Significant and rapid reduction of free endotoxin using a dialkylcarbamoyl chloride-coated wound dressing

Objective: Endotoxin causes inflammation and can impair wound healing. Conventional methods that reduce bioburden in wounds by killing microorganisms using antibiotics, topical antimicrobials or antimicrobial dressings may induce endotoxin release from Gram-negative bacteria. Another approach is to reduce bioburden by adsorbing microorganisms, without killing them, using dialkylcarbamoyl chloride (DACC)-coated wound dressings. This study evaluated the endotoxin-binding ability of a DACC-coated wound dressing (Sorbact Compress, Abigo Medical AB, Sweden) in vitro, including its effect on the level of natural endotoxin released from Gram-negative bacteria.
Method: Different concentrations of purified *Pseudomonas aeruginosa* endotoxin and a DACC-coated dressing were incubated at 37°C for various durations. After incubation, the dressing was removed and endotoxin concentration in the solution was quantified using a Limulus amebocyte lysate (LAL) assay. The DACC-coated dressing was also incubated with *Pseudomonas aeruginosa* cells for one hour at 37°C. After incubation, the dressing and bacterial cells were removed and shed endotoxin remaining in the solution was quantified.
Results: Overnight incubation of the DACC-coated wound dressing with various concentrations of purified *Pseudomonas aeruginosa* endotoxin (96–11000 EU/ml) consistently and significantly reduced levels of free endotoxin by 93–99% ($p<0.0001$). A significant endotoxin reduction of 39% ($p<0.001$) was observed after five minutes. The DACC-coated dressing incubated with clinically relevant *Pseudomonas aeruginosa* cells also reduced shed endotoxin by >99.95% ($p<0.0001$).
Conclusion: In this study, we showed that a DACC-coated wound dressing efficiently and rapidly binds both purified and shed endotoxin from *Pseudomonas aeruginosa* in vitro. This ability to remove both endotoxin and bacterial cells could promote the wound healing process.
Declaration of interest: YBS, AA and JH are employees of Abigo Medical AB. The authors have no other conflicts of interest to declare.

bioburden • DACC • dialkylcarbamoyl chloride • dressing • endotoxin binding • hydrophobic interaction • *Pseudomonas aeruginosa* • Sorbact • wound • wound care • wound dressing • wound healing • wound infection

A common method of managing the bioburden of wounds is to kill microorganisms in situ using antibiotics, topical antimicrobial agents or by wound dressings that contain antimicrobial substances.

Different types and amounts of antimicrobials have been used in antimicrobial wound dressings, which display large variations in their antimicrobial properties. Such dressings generally have a broad antimicrobial effect against Gram-positive and Gram-negative bacteria, fungi, viruses and protozoa.[1] Despite their benefits, some antimicrobial dressings are known to have a cytotoxic effect on keratinocytes in vitro[2,3] and raise concerns regarding the development of bacterial resistance to antimicrobial substances, such as silver.[4–6]

A novel paradigm in bioburden management, however, is to reduce the bioburden through adsorption of microorganisms onto the wound dressing without killing them.[7] Dialkylcarbamoyl chloride (DACC) is a hydrophobic fatty acid derivative. When DACC is used to coat a wound dressing, it creates a fabric with highly hydrophobic surface properties. Microorganisms are also known to express various cell surface hydrophobicity (CSH), which influences their ability to colonise and attach to a target.[7] In close contact, the cell membrane hydrophobicity of microorganisms and the hydrophobic nature of the DACC-coated surface lead to hydrophobic interaction between them (entropy-driven) and promote the formation of an irreversible bond.[7,8]

Unlike some antimicrobial dressings, which release compounds that have cytotoxic potential on keratinocytes in vitro,[2,3] DACC-coated dressings do not release any compound which may have a cytotoxic effect on cells. Additionally, DACC-coated dressings have also been shown not to have cytotoxic potential against L-929 mouse fibroblast cells.[9]

In a pilot comparative study of two antimicrobial dressings in infected leg ulcers, a DACC-coated dressing was shown to be significantly more effective at reducing the bacterial bioburden in critically colonised or locally infected hard-to-heal leg ulcers than silver-coated dressing.[10] In a single-blind controlled trial comparing the clinical efficacy of a DACC-coated dressing with a normal saline dressing with 2% mupirocin ointment in an infected epidermolysis bullosa (EB) wound, no

