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Results of directly applied activated carbon cloth in chronic wounds: a preliminary study

H.S. Scheer,[1] MD; **M. Kaiser**;[1] ***U. Zingg**,[1] MD

Corresponding author e-mail: urs.zingg@spital-limmattal.ch

1 Department of Surgery, Limmattal Hospital, Zurich-Schlieren, Switzerland.

Results of directly applied activated carbon cloth in chronic wounds: a preliminary study

Objective: Activated carbon (AC) has been used in wound therapy as an active substance inside dressings. Applying AC directly on a wound is a new concept. The aim of this study was to analyse the outcomes of chronic wounds which were managed with directly applied activated carbon knitted cloth (ACC, Zorflex) in Swiss patients.
Method: A retrospective analysis of the records of all patients with chronic wounds treated with ACC between 1 October 2013 and 31 December 2015 in an outpatient wound clinic. Chronic was defined as a wound being present for >3 weeks. Malignant wounds were excluded. The main outcome was the time to complete closure or readiness for spilt-thickness skin grafting (STSG). Descriptive data, including nutritional status and angiology results were obtained.
Results: There were 36 women and 34 men, median age 68 years old. The median body mass index (BMI) 28.1kg/m^2 and 76% (n=53) of patients had comorbidities. Angiology exam results showed signs of reduced arterial perfusion in 13% (n=9) of patients and malnutrition in 11% (n=8). Of the wounds included 34% (n=24) were on the trunk and 66% (n=46) on the extremities. The median wound size was 6.9cm^2 (range: 0.1-300cm^2). The wounds on the trunk were larger than wounds on extremities (10 versus 2cm^2). Overall, median time to wound closure was 51 days. In 94% (n=66) of patients, wounds closed without further intervention and 6% (n=4) underwent STSG. Patients with comorbidities showed longer wound healing times compared with those without. No adverse events such as allergies or skin irritation occurred. Cost analysis, including personnel and material and stratified according known wound closure times, showed ACC (US$ 1252) to be like hydrocolloids (US$ 1128), but substantially lower than white gauze (US$ 3026) and negative pressure wound therapy (NPWT) (US$ 2578).
Conclusion: ACC applied directly on chronic wounds of different aetiology is safe with short closure times. The cost efficiency is high. It combines the positive features of other wound dressings, such as hydrocolloids and NPWT, without their disadvantages. The dressing change of ACC is easy and non-specialised nurses or even patients themselves can be taught to perform it .
Declaration of interest: H.S. Scheer and U. Zingg have nothing to disclose and were responsible for the study design, data collection, analysis and interpretation of the results. M. Kaiser is a consultant for Chemviron Carbon and received financial support to attend conferences and training sessions. ACC and the additional dressing material were provided by Chemviron Carbon.

activated carbon dressing • wound healing • Zorflex

There are numerous definitions for chronic wounds, all of which include the lack of healing for a certain amount of time.[1] Although there is no consensus as to what is a chronic wound,[2,3] most authors regard a wound as chronic when no healing occurs after three or more weeks of treatment.[4] The origins of chronic wounds are diverse. The most common aetiologies are trauma, operation, poor perfusion or a combination of these and other factors. In wounds of a vascular nature, arterial, venous or diabetic disorders may be present.[5]

The standard therapy consists of cleaning, debridement and application of an appropriate dressing. The range of available dressings is vast and it depends on the wound specialist's experience, patient-related factors and cost-effectiveness which kind of treatment is used. In Switzerland, most wounds are managed in an outpatient setting in which specialised nurses perform the dressing changes. Additionally, home nursing by non-specialist nurses is used for simple wound care. The costs are covered by mandatory basic health insurance.

