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ORIGINAL ARTICLE

Ultraviolet-C Irradiation in the Management of Pressure Ulcers in People With Spinal Cord Injury: A Randomized, Placebo-Controlled Trial

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Abstract

Objective: To compare the effects of ultraviolet-C (UVC) with placebo-UVC on pressure ulcer healing in individuals with spinal cord injury (SCI).

Design: Double-blind randomized trial with stratification for ulcer location to buttock or lower extremity. Subjects were followed up for 1 year postintervention.

Setting: Rehabilitation institution.

Participants: Adult inpatients and outpatients (N=43) with SCI and stage 2 to 4 pressure ulcers (n=58).

Interventions: Ulcers and periwound skin were irradiated 3 times per week using UVC or placebo-UVC. The endpoint was wound closure or hospital discharge without closure.

Main Outcome Measures: Primary outcome was weekly percent area relative to baseline. Secondary outcomes were mean percent area change between consecutive weeks, surface appearance, weeks to closure, and impact on quality of life and wound status postintervention.

Results: Groups were similar at baseline for all demographic characteristics except ulcer duration ($P=.02$). Groups were similar when healing was compared overall. Subgroup analysis showed that the percent area relative to baseline for stage 2 buttock ulcers was significantly smaller in the group receiving UVC compared with placebo at weeks 3, 5, and 7. During weeks 1 through 8, these ulcers were 26% to 76% of baseline area using UVC versus 111% to 180% for placebo (achieved significant level [ASL], .03−.08; effect size, 0.5−0.8). Groups were similar in the percent area relative to baseline for stage 2 lower extremity ulcers. Group mean percent area change between consecutive weeks for all stage 2 ulcers was 36.6% with the use of UVC and 5.8% for placebo (ASL=.09). There were no group differences in the percent area relative to baseline and the mean percent area change between consecutive weeks for stage 3 to 4 ulcers. Groups were similar for all other secondary outcomes.

Conclusions: UVC is beneficial for stage 2 buttock ulcers. Further studies are warranted using a larger sample size, carefully considered exclusion criteria, and strategies to ensure homogeneity of the groups that are being compared.

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Pressure ulcers (PUs) are a serious secondary health condition after spinal cord injury (SCI). They increase hospital length of stay and restrict participation in rehabilitation.[1] The incidence of PUs in the SCI population may be up to 95% over the course of a lifetime, and PUs are a recurrent problem for many people.[2,3] More severe PUs, stage 3 or 4, and spreading infection increase the mortality risk post-SCI.[4] Lifestyle and psychosocial factors, such as inadequate nutrition, excessive moisture, smoking, and alcohol abuse, interact with severity of

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SCI, age, and history of previous ulcers to increase an individual's risk of developing PUs and delay their resolution.[2-4] A treatment that accelerates PU healing post-SCI would decrease the costs of care and could lead to significant improvements in quality of life by allowing persons to return sooner to their usual societal roles.

Although various physical agents have been studied in the context of PU care, there is questionable clinical evidence and several limitations associated with the research. This includes inconclusive findings,[5,6] trials lacking a placebo group or double-blinding,[7,8] practicality and safety issues,[9] compliance issues,[10,11] reports of declining healing rate with prolonged treatment,[11] and wound regression postintervention,[12] all of which underscore the need for further research in this field.

In vitro studies support using ultraviolet-C (UVC) for wound care. Effects include induction of releasable factors normally expressed during healing,[13,14] modification of growth factor receptors,[13,15,16] accelerated DNA synthesis, fibronectin release from fibroblasts,[17] and epidermal cell proliferation.[13] The killing of common wound pathogens and antibiotic-resistant organisms has also been shown.[17-22]

The literature provides only a few studies that examine the effects of ultraviolet irradiation (UV) on human wound healing. Vasodilatation, effective killing of pathogens, and accelerated wound closure have been shown using both ultraviolet-B and UVC.[21,23-27] The types of chronic wounds that have benefited from UV include venous and arterial disease ulcers,[28-30] superficial PUs in nursing home patients,[27,31] and PUs in individuals post-SCI.[26]

