CONTINUING MEDICAL EDUCATION

Wounds – From Physiology to Wound Dressing

Peter Kujath, Angela Michelsen

SUMMARY

Introduction: Optimal wound management remains the subject of active research. Improved knowledge of physiological wound healing, systemic research into wound dressing and the evaluation of chemical disinfection have given rise to new approaches to wound care.

Methods: Selective literature review.

Results: The primary goals of wound management are rapid wound closure and a functional and aesthetically satisfactory scar. While basic treatment for primary wound healing is often simple, a number of problems can arise in chronic wounds, especially in elderly patients and those with multiple morbidity. It is therefore essential to maintain the basic conditions for physiological wound healing, in particular adequate wound moistness. Each dressing change should entail an evaluation of the wound status, careful cleansing, and treatment tailored to the phase of wound healing. Many therapeutic agents formerly in use are now obsolete. A variety of specific preparations are available for wound covering, including inert, interactive and bioactive substances. There remains a lack of good evidence for these, however.

Conclusions: New findings in molecular and cell biology have improved our understanding of physiological wound healing, and approach to wound care and dressing.

Dtsch Arztebl Int 2008; 105(13): 239–48
DOI: 103238/arztebl.2008.0239

Key words: wound healing, wound care, wound dressing, chronic wounds

A wound may be defined as any disruption of the integrity of skin, mucous membrane or organ tissue. A distinction is made between simple wounds that are confined to the skin, and complicated wounds which are deeper and also involve injury to muscles, nerves, and vessels. Wounds can be caused by mechanical, thermal, chemical, and radiogenic trauma. To be distinguished from these are wounds that have their origin in underlying pathologies such as diabetes mellitus, chronic venous/arterial insufficiency, and immunological or dermatological diseases. The primary care of wounds is the task of the surgical disciplines. The monitoring of wounds and application of further wound dressings, however, can be carried out by all physicians and may also be delegated to nursing personnel. The primary goals of all wound management are rapid wound closure and a functional and aesthetically satisfactory scar. The learning aims of this article are therefore:

- to assess the level of knowledge of wound healing
- to satisfy the requirements for practicable and efficient dressing change.

Physiology of wound healing

Wound healing is an exceedingly complex process and has been the subject of research for more than 120 years (1, 2). New findings in molecular biology obtained in recent years have provided greater insights into the biological processes involved. The most important treatment principle in practical terms is to support the physiological course of the wound healing process and to avoid jeopardizing it through incorrect manipulations. Wound healing is traditionally divided into four, sometimes overlapping phases (3, 2), namely:

- exudative phase
- resorptive phase
- proliferative phase
- regenerative phase.

Definition

A wound may be defined as any disruption of the integrity of skin, mucous membrane or organ tissue.

FIGURE 1
Early phase of wound healing (3rd day). The defect is filled with a fibrin clot. The platelets involved activate neutrophil granulocytes, which remove foreign bodies or bacteria and stimulate the transformation of monocytes to macrophages. Macrophages play a central role in the early phase of wound healing, as they stimulate fibroblasts and vascular endothelium to form granulation tissue. All cellular interactions are controlled by cytokines (growth factors) (from [4]). VEGF, vascular endothelial growth factor; IGF, insulin-like growth factor; TGF, transforming growth factor; PDGFAB, platelet-derived growth factor AB/BB; KFG, keratinocyte growth factor; FGF, fibroblast growth factor

In recent English language publications, wound healing is divided into only three phases under immunological aspects: inflammation, proliferation, and wound modulation (4). Since the different phases give rise to consequences for wound care, a classification into four phases should be preferred for reasons of practicability. As an aid to understanding, the different phases will now be briefly outlined, because the dressing of wounds must be carried out in a phased manner. Every wound in which the skin integument is disrupted results in bleeding and activation of the coagulation cascade.

