The Use of a Silver–Nylon Dressing During Evacuation of Military Burn Casualties

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The military has used silver–nylon dressings as a topical antimicrobial on combat-related burns for the past 15 years. However, their clinical efficacy and associated risks have not been evaluated. Herein, the authors document our experience with the use of a specific silver–nylon dressing (Silverlon®) during global evacuation of casualties from combat zones to the United States sArmy Institute of Surgical Research Burn Center. A 10-year retrospective analysis was performed. Variables included patient demographics, total body surface area, length of stay, Injury Severity Score, incidence of urinary tract and burn infections, pneumonia, patient status at the time of discharge, and a composite endpoint. The patient cohort was stratified into two groups: Silverlon® (Group 1) and topical antimicrobial agents (Group 2). Data were analyzed using appropriate statistical tests ($P \leq .05$). Nine hundred eighty-eight patients (26 ± 6 years) were identified with 184 patients (Group 1) and 804 patients (Group 2). Silver–nylon dressings trended toward decreased wound infection rate (5.4 vs 9.5%) even when applied to full-thickness burn injuries. When compared with topical antimicrobial agents, the silver–nylon dressing was not associated with significant differences in burn-related complication. The authors demonstrate the antimicrobial efficacy of the silver–nylon dressing during global evacuation of burn casualties from combat zones to the burn center. Compared with topical antimicrobials, the silver–nylon dressing is lightweight and easy to apply and requires minimal wound management which makes it desirable as a burn dressing for combat applications as well as mass casualty situations.

Burns sustained during military operations constitute approximately 8% of all combat-related injuries. Typically, combat burn casualties undergo immediate medical stabilization in the deployed environment followed by evacuation through multiple echelons of care to the United States Army Institute of Surgical Research (USAISR) Burn Center in San Antonio, Texas. Key priorities of care of combat burn casualties during global evacuation include burn resuscitation, wound care, organ support, and damage control surgery, if necessary. On average, combat burn casualties arrive at the burn center approximately 4 days after injury for definitive surgery, which includes excision and grafting[1, 2].

Wound management immediately following combat-related burns includes debridement of devitalized tissue and application of topical antimicrobials as prophylaxis against infection during evacuation until surgical excision can be performed[3]. At USAISR, topical antimicrobials have included alternation of silver sulfadiazine (SSD) and 12% mafenide acetate cream or soaks with 5% mafenide acetate solution. Alternating creams require application of a one-sixteenth inch thick layer with dressing changes twice a day with complete removal of the cream, wound debridement, and reapplication[4]. On the other hand, 5% mafenide acetate solution applied to dry gauze covering burn wounds needs to be soaked every 6 hours to maintain appropriate antimicrobial levels in the wound bed. In general, mafenide acetate has been prone to cause pain on application[5, 6]. Silver-containing dressings such as, Silverlon® (Argentum Medical, Geneva, IL) which

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are comprised of nylon fibers coated with metallic silver, have also been used for wound care during global evacuation[7–9]. The sustained release of silver ions from the dressing on application of water every 6 hours has a theoretical benefit of providing broad spectrum antimicrobial coverage, which obviates the need for frequent dressing changes[7, 10]. Over the past decade, the aforementioned strategies have been used during evacuation of combat burn casualties[8, 9, 11].

A variety of commercial silver-containing dressings that differ in their silver content and dressing formulations are available for clinical use in the military as well as civilian populations[10, 12, 13]. The silver-containing dressings are a simple and shelf-stable alternative to cream and solution-based topical antimicrobials for civilian disaster preparations. Based on a cost-benefit-convenience decision by the US Army, Silverlon® is currently being used during aeromedical evacuation of military burn casualties and is being supplied to Combat and Support Hospitals including Tactical Forward Surgical Teams [8, 9]. Despite the on-going use of the silver–nylon dressing in military medicine, there is lack of information on its clinical efficacy and associated risks, if any. The objective of the study was to document our experience with the use of the silver–nylon dressing as an antimicrobial burn dressing on combat-related burns injuries during global evacuation from combat operations in Iraq and Afghanistan to the USAISR Burn Center in San Antonio, Texas.