In the 1990s, the primary author (E.L.N.) investigated the effects of a regimen of UVC and ultrasound on PU closure post-SCI compared with a nursing-care control group. Ultrasound/UVC produced a promising, albeit nonstatistically significant, difference.[7] Limitations included failure to account for subject withdrawals in the control group and uncertainty regarding whether ultrasound or UVC was the effective intervention. A recent informal survey of local practice by the primary author suggests that UVC is most commonly used for wound healing without the addition of ultrasound. However, no placebo-controlled studies of UVC have been conducted on human wounds. Hence, the current study aimed to determine whether UVC added to current best practice improved PU healing in people with SCI.

Methods

Setting

The study was conducted at the Toronto Rehabilitation Institute, University Health Network, Toronto, Ontario, Canada, and was approved by the institutional research ethics board. Subjects were recruited from 2 inpatient sites, an SCI rehabilitation center and a complex continuing care center, and from an outpatient wound care clinic.

List of abbreviations:

ASL	**achieved significance level**
PU	**pressure ulcer**
SCI	**spinal cord injury**
UV	**ultraviolet**
UVC	**ultraviolet-C**

Participants

Eligible persons were adults older than 18 years with an SCI at C2 to L2, American Spinal Injury Association Impairment Scale A to D, and stage 2 to 4 PUs. Ulcers that had been surgically repaired within 3 months, neoplastic wounds, and ulcers receiving negative pressure therapy were excluded. In the absence of published data on UVC effects on human wounds, we based our sample size calculations on a study that examined weekly percentage wound area reduction using ultrasound/UVC. Treated wounds were reduced to 0% of baseline area at a mean $\pm$ SD of 28.5$\pm$10.21 days compared with 48$\pm$21.62 days in a control group.[7] This difference yielded an effect size of 1.15, which we considered clinically significant. For this study, based on a 2-sample t test, with an alpha of 5%, a difference of 19 days (pooled SD$=$1.15), and a target power of 80%, a sample size of 28 ulcers per group would be needed to show a significant difference on wound healing rate.[32]

Randomization

Randomization was stratified for ulcer location, based on expected different healing rates for sacrococcygeal and ischial ulcers (hereon referred to as buttock ulcers) compared with hip and leg ulcers (hereon referred to as lower extremity ulcers).[7] A noninvestigator generated the random sequence electronically using a blocking factor to balance numbers for hip versus lower extremity location. Allocation was concealed using numbered, opaque envelopes that were opened at the bedside after signed consent. For subjects with multiple ulcers, randomization was performed for the largest ulcer, and any additional ulcers were allocated to the group of the largest ulcer.

Interventions

All subjects received treatment using their designated lamp plus standardized local wound care following published guidelines.[33,34] Pain, spasticity, incontinence, infection, nutrition, and metabolic status were addressed as part of overall care.

Bedrest was physician prescribed and depended on ulcer location. Periods off bedrest were permitted daily provided that appropriate wheelchair seating systems had been established and patients could independently relieve pressure through weight shifting or a wheelchair tilt system. If no new tissue erosion or induration was observed, time off bedrest was increased.

Six new UVC lamps[a] were used in the study (95% invisible output at 254nm plus visible light; intensity $\sim$15mW/cm^2). However, the supplier replaced the bulbs of 3 lamps with 4-mW visible light bulbs; thus only 3 lamps emitted UVC. All lamps were fitted with a filter cover that makes visible light appear blue; thus output from the real and placebo lamps looked identical, which enabled blinding in this study.

Lamps were tested on an anterior forearm of healthy individuals at a 2.5-cm skin-lamp distance[35] to confirm that (1) 15-second exposures ($\sim$225mJ/cm^2) using active lamps produced a patchy-pink erythema (E1) that peaked at 6 to 8 hours and disappeared about 24 hours postexposure; and (2) 15, 45, 90, and 180 seconds (E1, E2, E3, and E4, respectively) of placebo-UVC