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bacteria were found using a Gram-staining method in the wound with either the DACC-coated dressing or the saline dressing after three days of treatment. In the aforementioned study, it was demonstrated that the DACC-coated dressing was as effective as the antibiotic mupirocin in bioburden management of infected EB wounds.[11]

While killing any microorganisms present in wounds can reduce the bioburden, it can also lead to the release of toxic byproducts, such as endotoxin, into the wounds.[12] Endotoxin is a component of the outer cell membrane of Gram-negative bacteria and contributes to the integrity of the overall membrane structure. It consists of a polysaccharide chain anchored in the outer cell membrane via its lipid component containing fatty acids, termed lipid A. Lipid A is responsible for the toxicity of the endotoxin.[13] Endotoxins are mainly released due to bacterial cell growth and death, or damage to the outer membrane or cell wall of bacteria,[14,15] although smaller amounts of endotoxin are also secreted as part of cell membrane vesicle trafficking in the form of bacterial outer membrane vesicles.[16–18] The US Food and Drug Administration (FDA) has set the endotoxin limit for a medical device to be 20 endotoxin units (EU)/device for products that are directly or indirectly in contact with the cardiovascular and lymphatic system.[19]

Inflammation and pain are induced via several pathways by endotoxin.[20,21] Several in vitro studies suggest that endotoxin also contributes to a delay in wound healing.[22–25] Loryman et al. reported that endotoxin from *Pseudomonas aeruginosa* inhibited human epidermal keratinocyte migration in vitro,[24] while Brothers et al. have shown that endotoxin from *Serratia marcescens* contributes to impaired corneal wound healing.[25]

Because of the contributory effect of endotoxin on inflammation and a negative impact on wound healing, it would be advantageous for wound care products to be able to reduce the bioburden and, therefore, the presence of endotoxin in the wound by binding endotoxin. Previously, DACC-coated dressings have been shown to bind microorganisms by a physical, hydrophobic interaction.[8] Based on this hydrophobic interaction between DACC-coated wound dressings and microorganisms, it can be hypothesised that endotoxin, which contains a hydrophobic region in the lipid A, would also bind to this dressing.

In this study, the aim was to explore the ability of a DACC-coated wound dressing to bind *Pseudomonas aeruginosa* endotoxin in vitro, and to investigate its effect on the level of endotoxin released from Gram-negative bacteria.

Method

Wound dressing material

For endotoxin binding experiments, discs (14mm diameter (Ø)) were punched out from a DACC-coated dressing—Sorbact Compress (ABIGO Medical AB, Sweden). In the antimicrobial assay, discs were made from two dressing groups, namely:

- Wound contact layer group: Sorbact Compress, Mepitel Ag (Mölnlycke Health Care AB, Sweden), UrgoTul Ag (Urgo Medical, France), Acticoat Flex 3 and Acticoat Flex 7 (both from Smith+Nephew, UK)
- Foam dressing group: Sorbact Foam Dressing (ABIGO Medical AB, Sweden) and Mepilex Ag (Mölnlycke Health Care AB, Sweden).

Bacterial culturing

Pseudomonas aeruginosa was used as a model organism because it is one of the most common wound pathogens in hard-to-heal wounds. *Pseudomonas aeruginosa* CCUG 17619, a clinical isolate, was obtained from the Culture Collection of the University of Gothenburg, Sweden, and was used for all bacterial experiments. The strain was cultured for about 18 hours at 37°C, on 5% horse blood agar plate (HB agar; Service/Substrate, Sahlgrenska University Hospital, Sweden).

Preparation of *Pseudomonas aeruginosa* for binding experiment of endotoxin shed from live bacteria

Bacteria were cultured by incubating a single colony of the *Pseudomonas aeruginosa* in 3ml of tryptic soy broth (TSB, Sahlgrenska University Hospital, Sweden) for 24 hours at 37°C. The overnight cultures were washed twice in endotoxin-free water. Bacteria were then resuspended in 3ml of endotoxin-free water and its optical density at λ=600nm was measured in a spectrophotometer (V-1200, VWR, US). Based on the optical density, serial dilution was performed to reach the concentration of 10^8 colony forming units (CFU)/ml with endotoxin-free water. To confirm the number of bacteria, a dilution series was made using phosphate-buffered saline (PBS) (0.01M phosphate buffer, 0.85% NaCl, pH 7.4, Sahlgrenska University Hospital, Sweden), and cultured on HB agar plates overnight at 37°C. The bacterial colonies were counted on the following day.