MATERIALS AND METHODS

After Institutional Review Board approval, we conducted a retrospective study of consecutive service members burned during combat operations admitted to the USAISR Burn Center from March 2003 to December 2013. The data were collected from two sources, namely, query of electronic medical record and paper flight documentation. The variables included patient demographics (race, age, and gender), length of stay (LOS, days) in the hospital and burn intensive care unit, Injury Severity Score, total body surface area burned, and status of patients at the time of discharge. Laboratory records were reviewed to extract information on the incidence of urinary tract infection, pneumonia, bacteremia, and wound infection during the hospital stay. The cohort of patients was stratified into two groups: patients with combat-related burn injuries covered with the silver–nylon dressing (Group 1) and other topical antimicrobials (SSD, 12% mafenide acetate cream, and 5% mafenide acetate solution; Group 2). All burn dressings were applied before transport from the Role IV hospital in Landstuhl Germany to USAISR (estimated travel time of 8–12 hours). We also evaluated a composite endpoint that combines bacteremia, wound infection, and/or mortality as an outcome measure.

The USAISR Burn Center serves as the sole referral center for all combat burn injuries. The burn center is a 40-bed facility of which 16 beds are designated as intensive care unit beds. All definitive care for burned military personnel, including rehabilitation and reconstruction, takes place at USAISR. USAISR also functions as the civilian regional burn center for 49 counties in South Texas.

Statistical Analysis

As appropriate, the chi-squares test was used for categorical variables, a two-tailed student *t*-test or nonparametric Mann–Whitney test for continuous variables. Statistical significance was set at $P \leq .05$. Results are expressed as mean ± standard deviation (SD) or median ± interquartile range (IQR).

RESULTS

A total of 987 combat burn casualties (mean age: 26 ± 6 years) were identified with 184 patients (male: 178 [97%]; female: 6 [3%]) treated with the silver–nylon dressing (Group 1) and 803 patients (male: 780 [97%]; female: 23 [3%]) with topical agents (Group 2). The cohort included 484 (~49%) patients with third-degree burns. The median percent of full thickness burns in Group 1 (74 patients) was 10% (IQR: 3–33) and Group 2 (414 patients) was 10% (IQR: 3–30). Median total body surface area in Group 1 was 8.5% (IQR: 0–22) and 7% (IQR: 0–18.5) in Group 2 ($P = .767$). Median Injury Severity Score in Group 1 was 9 (IQR: 0–16) and 8 (IQR: 0–18) in Group 2 ($P = .803$). In Group 1, the median hospital LOS (11 days; IQR: 0–27) and ICU LOS (0 day; IQR: 0–12) were not significantly different from Group 2 (hospital LOS: 12 days [IQR: 0–31]; ICU LOS: 0 day [IQR: 0–10]; $P \geq .5$). The mean incidence of urinary tract infection was not significantly different between the groups (Group 1: $n = 5$ [2.7%]; Group 2: $n = 16$ [2%]; $P = .57$). Likewise, mean incidence of pneumonia (Group 1: $n = 22$ [12%]; Group 2: $n = 98$ [12.2%]; $P = 1.0$), bacteremia (Group 1: $n = 8$ [4.3%]; Group 2: $n = 44$ [5.5%]; $P = 1.0$), and wound infection (Group 1: $n = 10$ [5.4%]; Group 2: $n = 76$ [9.5%]; $P = .08$) were not significantly different between the groups. Overall, there was no difference in the mortality rate (Group 1: $n = 14$ [8%];

Table 1. Demographic data and clinical outcomes of combat burn casualties admitted to the Burn Intensive Care Unit (BICU) at the United States Army Institute of Surgical Research (USAISR)

