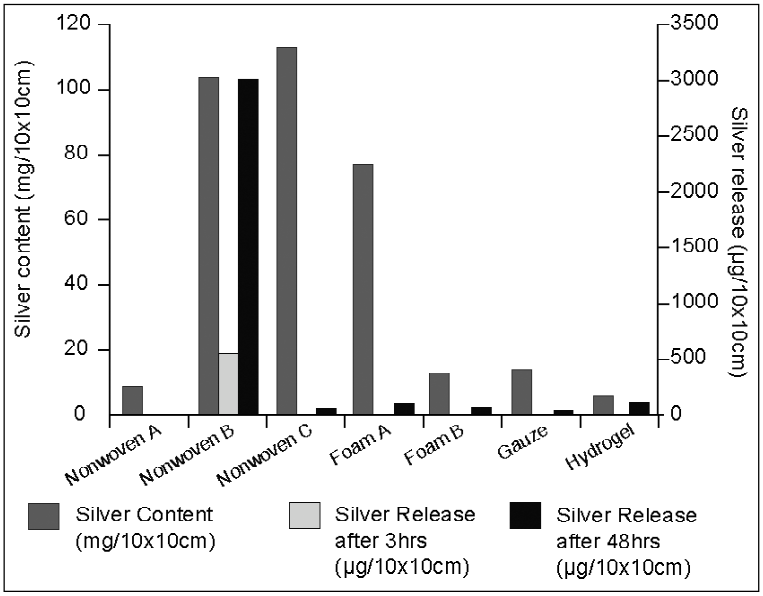

Figure 3. *Correlation between silver content and release.*

Fluid-handling properties. *Fluid absorption.* The free swell fluid absorption (when no compression was applied to the dressing) ranged from 0.2 to 66.8 (all values in g per 10 cm x 10 cm) and was greatest for the 2 foam dressings and least for the gauze. Free swell fluid absorption for nonwoven A was almost as great as the absorption for foam B but was greater than the absorption for the other nonfoam dressings.

When this experiment was repeated with a dressing compression of 40 mmHg (typical of the force applied by compression bandaging), fluid absorption remained greatest for foam A (32.9) but was greater for nonwoven A (11.4) than for foam B (Table 3). Fluid absorption for foam B and the other dressings ranged between 0.1 and 8.1.

The difference in fluid absorption between these 2 experiments was used to indicate how much fluid might be squeezed out of the dressing if pressure was applied (the fluid retention of the dressing). The percent fluid loss was approximately 20% for nonwoven A and nonwoven B, compared to approximately 50% for the other dressings (Figure 6).

Vertical wicking distance. Vertical wicking distance was determined for the 3 fibrous dressings. For nonwoven A and nonwoven C, the wicking distances were 12.5 and 17.8 mm, respectively, using the standard test procedure. Using this pro-