Exudative phase: This phase is characterized by the formation of fibrin and an influx of platelets which together form a visible clot. In the exudative phase, the platelets secrete various mediators of wound healing known as growth factors. These in turn activate macrophages and fibroblasts (figure 1). The further biological processes are controlled by the mediators (growth factors) already released and by cytokines, which cause an influx of cellular structures. More than 30 cytokines

have so far been identified, and are released by macrophages, platelets, fibroblasts, epidermal cells, and neutrophil leukocytes.

Resorptive phase: The resulting degradation products of fibrin lead to activation of chemotaxis in the resorptive phase. After only 24 to 48 hours, leukocytes and macrophages migrate into the wound (inflammation). These cellular components are able to autolyze and remove avital tissue by fermentative processes. Overall, a highly effective system of phagocytosis, anti-infectious defense, and immune system is created (5, 6).

Proliferative phase: Between the third and seventh day, immigration of fibroblasts with vascular proliferation occurs during the proliferative phase. The characteristic feature is the formation of granulation tissue. Epidermal cells grow into the wound from the margins. A visible, delicate border forms (figure 2).

These processes are also controlled by various growth factors (cytokines). The fibroblasts form a new extracellular matrix. The capillaries that have developed supply the tissue with the oxygen necessary for metabolism. The primary clot is broken down by factors of the fibrinolysis system: u-PA (urokinase plasminogen activator) and t-PA (tissue plasminogen activator). The various matrix metalloproteinases (MMP) remodel the extracellular matrix (7).

Understandably, these biological processes can only take place in a controlled manner if activating and inhibiting reactions are in a balanced ratio to each other. This complex biological remodeling of the tissue of immigrating fibroblasts and capillary buds into a structured extracellular matrix demands a gentle approach when changing dressings.

Regenerative phase: This phase can last for up to a year. The maturation of collagen leads to an increase in the wound's tearing resistance. The main characteristics of this phase are epithelization and scar formation. Remodeling and restructuring processes are also constantly in progress during this phase. For example, type III collagen is transformed into type I collagen of the more mature wound (8). The interactions between the extracellular matrix and cell structures of the wound are regulated by transmembrane cell receptors (integrins) and cytokines (6). Besides the pathological level of wound healing just described, there is also a clinical classification, in which wound healing is divided into primary wound healing (pp) "sanatio per primam intentionem" and secondary wound healing (ps) "sanatio per secundam intentionem" (1).

Factors of wound healing

More than 30 cytokines involved in wound healing have so far been identified. They regenerate themselves from macrophages, platelets, fibroblasts, epidermal cells, and neutrophil leukocytes.

Phases of wound healing

- Exudative phase
- Resorptive phase
- Proliferative phase
- Regenerative phase

Primary wound healing

Primary wound healing is the uncomplicated healing process of non-infected, well-adapted wounds. If the healing process is disturbed by local factors such as infections, dehiscence, inadequate blood perfusion or systemic factors such as immunocompromise, a situation of secondary wound healing develops.

Every surgical wound should be inspected at least once daily in the first few postoperative days. The commonest complications of a primary wound are infection and secondary bleeding. Infection betrays its presence through the classical features "dolor, rubor, calor, tumor." If signs of abscess formation are present, an adequate incision should be made to drain the pus and the wound should be locally irrigated. Anesthesia should be provided (see secondary wound healing). Hematomas, whether in the form of bloody imbibition or coagulum, can be tolerated up to a volume of 50 to 200 mL depending on the size of the wound. Only when larger clots are present can wound healing be improved and hastened by removing the hematoma.

Since a primarily healing, clean wound soon closes due to crosslinking of fibrin, gentle mechanical cleansing can already be performed after 24 hours. Primary healing wounds may be irrigated after 24 hours to cleanse them of scab tissue and residues of the surgical disinfectant. The wound should be disinfected with a wound antiseptic such as octenidine dihydrochloride 0.1%/phenoxyethanol 2%, polyhexanide 0.04% or PVP-iodine preparation (*box 1*). A protective dressing can then be applied. Most patients find it very pleasant to have the wound covered with an adhesive dressing (9). Wound staples or sutures should be removed as recommended by the treating surgeon, and also depending on the blood circulation conditions in the affected region of the body.