Parameters	Silver–nylon	Topical agents	*P*
Total patients, *n* (%)	184 (18.6)	803 (81.4)	–
Age, yr (median [IQR])	25.5 (8)	24(7)	.536
Male, *n* (%)	178 (97)	780 (97)	–
Female, *n* (%)	6 (3)	23 (3)	–
Third degree burns			
Patients, *n* (%)	74 (60)	414 (48)	–
% (median [IQR])	10 (31)	10 (30)	.810
TBSA, % (median [IQR])	8.5 (22)	7 (18.5)	.767
ISS (median [IQR])	9 (16)	8 (18)	.803
Hospital LOS, days (median [IQR])	11 (27)	12 (31)	.503
Burn ICU LOS, days (median [IQR])	0 (12)	0 (10)	.540
UTI, *n* (%)	5 (2.7)	16 (2)	.57
Pneumonia, *n* (%)	22 (12)	98 (12)	1.0
Bacteremia, *n* (%)	8 (4.3)	44 (5.5)	.71
Wound infection, *n* (%)	10 (5.4)	76 (9.5)	.08
Composite endpoint, *n* (%)	26 (14)	146 (18)	.19
Discharge condition, *n* (%)			
Full recovery	136 (74)	649 (81)	.156
Moderate recovery	26 (14)	76 (9.5)	.179
Death	14 (8)	55 (7)	.152

Group 2: $n = 55$ [7%]; $P = .152$) or the composite endpoint ($P = .19$) (Table 1).

DISCUSSION

The objective of the study was to document our experience with the use a silver–nylon dressing as an antimicrobial dressing on combat-related burns injuries during global evacuation from combat operations in Iraq and Afghanistan to the USAISR Burn Center. The primary finding is that when compared with topical antimicrobials, the silver–nylon dressing was not associated with a significant difference in pertinent burn-related complications. The silver–nylon dressing trends to reduce wound infection rates (5.4 vs 9.5%) even when applied to full-thickness burn injuries.

The silver–nylon dressing trending towards reduced incidence of burn infection may be due to a number of factors. The silver–nylon dressing is an elastic bandage that can be immediately applied over burn injuries in the deployed environment. The immediate application of the dressing prevents further exposure of the wound to the environment. Upon moistening, the silver–nylon dressing releases positively charged silver ions in a sustained manner into the wound bed allowing the dressing to remain in place for 5–7 days[7, 14]. Compared with topical antimicrobials, the need for fewer dressing changes with the silver–nylon dressing reduces wound exposure to external pathogens. Unlike topical antimicrobial creams, the silver–nylon dressing may prevent maceration of the wound bed and formation of loose edges, which together may impede bacterial proliferation and ingress in the devitalized tissue[15–17]. The silver–nylon dressing has been shown to reduce infection in other applications, which corroborates the finding of this study[18–20].

The silver–nylon dressing used in this study has been approved by the U.S. Food and Drug Administration for local burn wound management of partial and deep partial thickness burns. The use of the dressing on full-thickness burns provides evidence of the efficacy of the dressing for severe burn injuries as well. Regular assessment of wound healing and burn depth is critical for burn wound management. SSD creams adhere to burn wounds giving it a whitish appearance, have poor penetration in the burn eschar, and form a pseudo-eschar[21, 22]. The film formed over the burn makes the wound appear deeper, thereby complicating burn wound assessment. From a clinical standpoint, the silver–nylon dressing is beneficial as it allows for regular and unbiased burn wound assessment with minimal patient discomfort.