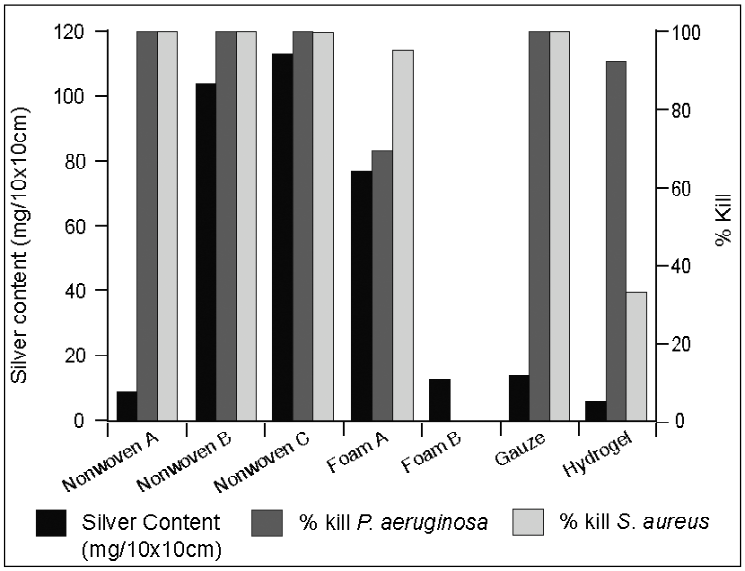

Figure 4. *Correlation between silver release and activity.*

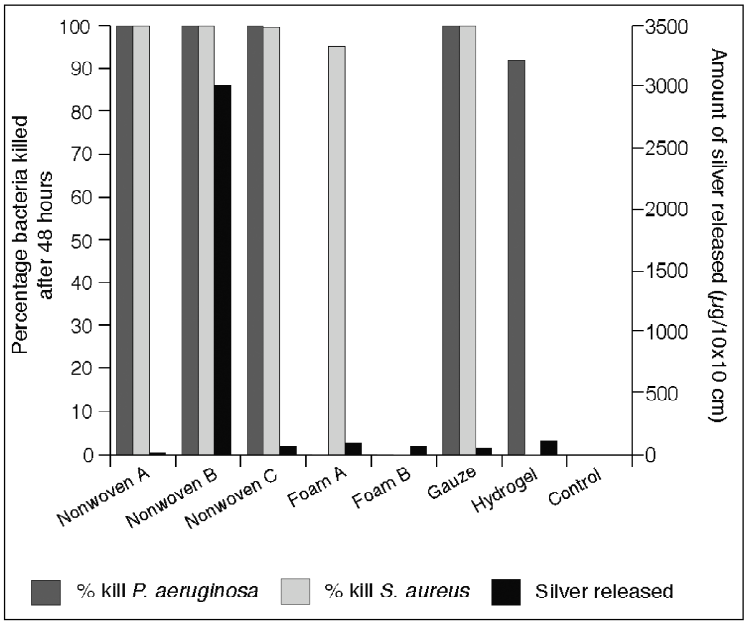

Figure 5. *Plot of silver release against antibacterial activity at 48 hours for* S. aureus *and* P. aeruginosa.

cedure, fluid did not appear to be absorbed by nonwoven B but remained on the surface of the dressing, suggesting that there is likely to be a delay before fluid absorption occurs with this dressing. The test period was then extended for nonwoven B until absorption occurred and the wicking distance was allowed to equilibrate. Under these conditions, the vertical wicking distance for nonwoven B was 33 mm.

Dehydration. The rate of dehydration was assessed for 6 dressings. (Nonwoven B was excluded, since it was not possible to reproducibly hydrate this dressing.) The rate of dehydration ranged from 0.0116 g/min for nonwoven A to 0.0251 g/min for foam A (Figure 7). Most dressings dried out within approximately 23 hours; however, for gauze, complete dehydration occurred after approximately 40 minutes. The assay was discontinued at this point.

Dressing pH. The pH of each of the dressings in water was measured over the course of 1 day. After 3 hours, pH values ranged from 5.4 for nonwoven A to 9.5 for nonwoven B (Table 4). After 24 hours, the pH range was reduced: the lower values remained constant at 5.4 (nonwoven A), but the higher values reduced to 7.7 (nonwoven B, foam B).

Discussion

As expected, each SCD examined in this study showed a degree of antibacterial activity against the wound pathogens tested, with the exception of foam B, which was ineffective against *P. aeruginosa* and only marginally effective against *S. aureus*. Nonwoven B reduced the *S. aureus* count to below the limit of detection by 24 hours. However, nonwoven A, nonwoven B, gauze, and nonwoven C all remained effective after rechallenge with *S. aureus*. Nonwoven A and nonwoven B were both highly effective against *P. aeruginosa*, reducing the bacterial count to undetectable levels within 24 hours. Gauze and nonwoven C were also effective against the initial challenge but were less effective against rechallenge with *P. aeruginosa*. These data demonstrating the antibacterial activity of silver-containing dressings are similar to those reported previously for nonwoven A,[5,6] nonwoven B (in alternative forms),[11] hydrogel,[10] and foam A.[10]

Comparison of the silver content of the 7 dressings revealed a more than 10-fold difference

between nonwoven C and nonwoven B (dressings with the highest silver content) and nonwoven A and hydrogel (dressings with the lowest). There was an even greater difference (180-fold) in the amount of silver released into water after 48 hours between nonwoven B (showing the greatest release) and nonwoven A (showing the lowest release of silver). These differences, however, do not correlate with the antibacterial activity seen.

It is important to remember that all published tests of aqueous silver concentrations (including this study) fail to distinguish between active ionic silver (Ag^+) and inactive silver in solution (eg, Ag^0)—that is, they measure total silver only. The findings of this study show, however, that a greater amount of silver (in any form) released by a dressing does not necessarily lead to a greater rate or degree of antimicrobial activity.

In conjunction with a measured or calculated total aqueous silver concentration, a widely reported test that has been used to predict the potential antimicrobial efficacy of dressings is the minimum inhibitory concentration (MIC). In these laboratory tests, ionic silver is added to a test culture in the form of a simple solution, and it is assumed that all the silver added remains active. Under these conditions, the MIC for silver is typically found to be in the range of 5–40 µg/mL.[12] This value is less than the concentration of silver that has been shown to be released by nonwoven B in this and other studies,[12] which would support the case for use of MICs in dressing selection. However, other dressings (eg, nonwoven A) have shown very similar antimicrobial activity to nonwoven B but with a far lower level of silver release (17 µg compared to 3,011 µg per 10 cm x 10 cm dressing over 48 hours) and with a measured total silver concentration in solution of as little as 1 µg/mL.[13] This would suggest that using MIC data in selection of a SCD might be flawed and, hence, inappropriate.