Following a thyroid operation the wound sutures can be removed on about the fourth to fifth day, in the thoracic region after seven days, and on the lower extremities after 10 to 14 days. Factors to be considered are comorbidities such as diabetes mellitus, immunosuppressive medication, increased skin tension in defect closure or edema formation, which make it necessary to leave the suture material in place for longer.

Secondary wound healing

The overriding principle of wound management in secondary wound healing is to ensure the presence of a moist, physiological environment. Air and especially

From the 3rd to 7th day immigration of fibroblasts and vascular proliferation occur with ingrowth of capillaries (proliferative phase). In the repair or regeneration phase, the matrix metalloproteinases (MMP 1, 2, 3, 13) then induce remodeling of the extracellular matrix into tearing-resistant collagen structures. Depending on the size of the wound, epithelization and scar formation occur. u-pA, urokinase plasminogen activator; t-PA, tissue plasminogen activator (from [4])

BOX 1

Recommended antiseptics for all wounds*1

- **Polyhexanide 0.04%**
 - Controls all relevant bacteria and fungi
 - Is not sporocidal/virucidal
 - Exposure period 10–15 min
 - Relatively tissue sparing (16)
- **Octenidine dihydrochloride, 0.1%, phenoxyethanol 2%**
 - Controls all relevant etiologic agents after an exposure period of 2 min
 - Colorless
 - Painless
- **PVP-iodine preparations**
 - Broad spectrum
 - Unpleasant discolorations
 - No dilution allowed
 - Contraindications: hyperthyroidism

*1 modified from 15, 16

Wound healing

The following types of wound healing are distinguished:

- Primary wound healing (pp)
- Secondary wound healing (ps)

Complications

Commonest complications of a primary wound are infection and secondary bleeding.

Key words: "dolor, rubor, calor, tumor."

BOX 2

Planning and performance of dressing change

- With exact planning, dressing changes can be performed by one person
- Place material in readiness on a sterile surface
 - Disposable gloves
 - Vessel with irrigation solution (0.9% saline solution, possibly an antiseptic)
 - Underlay
 - Sterile compresses
 - Dressing pad
 - Wound dressing
 - Waste container
- Hand disinfection: sterile gloves or sterile forceps
- Remove dressing and place in waste container
 - Wound disinfection
 - Wound cleansing
 - Dressing pad (according to the stage of wound healing)
 - Skin care
 - Wound dressing according to wound healing
- Disposal of waste container
- Hand disinfection

oxygen are cytotoxic and, if the wound is allowed to become dry, inevitably lead to extensive tissue necroses which cause irreparable damage especially in capillary-free (bradytrophic) tissue.

The second important principle is compliance with the basic requirements of hygienic wound care. An open wound is invariably contaminated with potentially pathogenic microorganisms present in the environment. The purpose of applying further wound dressings must be to allow the immune status to ward off the bacteria already present, avoid further colonization from outside and thereby prevent infection.

For painful wounds, appropriate pain relief should be included in the dressing change schedule. An oral analgesic is recommended depending on the size and extent of the wound. Available medications include non-steroidal anti-inflammatory drugs (NSAIDs), metamizole, paracetamol or COX-2 inhibitors. These medicines should be administered about 30 to 60 minutes before changing

the dressing. The findings of a meta-analysis of six studies have shown that satisfactory results are obtained with local analgesia with an ointment mixture of lidocaine and prilocaine (10). An exposure period of about one hour should be ensured. A film cover is unnecessary if it is certain that the ointment exerts its effects in a controlled manner.

A swab sample for microbiological analysis should be collected if possible at the beginning of wound treatment. The sample should be analyzed for gram positive and gram negative pathogens and anaerobic microorganisms. In high-risk patients (age > 75 years, diabetes mellitus, immunocompromise, long-term hospitalization), a test for methicillin-resistant *Staphylococcus aureus* (MRSA) strains should be performed.