Compared with solution and cream-based topical antimicrobial agents, the silver–nylon dressing has several advantages. Unlike mafenide acetate cream (12%) that causes pain on contact with intact free nerve endings and forms a neoeschar often requiring

hydrotherapy to remove[5, 23], the application and dressing changes of the silver–nylon dressing are relatively pain-free. Silver particles when absorbed systematically do not result in metabolic acidosis often observed with mafenide acetate solution (5%) application, especially in patients with pulmonary dysfunction[24–27]. As opposed to mafenide acetate that lacks antifungal properties[28, 29], the silver–nylon dressing provides a broad spectrum fungicidal activity that may possibly mitigate burn-related fungal infection[30, 31]. Unlike hydrochlorous acid and sodium hypochlorite solutions that are cytotoxic to human cells and detrimental to macrophage survival and function, the silver–nylon dressing does not present any deleterious effect to human cells[32, 33]. The silver–nylon dressing when applied to burn wounds does not stain tissues as observed with silver nitrate solution that turns black on contact with tissue and also causes electrolyte disturbances[34, 35]. The silver–nylon dressing is hypoallergenic and neither presents cytotoxicity nor impairs re-epithelialization as reported with SSD cream[36].

SSD cream contains 1% SSD by weight and 30% of that compound contains silver, which suggests that SSD cream releases ~3 mg of silver for each gram of cream. Thus, a 16 in.^{2} burn would need 17 g of SSD to release the same amount of silver as that of the silver–nylon dressing (52 mg/l). Unlike the silver–nylon dressing that can be left untouched on the burn wound for 7 days, SSD needs to be changed twice daily. This implies that in 1 week, a 16 in.^{2} burn would need ~300–400 g (one tube) of SSD cream. The acquisition cost of one tube of the SSD cream is twice as much as that of a single 4" × 4" silver–nylon dressing. Additionally, the twice daily changes needed with SSD cream increase indirect costs of nursing resources and medical supplies. Collectively, from cost as well convenience stand-point, the silver–nylon may be a cost-effective option compared with topical antimicrobial agents.

Immediate global evacuation of burn casualties from combat zones though desirable may be prolonged due to operational requirements. Additionally, the threat of nuclear and chemical terrorism has made it necessary to develop disaster plans for mass casualty incidents. Under such scenarios, an antimicrobial dressing that can easily be applied over burn wounds with minimal wound management is highly desirable. The silver–nylon dressing has ~550 mg of silver in each 4" × 4" dressing. Within 24 hours, the dressing releases 9–10% (52 mg/l) of its silver, which is higher than that needed for an effective and rapid bacterial kill. The residual silver in the dressing provides a sustained release of silver ions, thereby allowing for fewer dressing changes[7, 37]. The fewer dressing changes per patient facilitate optimal management of medical inventory and nursing resources that are critical during planning of combat medical operations[38]. The elastic nature of the silver–nylon dressing allows for ease in application over burn wounds in austere situations by responders that may not be formally trained in burn wound management. Although the use of the dressing by nonmedical personnel may increase the risk of excessive compression, we are of the opinion that this risk can be mitigated by imparting minimal education and training as the dressing is user friendly. Unlike topical antimicrobial agents, the silver–nylon dressing comes in different configurations (gloves, rolls), it is light-weight (~3 g) making it easy to store and transport, can endure extreme temperatures without compromising its antimicrobial properties, and has a stable shelf life of 5 years. Together, the aforementioned properties recommend the use of the silver–nylon dressing as a viable burn dressing for combat operations and mass casualty situations.

The retrospective design is a limitation of the study. The lack of a prospectively selected cohort or control group limits the ability to validate the efficacy of the silver–nylon dressing in comparison to other commercially available burn dressings. Although the study only examined combat-related burn injuries, the findings can be extended to civilian burn injuries as well.

CONCLUSION

The study demonstrates the efficacy of the silver–nylon dressing as an antimicrobial dressing during global evacuation of burn casualties from combat zones to the military burn center for definitive care. Compared with topical antimicrobial agents, the silver–nylon dressing is lightweight and easy to apply and requires minimal wound management that makes it a viable burn dressing for combat operations and mass casualty situations. The study underscores the need to develop prospective clinical trials to establish the clinical efficacy of the silver–nylon dressing compared with other commercially available burn wound dressings.

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