Active carbon is a well-known substance incorporated in dressings that are used on inflamed and granulating wounds. The carbon is knitted. It develops very strong Van-der-Waals forces (weak, short-range electrostatic attractive forces) which drain secretion, bacteria and odours.[6] As well as its use as a wound dressings, activated carbon is used to treat oral intoxication and poisoning as it binds the poison and is not resorbed by the intestinal mucosa. These properties led to the theory that AC may be placed directly on a wound without a surrounding cover. To give the AC a better texture and handling, a fine knitted activated carbon cloth (ACC) was developed (Zorflex, Chemviron Carbon).

The objective of this study was to evaluate the efficacy, efficiency and safety of ACC applied directly in a cohort of patients with chronic wounds.

Methods

A retrospective analysis of patient records identified all consecutive patients with chronic wounds, defined as being present for ≥3 weeks, treated with ACC in our

H.S. Scheer,[1] MD; **M. Kaiser**;[1] ***U. Zingg**,[1] MD
Corresponding author e-mail: urs.zingg@spital-limmattal.ch
1 Department of Surgery, Limmattal Hospital, Zurich-Schlieren, Switzerland.

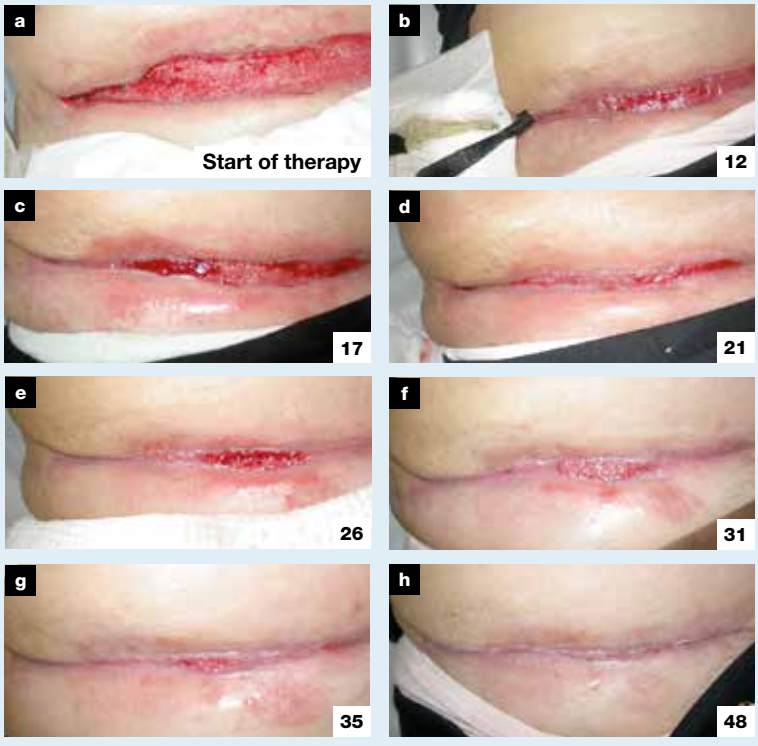
Table 1. Size of wounds in different locations

	Upper extremity	Trunk	Lower extremity
Size (cm^2)	4	10	5
Time to closure (days)	30	52	62
Visits	7	9	8

Table 2. Different dressing used on the wounds before activated carbon cloth

	%
Sulfadiazin silver cream	1
Aquacel (Convatec)	1
Bactigras tulle gras with chlorhexidine acetate 0.5% (Smith & Nephew)	5
Betadine ointment (Mundipharma Medical Company)	3
Hydrotac (Hartmann)	4
Hydroclean (Hartmann)	4
Hyiodine (Hartmann)	4
None	4
Wet gauze	4
PolyMem (own brand)	6
Algisite M (Smith & Nephew)	7
Dry white gauze	23
Negative pressure wound therapy (NPWT)	34

Fig 1. Healing process in an abdominal wound with the application of activated carbon cloth during 48 days until complete wound closure. Start of therapy (**a**), day 12 (**b**), day 17 (**c**), day 21 (**d**), day 26 (**e**), day 21 (**f**) day 35 (**g**) and day 48 (**h**)



outpatient wound clinic between October 2013 and December 2015. Wounds that were malignant in origin were excluded as were those patients of <18 years old. Patient appointments at the outpatient wound clinic varied according to the condition of the individual wound, with intervals between three days and two weeks. The study was approved by the ethics committee of the State of Zurich and patients' consent was obtained for the use of the medical records and photography.