Preparation of *Pseudomonas aeruginosa* for antimicrobial assay

For the antimicrobial assay, bacterial colonies from the HB plate were taken and resuspended in PBS solution and diluted to a concentration of 10^8 CFU/ml. The concentration was confirmed by performing a dilution series in PBS and plating on HB plates. The plate was incubated at 37°C for 24 hours and bacterial colonies were counted on the following day.

Binding of endotoxin to DACC-coated dressing

Purified endotoxin

For endotoxin binding experiments, two 14mm Ø discs of Sorbact Compress were incubated in 50µl of a wide range of concentrations (96–11000 EU/ml) of purified *Pseudomonas aeruginosa* 10 (serotype 10.22, ATCC 27316) endotoxin (Sigma-Aldrich, US). The incubation was performed in an Eppendorf tube (Eppendorf,

Germany) at 37°C for 24 hours. Maximum recovery diluent (MRD, Peptone 1.0g/l, sodium chloride 8.5g/l) (Sigma-Aldrich, US) was used at a 50% dilution (diluted with endotoxin-free water) (0.5×MRD) for endotoxin dilutions and the binding step.

Following incubation overnight, 450µl of 0.5×MRD was added to each sample and vortexed for one minute at maximum speed to release all unbound endotoxin into the solution. The DACC-coated dressing discs were then removed. Control samples consisted of the endotoxin solutions without the dressing discs. The control samples of each endotoxin concentration were run in duplicate and the media with DACC-coated dressing discs were run in triplicate.

Binding kinetics were evaluated by incubating two 14mm Ø discs in 50µl of 1000 EU/ml and 4000 EU/ml purified *Pseudomonas aeruginosa* 10 endotoxin (Sigma-Aldrich, US). The incubation was performed in an Eppendorf tube at 37°C for different durations:

- 1000 EU/ml: 0, 3 hours, 5.5 hours, 8 hours, 24 hours, 48 hours
- 4000 EU/ml: 0, 5 minutes, 30 minutes, 60 minutes, 24 hours.

After incubation, 450µl of 0.5×MRD was added to each sample and vortexed for one minute at maximum speed to release all unbound endotoxin into the solution. The DACC-coated dressing discs were then removed and surrounding media were kept for further analysis.

All samples were frozen at –20°C until endotoxin quantification. All samples of each kinetic experiment were analysed at the same time to avoid variability. However, different experiments were analysed at separate times. The initial concentration of endotoxin was also quantified using the same protocol as for the samples. Samples for each timepoint were run in triplicates.

Natural endotoxin shed from *Pseudomonas aeruginosa*

The effect of the DACC-coated dressing on the level of natural endotoxin released from Gram-negative bacteria was tested by incubating two 14mm Ø discs in 50µl of 10^8 CFU/ml *Pseudomonas aeruginosa* CCUG 17619 in endotoxin-free water. The incubation was performed in an Eppendorf tube at 37°C, for one hour. Endotoxin-free water and one-hour incubation were applied to avoid bacterial growth. The control sample consisted of 50µl of 10^8 CFU/ml *Pseudomonas aeruginosa* CCUG 17619 without the dressing discs.

Following incubation overnight, 950µl of endotoxin-free water was added to each sample and vortexed for one minute at maximum speed to release all unbound cells and endotoxin into the solution. The dressing material was then removed and centrifugation (3300×g for 15 minutes) was performed followed by sterile filtration to separate intact bacteria from the supernatant. The supernatants were analysed for endotoxin. The controls (no dressing) and samples with DACC-coated dressing discs were run in triplicate.

Quantification of endotoxin

In the binding of purified endotoxin and the binding kinetics experiments (1000 EU/ml), the endotoxin solutions obtained after the binding assay were diluted with 0.5×MRD and quantified using the Pierce Chromogenic Endotoxin Quant Kit (Thermo Scientific, US) based on the Limulus amoebocyte lysate (LAL) test. The standard curve supplied was also diluted with 0.5×MRD. In the investigation of the effect of the DACC-coated dressing on the level of natural endotoxin released from Gram-negative bacteria and binding kinetics experiments (4000 EU/ml), endotoxin was quantified commercially using the Kinetic chromogenic LAL assay (Endochrome-K) (Charles River, US).