An open wound does not require antibiotic treatment. If there is persisting fever, leukocytosis, and CRP elevation, a close inspection or revision of the wound – if appropriate, in the hospital setting – should be performed to clarify the possibility of an infection. In the presence of elevated inflammatory parameters, such as fever above 38.5 °C measured sublingually, leukocytosis above 10 000/μL and CRP fourfold higher than normal, systemic antibiotic therapy should be initiated (if two of the parameters are positive). For moderately severe infections, the Paul Ehrlich Society recommends aminopenicillin with β-lactamase inhibitor, a group 1 and 2 cephalosporin or a group 4 fluoroquinolone. The need for antibiotic therapy should also be considered in the presence of immunocompromise, i.e. in patients post transplantation or with diabetes mellitus or patients undergoing chemotherapy. Occasionally an inflammation characterized by erythema, swelling and pain is present in the wound margins. If the subcutaneous tissue is also infiltrated, a phlegmon is present. This accompanying inflammation requires particularly close monitoring. Most authors in the literature support the use of antimicrobial chemotherapy in such cases (11).

Dressing change in secondary wound healing
Wound cleansing

In the early phases of wound healing – the exudative phase and the resorptive phase – blood and plasma constituents, clots and cell detritus are present in the wound and should be carefully removed. This mechanical wound cleansing is an important precondition for rapid, uncomplicated wound healing and is known as debridement.

Secondary wound healing

Ensuring a moist, physiological environment is the paramount principle of wound care.

Wound swab

For secondary wounds, a microbiological swab sample should be taken at the beginning of treatment.

Bacteria and degradation products of corpuscular elements have been shown to disturb or inhibit wound healing (12). The simplest procedure for cleansing a wound is irrigation. According to existing knowledge, drinking water can safely be used for this purpose in acute and chronic wounds (13, 14).

Wound disinfection

For more than 100 years, physicians have experimented with substances to which they ascribed wound disinfectant properties. These include dye-based agents such as gentian violet, alcoholic disinfectants and a wide variety of protein precipitating agents ($H_2O_2/NaCl$ 10%). When used over extended periods, however, these substances disturb wound healing and lead to chronification. Protein precipitating agents, iodoform, potassium permanganate, and boric acid are now considered obsolete. A negative list has been compiled of preparations that should no longer be used due to lacking proof of efficacy, high toxicity, and high allergy potential (15).

The effect of antiseptics is to be regarded as low (evidence level D) (*table*) (see also the German language website www.wundzentrum-hamburg.de). Under no circumstances must antiseptics adversely affect the wound healing processes. Wound antiseptics considered to have no serious deleterious effects on the wound healing process are octenidine dihydrochlorid 0.1%/phenoxyethanol 2%, polyhexanide 0.04% or PVP-iodine preparation (*box 1*) (15, 16). An essential requirement is open wound treatment, which fundamentally alters the environment for the etiologic agents. Under these conditions the bacteria find it difficult to colonize and as a result hardly influence the course of wound healing. The moist environment is the most important factor for the healing process, since it promotes cell growth, angiogenesis, and fibrinolysis (2).

Wound coverage/maintenance of a moist environment

For physiological wound healing it is essential to maintain a moist wound environment (18, 19) (*figure 3a, b, c, d*) (*box 2*). A distinction is drawn between inactive, interactive, and (bio)active wound dressings (transplant materials).

Inactive or conventional wound dressings are distinguished by their high absorberency. They are made of cotton (gauze compresses), synthetic fibers (non-wovens) or several layers of material (wound gauzes). To maintain a moist environment, these compresses are saturated in physiological saline solution and covered with a waterproof film.