Table 3. Fluid absorption of silver-containing dressings

	Fluid Absorption (g/10 cm x 10 cm)	
	Zero Compression	40 mmHg Compression
Nonwoven A	14.1	11.4
Nonwoven B	4.9	3.9
Nonwoven C	9.9	5.2
Foam A	66.8	32.9
Foam B	17.5	8.1
Gauze	0.2	0.1
Hydrogel	2.9	1.2

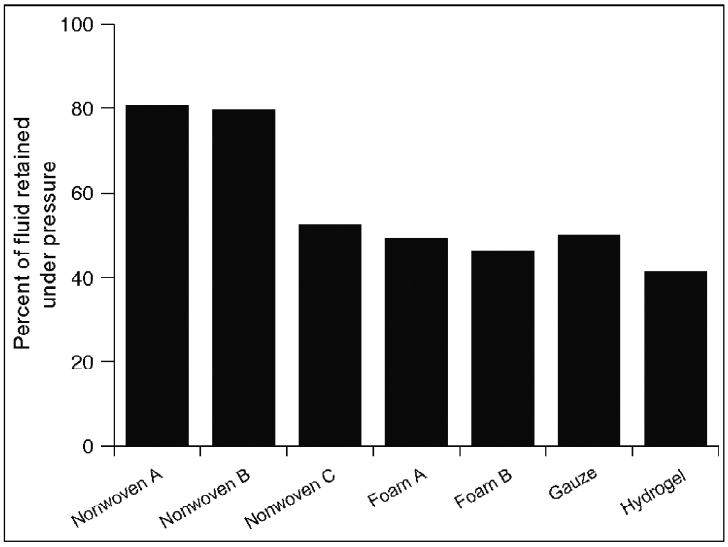

Figure 6. *Percentage fluid retained under pressure for a range of silver-containing dressings.*

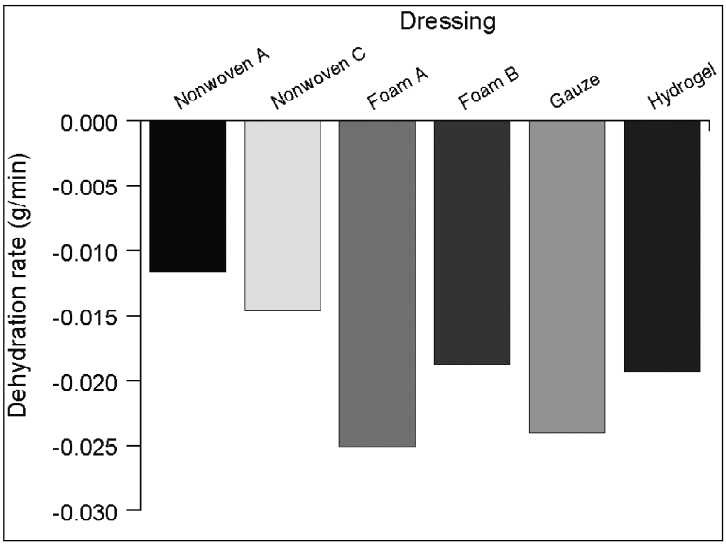

Figure 7. *Comparative dehydration rates for silver-containing dressings.*

Table 4. Dressing pH in deionized water

	pH After 3 Hours	pH After 24 Hours
Nonwoven A	5.4	5.4
Nonwoven B	9.5	7.7
Nonwoven C	7.2	6.8
Foam A	8.0	7.2
Foam B	8.0	7.7
Gauze	8.2	7.4
Hydrogel	6.6	6.5

In the case of SCDs, the assumptions made for MIC testing may not be valid. For example, a simple solution delivered as a bolus cannot be used to represent a complex slow release formulation. Product promotional literature and company-sponsored research indicate that many of the products tested have a low tendency to dose dump silver and provide an extended and/or controlled availability of silver.[14] Similarly, silver cannot be equated to the active forms of silver, and as demonstrated in this study, there appears to be no correlation between total silver in solution and antimicrobial efficacy.

A potential explanation for why SCDs behave in this way is the oligodynamic nature of ionic silver.[4] Exposure to low levels of constantly replenished ionic silver over an extended period of time causes selective accumulation of silver ions within the bacterial cell and subsequent death. The concentration of ionic silver is kept low due to the low solubility of silver ions in wound fluids. Optimal activity is therefore observed for dressings that can produce and maintain the highest concentration of ionic silver permitted by the total wound environment.

Since it is difficult to assess each of these properties of a dressing accurately by simple chemical measurements, it is likely that a direct measure of antibacterial activity in a simulated wound environment (as used in this study) is a more accurate measure of potential clinical antimicrobial activity than measures of silver content or release into an unrealistic solution, such as water, or measures of MIC data.