The mean endotoxin concentration for each duplicate or triplicate sample was calculated. All samples and controls in the same experiment were quantified in the same run to avoid any intervariation in the LAL assay.

Antimicrobial assay

To investigate the effect of various dressings impregnated with different antimicrobials on the viability of bacterial cells, an antimicrobial assay based on the zone of inhibition on agar plate was performed according to the Kirby–Bauer disk diffusion susceptibility test protocol.[26] *Pseudomonas aeruginosa* CCUG 17619 was spread evenly onto cation-adjusted Mueller–Hinton agar (Sahlgrenska University Hospital, Sweden) using a cotton swab. All wound dressing materials, made as described above, were placed onto the Mueller–Hinton agar plate. The agar plate was then incubated for 18–24 hours at 37°C before measurement of the zone of inhibition (ZOI). A minimum of three samples for each dressing were used in this experiment.

Statistics

All statistical calculations and Student t-tests were performed (two-tailed distribution and two-sample equal variance variables) using Microsoft Excel (Microsoft, US). Graphs were created using GraphPad Prism 8.4.2 (GraphPad, US).

Results

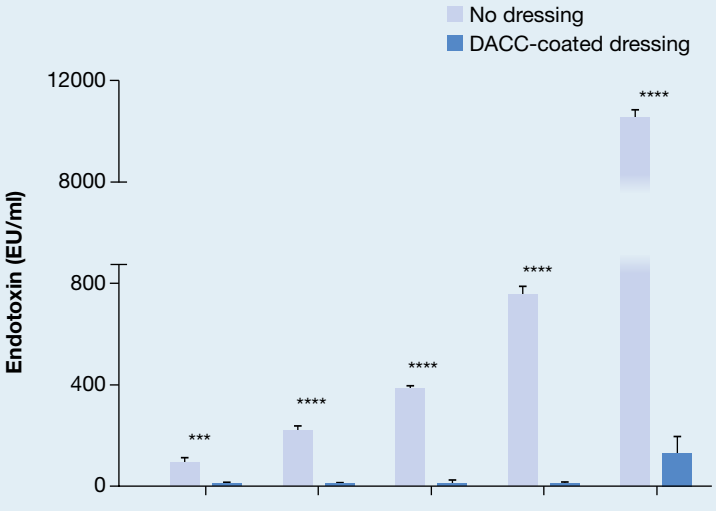
Binding of purified *Pseudomonas aeruginosa* endotoxin

The ability of the DACC-coated dressing to bind purified endotoxin from *Pseudomonas aeruginosa* was analysed using the binding assay (Fig 1). Overnight incubation of the DACC-coated wound dressing with a wide range of concentrations of endotoxin consistently resulted in a significant reduction of the endotoxin levels (93–99%) ($p<0.0001$) compared with the no-dressing control (Fig 1). Even at the highest concentration tested (11000 EU/ml), a 99% ($p<0.0001$) reduction of the endotoxin level was observed.

Binding kinetics

The binding kinetics of purified *Pseudomonas aeruginosa* endotoxin to the DACC-coated dressing discs were

Fig 1. Binding of purified *Pseudomonas aeruginosa* endotoxin by dialkylcarbamoyl chloride (DACC)-coated dressing. Endotoxin remaining in the medium after overnight incubation with the DACC-coated dressing discs was analysed by using Limulus amoebocyte lysate (LAL) assay. The various concentrations of the endotoxin used and the reduction of their levels, are shown beneath the respective bars. The controls (no dressing) of each endotoxin concentration were run in duplicate, and media with DACC-coated dressing discs (Sorbact Compress) were run in triplicate. Significant differences between the controls and the media with DACC-coated dressing discs are indicated by asterisks: ***p<0.001; ****p<0.0001



Endotoxin added (EU/ml)	96	230	400	780	11,000
Reduction (%)	93	98	97	99	99

followed by analysing two concentrations of endotoxin (1000 EU/ml and 4000 EU/ml) at various times (Fig 2).