Data were collected from medical records and the compulsory photographic documentation including: basic demographics, history of vascular disease including angiology reports, comorbidities assessed with the Charlson Comorbidity Index,[7] wound healing progress over time, odour, wound drainage and costs. The Charlson Comorbidity index allowed us to divide patients into groups based on the severity of their comorbidities. Depending on the study, two or more groups can be created.[7] Accordingly, we grouped the Charlson Comorbidity Index as follows:

- 0 points=no comorbidities
- 1–2 points: mild
- 3–4 points: moderate
- >5 points: severe.[8]

The primary outcome was the time to complete epithelialisation or readiness for split-thickness skin graft (STSG). In the latter, the day of skin grafting was defined as time of wound closure.

Cost analysis was performed using the Swiss ambulatory tariff structure (Tarmed). These were calculated using the cost of dressing plus the cost of the wound clinic consultation period, usually 30 minutes, checking the patient history, cleaning, debriding and changing the dressing, this was longer if negative pressure wound therapy (NPWT) was given Cost are presented as per dressing change or per day as appropriate as well as for a defined time of 50 days.

Results

There were 36 women and 34 men, with a median age 68 years (range: 17–94 year old) and a median body mass index (BMI) 28.1 kg/m^2 (range: 18.7–52.7 kg/m^2). The wounds had the following aetiologies: trauma 26% (n=18), postoperative 51% (n=36), arterial 3% (n=2), venous 6% (n=4), poor perfusion and 14% (n=10) with unclear wound.

Angiological exams showed signs of inadequate perfusion in 9 patients (13%): 7% (n=5) venous, 3% (n=22) arterial and 3% (n=2) mixed origin.

Diabetes was present in 19% (n=13) of patients and malnutrition in 11% (n=8). The comorbidities according the Charlson Index were severe in 8 patients, moderate in 17, and mild in 28 patients, with 17 patients having no comorbidities.

The location of the wounds was as follows: 24 on the trunk, the abdomen, thorax or back, and 46 on the extremities. The median initial wound size was 6.9cm^2 (range: 0.1-300cm^2). Wounds on the trunk were larger than wounds on extremities (Table 1). A large number of

Table 3. Cost calculation for different dressing types

	Personnel costs per dressing change (US$)	Material costs per dressing change (US$)	Personnel costs for therapy of 50 days (US$)	Material costs for therapy of 50 days (US$)	Total costs of therapy of 50 days (US$)
White gauze dressing changed daily	96	5	4777	265	5042
Hydrocolliod dressing changed every 4 days	96	7	1242	91	1334
NPWT changed every 4 days	115	79 (per day)	1491	3916	5408
ACC (10x10cm) changed every 4 days	96	6	1242	72	1314

ACC–activated carbon cloth; NPWT—negative pressure wound therapy

different dressings were used before the application of ACC (Table 2).

Wound drainage, which was assessed subjectively, with ACC was adequate and any present odours had gone as assessed by two investigators at every visit. No side effects, such as allergies or skin irritation, occurred during the application of ACC.

Overall, median time to wound closure was 51 days (range: 5–330 days). Epithelialisation was seen in 66 patients (94%) and median time to wound closure was 54.5 days (range: 5–330 days). Skin grafting was performed on 4 wounds (6%) the median day 25 (range: day 5–36). The wound closure time was similar in wounds on the trunk compared with those on extremities (52 versus 53 days). No wound reopened within two weeks of complete epithelialisation. An example is shown in Fig 1.

In patients with a high number of comorbidities the median time to complete wound closure was 62.5 days (range: 25–86 days). In patients with no comorbidities (Charlson Index Score: 0) median time to complete wound closure was in 35 days (range: 5–98 days).