TABLE

Negative list of preparations for wound healing which should no longer be used due to lacking proof of efficacy, toxicity, and high allergic potential*¹

Substance group	Preparation
Dyes	Crystal violet solution, pyocytanin solution (methylosanilinium chloride), brilliant green solution, ethacridine lactate
Mercuric solutions	Mercurochrome, sublimate, oxycyanide
Officinal substances	Alum, boric acid, Castellani's solution (colored and uncolored), 8-quinolone sulfate, chloramine-T, fuchsine, urea, ichthyol, iodoform, ethanolic iodine solution (German Pharmacopoeia [DAB]), potassium permanganate, cod liver oil, metronidazole, phenol, Peru balsam, silver nitrate, tannin, trypanflavin
Pastes without active substance	Cod liver oil-zinc paste, soft zinc paste
Pastes with active substance	Nystatin paste
Infusion solutions	Glucose solutions, various %
	NaCl 10%
	Amino acid solution of different concentrations
Veterinary preparations	Bag balm (white or yellow) Horse ointment, Lexer ointment
Foods/commodities	Honey, sugar, salt, toothpaste, curd, raw eggs, cabbage leaves, oxblood, walnut leaf mash, newspaper, sea sand, fuller's earth, garlic, pepper, powdered coffee, petrol, glycerol, tea tree oil, lavender oil
Medicines	Topical antibiotics neomycin, gentamicin, penicillin, tetracyclines, nitrofurazene, framycetin
	Insulin ampules
	Heparin ampules

*¹ modified from Sellmer, www.wundzentrum-hamburg.de (15, 16)

The advantages of these dressings are their absorberency (usage without moistening indicated for heavily exudating wounds) and their low cost. Disadvantages are the possible desiccation of the wound and adhesion to the wound bed. Fresh granulation tissue is then destroyed on changing dressings, and is also very painful for the patient (9, 17).

Interactive wound dressings have to meet numerous requirements:

Cleansing of wounds

The wound is washed out with drinking water. Harder layers require debridement with moist compresses or instruments.

Moist environment

The moist environment of open wounds promotes cell growth, angiogenesis, and fibrinolysis.

Figure 3: Wound healing: a) wound on the lateral side of the lower leg with extensive necroses and fibrin residues in an 82-year-old female patient (left caudal, right cranial). The state of the wound is a consequence of incorrect treatment (dry wound dressing). b) The wound was surgically debrided and covered with a moist dressing. Individual areas of granulation are forming (proliferative phase of wound healing). c) Continued moist dressings, continued granulation also beyond the tendon level (repair phase of wound healing). d) After placement of a secondary suture, a stable scar has formed. The care of the distal part of the wound could be improved.

- maintenance of the moist environment including a pH of 5.5,
- absorption of toxic components of bacterial degradation products,
- protection against secondary infection,
- gentle, painless dressing change, and
- practicability.

Interactive, hydroactive wound dressings which because of their special material properties enter into interaction with the wound, were devised to satisfy these criteria. They promote optimal conditions for wound healing and are used in a manner suited to the different phases of wound healing. They also offer two benefits for patients: changing the dressing is much less painful and dressings can be left in place for several days if necessary.

At present about 250 different wound dressings are supplied by several manufacturers (20). Retaining an overview is difficult considering the wide variety of

products (*box 3*). The benefits offered by individual classes of wound dressings have been analyzed in 42 controlled, randomized studies in a Cochrane Review. None of these studies provided evidence that better wound healing is achieved with hydrocolloids, alginates, foam dressings, or hydrogels. The same results were also achieved using dressings that were merely able to maintain a moist environment (17).

(Bio)active dressings include autologous skin, lyophilized porcine skin, autologous keratinocytes, collagen-based wound dressings, and the use of growth factors. These (bio)active wound dressings should be reserved for special indications involving chronic wounds, if appropriate in the hospital setting (evidence level C).

Skin care on dressing change

A healthy wound environment is indispensable for uncomplicated wound healing. The skin must be cleaned

Wound dressings

A distinction is made between:

- inactive,
- interactive, and
- (bio)active wound dressings (graft materials).