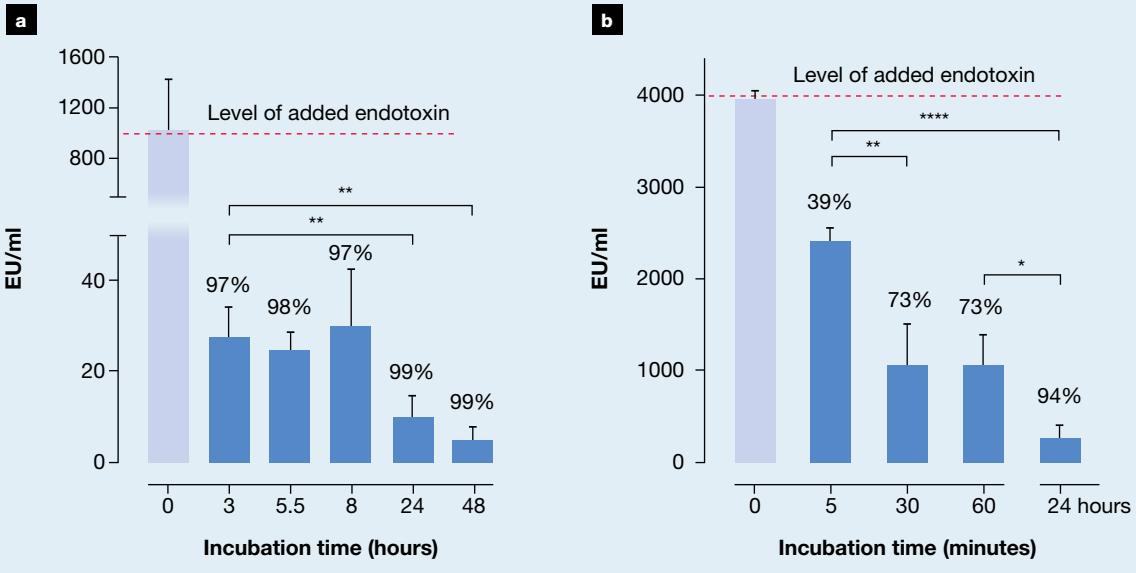
In the first experiment, using 1000 EU/ml of purified *Pseudomonas aeruginosa* endotoxin, the LAL assay showed that 97% ($p<0.0001$ from time 0) of the endotoxin was bound after three hours of incubation with the DACC-coated dressing discs (Fig 2a). The reduction of endotoxin increased further to 99% between 3–24 hours ($p<0.01$).

Since the binding kinetics appeared to be quite fast, a second experiment was performed to increase the sampling frequency at earlier timepoints. A significant reduction (39%) of the purified endotoxin level (4000 EU/ml) was observed after five minutes of incubation ($p<0.001$ from time 0) (Fig 2b), and within 30 minutes 73% of the free endotoxin was bound to the DACC-coated dressing. The reduction of free endotoxin significantly increased over time to 94% after 24 hours of incubation.

The effect of the DACC-coated dressing on the level of endotoxin released from Gram-negative bacteria

The one-hour incubation of a *Pseudomonas aeruginosa* cell suspension (10^8 CFU/ml), with and without the DACC-coated dressing, showed that the control (without dressing), after removal of bacterial cells, released 420 EU/ml of endotoxin. In contrast, the presence of the DACC-coated dressing resulted in no detectable free endotoxin (<0.20 EU/ml), indicating that >99.95% of the endotoxin was removed by binding to the dressing ($p<0.0001$).

Fig 2. Binding kinetics of purified *Pseudomonas aeruginosa* endotoxin to dialkylcarbamoyl chloride (DACC)-coated dressing. Endotoxin remaining in the medium was analysed at various times during incubation with the dressing discs, and performed at 1000 EU/ml **(a)** and 4000 EU/ml **(b)** of endotoxin. The reduction percentages of the endotoxin are shown above the respective bars. Each time was run in triplicate. The unfilled bars in **(a)** and **(b)** represent the initial purified endotoxin concentration at the start of incubation. Significant differences between different time points are indicated by asterisks: *p<0.05; **p<0.01; ***p<0.001; ****p<0.0001



Killing of *Pseudomonas aeruginosa* by various wound dressings, releasing antimicrobial agents into the surroundings

Since shedding of endotoxin can be induced by killing Gram-negative bacteria with antimicrobial substances, thus affecting the wound healing process, various antimicrobial wound dressings were compared for their ability to kill *Pseudomonas aeruginosa*.