There were 9 patients receiving immunosuppressive therapy. In these patients the median days until complete wound closure was 39; however, the wounds were small having a median size of 4cm^2. Patients without immunosuppressive therapy had a median wound size of 8cm^2 and 56 days until complete wound closure.

The costs of the four different kinds of treatment are summarised in Table 3 in detail. Based on a treatment duration of 50 days, the costs, including personnel and material were US$1314 for ACC, US$1334 for hydrocolloids (HD), 5042 US$ for white gauze and US$5408 for NPWT. The high cost for white gauze dressing is explained by the fact that this type of dressing must be changed daily, and usually by home nursing staff, in contrast to all other wound dressings.

We performed an additional analysis, stratified according to the known median durations of the most common wound dressings: ACC 50 days equivalent to US$ 1252; HD 45 days equivalent US$ 1128; gauze therapy 30 days equivalent US$ 3026; NPWT 24 days equivalent US$ 2578.

Discussion

In this study, wound closure with ACC was achieved in all patients within a median of 51 days without any adverse effects. Of 70 patients, only 4 required split skin grafting. Established alternative treatments, such as NPWT or HD, showed similar or slightly shorter wound closure times; however, in some case series not with a high success rate or with low patient numbers. Argenta et al. found a complete closure of chronic wounds with NPWT only in 15% of patients, within 28 days.[9] In a case series of 4 patients with abdominal wound dehiscence, 24 days were needed to close the wounds completely.[10] Chronic leg ulcers have been shown to close within 29 days of NPWT.[11] In contrast, HD wound closure of similar wounds took longer, up to 45 days.[11] In a comparative study by Ubbink et al., including several kinds of chronic wounds, complete healing was seen after 48 days with HD and after 30 days with gauze dressings.[12]

The comparison of the different studies regarding wound closure is difficult. The reasons are a high heterogeneity of the wound aetiologies, the patients' basic conditions and the dressings used. Furthermore, different definitions of complete wound closure, such as epithelialisation,[12] preparation time plus healing time of skin grafting[11] or time to closure by flap technique[10] have been used.

For smaller wounds, it is desirable to achieve complete epithelialisation without the need for skin grafting. In our series, wound closure without further intervention was successful in all but four patients. Despite the fact that STSG might speed up the time to complete wound closure, it also includes the perioperative risks and the danger of graft necrosis, especially in patients with comorbidities and immunosuppression. In studies on NPWT, definitive wound closure is often achieved with additional skin grafting,[10,11] thus again making comparisons difficult with our results of ACC treatment.

Overall, 53 patients suffered from comorbidities, malnutrition or were taking immunosuppressive medication. These conditions influence wound healing and need to be taken into consideration.[13,14] A number of studies did not mention any treatment confounders,[9] or they focus on a single one like in adequate perfusion.[11]

Some use the ASA Score,[10] which might not be ideal in this setting as it is a very general score, applied by the anaesthetist with the focus on risk factors for an anaesthetic procedure.

The results for the healing time with ACC treatment illustrate the impact of comorbidities. With a Charlson Index Score of 0 the median healing time was 35 days compared to 62.5 days in patients with a Charlson Index of 3. Furthermore, immunosuppressants decrease the speed of wound healing.[14] Patients with immunosuppressive therapy usually need a longer time to complete wound healing compared with those without immunosuppressive therapy. In our small cohort of nine patients taking immunosuppressive medication, this finding could not be reproduced. However, average wound size in these patients was substantially smaller compared with the ones without any immunosuppressive therapy.

The most important factor for a quick and complete wound healing is probably an adequate blood perfusion.[15] The localisation of the wound influences the healing conditions. The parts of the body differ in their cutaneous blood perfusion.[16] The results of this study do not show a difference in wound healing time between extremity wounds and those on the trunk, respectively. This might be caused by the difference in size with the wound on the trunk being larger and the fact, that all patients with non-healing extremity wounds were assessed by an angiologist and treated accordingly.