Some commentators have suggested that the release of large amounts of silver into the wound may have detrimental effects on healing,[15] and there have been some reports of systemic toxic effects, such as renal dysfunction.[16] Burrell[12] has commented on the fact that treatments, such as silver sulfadiazine (SSD), which compensate for the inactivation of silver ions by providing a large excess of active silver agent, have created problems for healthcare providers and patients. During the course of the present study, it was noted that the deionized water into which silver was being released turned yellow after use with nonwoven B and with nonwoven C. This suggests that in cases where the silver is initially presented in a metallic and not an ionic form and where the concentrations of silver in the dressing are particularly high, a reaction occurs between the dressings and the silver contained within them. The wound may be exposed to the resulting yellow compound or complex, the effects of which remain to be determined. Clinical experience with various forms of nonwoven B has shown that it can lead to the deposition of silver in the wound and subsequent staining.[17] Three *in-vitro* studies have also shown that the release of nanocrystalline silver from dressings is toxic to keratinocytes and fibroblasts.[18–20] Further investigation is needed to clarify the effects of this on wound healing.

As Lansdown[21] has highlighted, the physical components of SCDs are also important for the role they play in enhancing the wound environment and promoting favorable conditions for reepithelization and repair. Of the properties examined in this study, fluid handling is of particular importance for dressing choice. Ideally, a dressing should have the ability to rapidly absorb exudate, have a high absorptive capacity, and also not release fluid when compressed (eg, when a patient turns in bed). Comparison of the fluid-handling properties of the 7 SCDs demonstrated a variety of effects. Nonwoven C and the 2 foams showed a high absorptive capacity; however, a much lower retention capacity suggests that as much as 50% of the fluid absorbed might be lost under conditions of compression. Nonwoven A showed a high level of absorption but also demonstrated superior fluid retention with a drop of only around 20% under compression. This was combined with a low degree of capillary wicking. In contrast, gauze demonstrated poor fluid-handling properties, having a very low absorptive capacity. Initially, the sur-

Table 5. A summary of physical, chemical, and antibacterial properties of silver-containing dressings

	Nonwoven A	Nonwoven B	Nonwoven C	Foam A	Foam B	Gauze	Hydrogel
Antibacterial activity (after 7 days)	+++	+++	++	+	+	++	+
Fluid handling properties	+++	++	++	+++	++	+	++
Moisture retention	+++	+++	++	+	++	++	++
Skin-friendly pH	+++	+	++	++	+	++	+++

face of nonwoven B dressing appeared to be hydrophobic, resisting the absorption of any fluid. When absorption did occur, it was less than that expected for an alginate-type dressing. Nonwoven B also showed a tendency to wick fluid, a physical property that may lead to leakage, maceration, and possible tissue damage to the periwound area.

Dehydration is a measure of how well fluid is bound into the dressing and may be an indication of the dressing's ability to maintain a moist wound environment for optimal wound healing. The dehydration rates in this study were measured without the presence of a secondary cover dressing and are an indication of the relative properties of the dressings themselves. For a fixed area of dressing, nonwoven A and nonwoven C had the lowest dehydration rates. Gauze, the foams, and the hydrogel showed significantly higher rates of dehydration.

Dressing pH was measured to provide an indication of how the surface of a dressing changes when wet. It has been suggested that dressings with a slightly acidic pH (similar to that of healthy skin; pH of 5.5) may be most comfortable to wear. There have been reports, however, of some dressings causing irritation or stinging after absorbing exudate, suggesting that a change in dressing pH may be occurring. Dressings such as nonwoven B and gauze showed an alkaline pH (greater than pH 7), which gradually adapted to a more neutral pH (pH 7) by the 24-hour timepoint, indicating that some form of chemical reaction may be taking place. In contrast, nonwoven A and hydrogel remained stable throughout, with slightly acidic pH values of 5.4 and 6.6/6.5, respectively.

Table 5 summarizes the physical, chemical, and antibacterial properties of the proprietary SCDs studied. This demonstrates the range of properties of the dressings examined, which may have implications for their clinical use. The mixture of antibacterial and fluid-handling properties shown in these studies suggests that individual silver-containing antibacterial dressings have different characteristics that make them more or less suitable for different types of wounds. This study suggests that antibacterial dressing selection should be based on an assessment of the overall properties of the dressing clinically relevant to the wound type and condition rather than on silver content or deposition alone.

Conclusions

Dressing selection is a vital part of the successful management of infected wounds and those at risk of infection. Choice of an appropriate antibacterial dressing should be based on the wound type and condition and on clinically applicable measures, such as antibacterial, healing, and exudate handling effects, and not on any single laboratory parameter.

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