Using the antimicrobial assay based on the ZOI, the release of antimicrobial substances from various dressings into the surroundings were determined (Table 1). No ZOI was observed for the two DACC-coated dressings. In contrast, various sizes of ZOI were evident for all other antimicrobial-containing dressings.

Discussion

Endotoxin has been known to cause inflammation and the presence of free endotoxin in a wound has been shown to delay cell migration, which can lead to slower wound healing.[22–25] In the present study, it was shown that the DACC-coated wound dressing effectively bound *Pseudomonas aeruginosa* endotoxin.

Several studies have reported that DACC-coated wound dressings reduce the bioburden of wounds by binding microorganisms.[7,8,10,11,27–29] This approach has been proven to be more effective in reducing the bioburden than silver-coated dressings,[10] and as effective as antibiotic (mupirocin) treatment in bioburden management in EB-infected wounds.[11] In the present study, the binding ability of DACC-coated wound dressings and their effect on free endotoxin from Gram-negative bacteria were investigated in vitro.

The DACC-coated dressing not only binds bacteria,[8] but our results showed that it also binds free endotoxin in the surrounding media, causing a significant reduction, even at a very high endotoxin concentration (11000 EU/ml). Furthermore, endotoxin that bound to the dressing appeared to adhere strongly, given that it could not be released by extensive vortexing. In addition, it was a fast-adhering process with an almost 40% endotoxin reduction within the first five minutes, up to 97% within three hours, and up to 99% by 24 hours. The ability of the DACC-coated dressing to continuously reduce free endotoxin concentration is important because it can be used for up to seven days. Thus, the longer the dressing is worn, the more endotoxin it may remove, which could be favourable to wound healing.

Endotoxin is released into the environment, mainly when Gram-negative bacterial cells grow, die or become damaged, and it is released as discs, blebs or vesicles of the bacterial outer membrane.[14–18,30] Few studies have investigated the effect of wound treatment, especially impregnated or coated wound dressings, on levels of endotoxin released from Gram-negative bacteria. In our study, after a one-hour incubation of a clinically relevant *Pseudomonas aeruginosa* strain with a DACC-coated dressing, no increase of free endotoxin concentration was observed. Instead, free endotoxin was significantly reduced to below detection limit (>99.95% reduction, $p<0.0001$), showing that the DACC-coated dressing not only can bind purified endotoxin, but is also able to bind endotoxin shed from live *Pseudomonas aeruginosa* cells. This binding of endotoxin shed from the *Pseudomonas aeruginosa* cells is markedly better than the binding of purified endotoxin from *Pseudomonas aeruginosa* 10 (73% reduction). These endotoxin forms have been shown to express different Limulus activity.[30] The activity of endotoxin shed into culture medium has been shown to be the most Limulus-active form of endotoxin compared to cell-bound and purified endotoxin.[30]

By evaluating the binding of endotoxin shed by *Pseudomonas aeruginosa* cells into the medium, it was also possible to find out whether Gram-negative bacteria, which will also bind to the dressing through hydrophobic interaction, would affect the endotoxin binding. Our study showed that the presence of *Pseudomonas aeruginosa* cells did not negatively affect the endotoxin binding to the DACC-coated dressing.

In an in vitro study, Ronner et al. demonstrated a significantly higher initial adhesion of *Staphylococcus aureus* to a DACC-coated dressing compared with an uncoated dressing.[8] Thus, hydrophobic interaction plays a substantial role in this higher initial adhesion of microorganisms. The lipid A component of endotoxin is also hydrophobic via its fatty acids and is likely to bind to DACC-coated dressings through the same mechanism. Since lipid A of endotoxin is a strong inducer of the host inflammatory response, hydrophobic interaction between lipid A and DACC-coated dressings may neutralise its proinflammatory activity.