In the literature, most chronic abdominal wounds are abdominal dehiscence after laparotomy.[17–19] A differentiation between full-thickness wounds with exposure of abdominal viscera and partial-thickness with prevented evisceration was introduced by Argenta et al. in 2006.[18] This definition allows selecting partial-thickness abdominal wounds as defects which are able to epithelialise without additional surgery. De Vooght et al. published a series of six patients who were treated with NPWT for a median of 24 days.[10] The wounds were then closed by skin grafting or allowed to heal without surgery. The time until complete wound closure and the median wound size were not mentioned. In our series 15 patients had wounds after open abdomen or abdominal wound complications with a median wound size of 13cm^2. With one exception, the ACC treatment was applied until complete wound closure, a patient with an initial wound size of 225cm^2 was first treated with ACC. The wound size decreased to 35cm^2 and was then closed by split-thickness skin grafting.

Time and quality of healing are the most important outcome parameters. However, the time and effort that needs to be invested must be taken into account. The individual advantages of a specific dressing, the complexity and the number of dressing changes, whether the treatment is done in outpatient clinics or at home, and by whom, and the comfort for the patient are important factors.

Wet gauze dressings are easy to apply, safe and proven to support a fast wound healing but have to be changed at least once per day.[12,20] The dressing changes can be painful, they restrict the patient in his daily plans and usually require home nursing. In contrast, HD can be left for 2–4 days, absorb liquids, relieve pain and keep the wound wet and promote the process of epithelialisation.[20,21] However, an application on infected wounds is not recommended.[22]

NPWT is highly absorptive and keeps the wound bed wet. The negative pressure and the drainage of the interstitial fluid are supposed to cause shortening of the healing time.[23] The data concerning the reduction of bacteria are contradictory.[9,24] There are data suggesting that the bacterial load could be reduced,[25] or that the bacterial load is enhanced under NPWT,[24] possibly due to the occlusive dressing. The main disadvantages of NPWT are that it is time-consuming with complex dressing changes and at a the substantially higher price.[26]

ACC dressings can absorb fluids and antimicrobial properties,[6] is less time-consuming compared with NPWT and is changed in intervals of usually 3–5 days, but can be left up to seven days on the wound.[6,27] Furthermore, dressings must not necessarily be done by a wound specialist.

Subjectively, patients who experienced NPWT therapy prior to ACC favoured the latter treatment. The main reasons may be the less painful dressing changes, and therefore reduced anxiety of the patients, and the missing restriction caused by the NPWT machine.[28] Malodour affects quality of life negatively but it improves when the wound stops to smell.[29] We found, similar to other authors, that ACC application stops the malodour of smelly wounds quickly and permanently. [30]

An important factor in the treatment of chronic wounds are costs. The costs for an ACC treatment are substantially lower compared with simple white gauze dressings, HD and NPWT therapy. Our cost calculation refers to defined fixed treatment duration of 50 days. However, the stratified analysis according to the known median durations of the different wound therapy regimens indicated again a high-cost efficiency of ACC despite the fact that the median time to wound closure was longer. For white gauze dressings, the most important factor that causes cost is the necessity for a daily change, in contrast to all other dressings.

Limitations

The present study has a number of limitations. It is not a comparison of two or more different wound dressings. Apart from the time period to wound closure, a number of parameters are subjective, such as acceptance by the patient or odour control.

Conclusion

In conclusion, this study demonstrates the properties and advantages of AC in the form of a fine knitted cloth. Due to this structure AC adheres to the wound without sticking, promotes drainage and is antimicrobial. In presence of comorbidities, a complete wound closure could be achieved without a larger time effort. **JWC**

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Reflective questions

- Do we have to set new standards in defining different types of chronic wounds?
- Where could activated carbon cloth (ACC) fit into a modern wound therapy regime?
- What influences patient's quality of life in the treatment of chronic wounds the most?
- Which factors besides cost efficiency affect implementation of new treatment options?

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