By using a computer simulation, Ding et al. described electrostatic and hydrophobic interactions as important binding forces in the endotoxin adsorption mechanism of a material.[31] Also, in their in vivo wound healing study in mice treated with *Pseudomonas aeruginosa* or purified endotoxin, they showed significantly fewer

Table 1. Antimicrobial effect of wound dressings on the growth of *Pseudomonas aeruginosa*

Wound dressing	Inhibition zone*, cm, mean±SD
Wound contact layer	
Sorbact Compress, n=6	0
Mepitel Ag, n=3	2.0±0.1
UrgoTul Ag, n=3	2.2±0.1
Acticoat Flex 3, n=3	2.0±0.1
Acticoat Flex 7, n=3	2.1±0.1
Foam dressing	
Sorbact Foam Dressing, n=3	0
Mepilex Ag, n=3	1.4±0.1

*Discs of wound dressings were placed on an agar plate covered with a *Pseudomonas aeruginosa* suspension and grown overnight at 37°C. The growth inhibition zone around each wound dressing disc was measured; SD—standard deviation

infiltrated inflammatory cells in the wound in the presence of endotoxin-binding material than in its absence.[31]

The impact of a silver-containing dressing on endotoxin release from *Pseudomonas aeruginosa* during overnight incubation was compared with that of a DACC-coated wound dressing in a study by Braunwarth et al.[32] The authors showed that the silver ion-impregnated dressing released a significantly lower amount of bacterial endotoxins compared with the DACC-coated dressing. The reason for the discrepancy between our results and the study by Braunwarth et al. could be that they used an incubation step, which favoured the silver-containing dressing, while allowing bacterial growth overnight in the presence of the DACC-coated dressing. After incubation, they performed the autoclavation step. Autoclavation causes release of endotoxin from all cells present in the system rather than endotoxin release induced by silver or a DACC-coated dressing. Our study was designed to follow the effect of the DACC-coated dressing on endotoxin from *Pseudomonas aeruginosa* cells by using a one-hour incubation to avoid bacterial growth, and using centrifugation and sterile filtration to separate the live bacteria from the shed endotoxin.

No ZOI was observed around the DACC-coated dressings in this study, which clearly showed that these dressings do not release any antimicrobial substance. This corroborates the mode of action of DACC-coated dressings, i.e., they reduce the bioburden by binding, not killing, microorganisms.[7,8,10,11,27–29] This was confirmed by investigating the viability of microorganisms bound to a DACC-coated dressing using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) staining. The MTT dye molecule is a widely used reliable indicator of cellular metabolic activity. MTT staining showed that microorganisms bound to a DACC-coated dressing (Sorbact Compress) are viable (Husmark et al., unpublished data).

In contrast, a consistent ZOI surrounded all other antimicrobial-containing dressings tested, demonstrating that these dressings released antimicrobial substances. In some in vitro and in vivo studies investigating endotoxin release from *Escherichia coli* induced by different antibiotics, it has been shown that the amount and rate of endotoxin release are dependent on both class and concentration of antibiotic used.[14,15] Destruction of Gram-negative bacteria generally increases the endotoxin levels in an environment, and, like antibiotics, the rate and amount of endotoxin released are likely to be affected by both the antimicrobial concentration in wound dressings and how it affects the outer membrane of the Gram-negative bacteria.

Endotoxin presence in wounds has been shown to cause inflammation and negatively affect wound healing. In our in vitro study, the DACC-coated dressing did not result in increase of endotoxin level from Gram-negative bacterial cells, but significantly reduced the level of free endotoxin within minutes. How this in vitro endotoxin binding effect translates into the in vivo situation of inflammation and wound healing needs to be further investigated.

Limitations

The main limitation of the study is that it is a pure in vitro study and, as such, does not fully replicate the complex environment in a real-life wound.

Conclusion

The mode of action of DACC-coated dressings has been established as reducing the bioburden in wounds through hydrophobic interaction rather than by killing microorganisms.[7,8,10,11,27–29] The capability of these dressings can now be extended to include their ability to reduce free endotoxin rapidly and significantly. The implication of these in vitro results regarding changes in the reduction of inflammation and pain, and the wound healing process, remains to be further investigated. JWC

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Reflective questions

- In which wounds may endotoxins play a role in delaying healing? How?
- How are wounds best treated in order to reduce potential harmful action of endotoxin?
- What further studies should be performed to investigate the role of endotoxin in wounds?

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