Bioactive wound dressings

These include:

- Autologous skin
- Lyophilized porcine skin
- Autologous keratinocytes
- Collagen-based wound dressings
- Use of growth factors

BOX 3

Interactive wound dressings*

● Alginates

- Made from algae (calcium alginate combined with carboxymethylcellulose)
- Good swelling properties
- Enclose bacteria and cell detritus
- For cleansing of infected wounds
- Must not come into contact with healthy skin
- No saturation with disinfectant (inactivation possible)
- Used in the early phase of wound healing

● Hydrofiber dressings

- Made from cellulose
- Vertical wicking - no softening of wound margins
- Forms a gel plate
- Allows painless dressing change
- Used in the exudative phase of wound healing

● Silver-containing dressings

- Bactericidal action
- Odor binding with charcoal
- For infected wounds

● Hydrogels

- Clear, sterile gels with hydrocolloid constituents
- Maintain a moist wound environment
- For detachment of necroses and fibrin
- Readily combined with a hydrofiber dressing
- Relatively painless dressing change

● Hydrocolloids

- Cell detritus and bacteria are enclosed
- Good protection in the epithelization phase
- For superficial wounds
- Not for clinically infected wounds

● Hydropolymer dressings

- Absorb wound exudate, swelling effect
- For insertion in wound cavities
- Especially for sensitive skin because not so strongly adhesive
- Not for infected wounds

● Foam dressings

- Vertical wicking of wound exudate
- Not for infected wounds
- For covering skin defects

● Impregnated gauzes

- Impregnated with ointments, grease or silicone
- Due to porous structure, good exudate drainage in gauze compress overlay
- Prevents adhesion to the dressing
- Keeps the wound slightly moist

* modified from (2, 19, 20)

of all exudates and dressing residues. Compresses should ensure that the skin remains dry in the interdigital regions and skin folds. For normal skin pH5 gel creams and for dry skin, especially in diabetics, also urea-containing products with a high lipid content are recommended.

If skin macerations have occurred, the exudate should be controlled using suitably absorbent dressings. Intermittently covering the peri-wound area with hydrocolloids may also be helpful. For prophylaxis and treatment of macerations of the wound margins, a non-irritating, air-permeable and water repellent protective film may be applied to the skin. Zinc paste is obsolete because it has an occlusive effect and desiccates the wound margin. Special attention should be devoted to

the treatment of hyperkeratoses as they frequently give rise to ulcerations. In addition to podological treatment, surgical removal of hyperkeratoses is often required. Also helpful are ointments containing urea (5% to 10%) and salicylic acid (2.5% to 10%).

Vacuum sealing

Vacuum sealing involves placing a piece of foam over the wound, thereby creating a suction effect and subjecting the entire wound area to negative pressure. This technique combines three principles of wound treatment:

- wound cleansing by continuous drainage,
- modification of the wound environment and reduction of bacterial colonization, and
- maintaining a moist environment.

Vacuum sealing

Vacuum sealing is indicated for complicated, surgically debrided wounds in the proliferative phase.

Skin care on dressing change

A healthy wound environment is indispensable for uncomplicated wound healing. The skin must be freed from all exudates and dressing residues.

BOX 4

Staged schedule for wound closure depending on the size and extent of the wound defect*¹

- Secondary epithelization of the wound
- Secondary wound closure
- Mesh graft
- Split-thickness skin graft
- Cutaneous rotation and sliding flap
- Free microvascular flap plasty

*¹ modified from (24)

Vacuum sealing is indicated for surgically debrided wounds in the proliferative phase. Heavy exudation and deep wound pockets can be effectively treated by the inserted sponges. This creates a practicable, hygienic situation for the patient and his environment. Whether the processes involved in physiological wound healing are accelerated by vacuum sealing has not been demonstrated (21, 22). Vacuum therapy can also be performed in the outpatient setting. Its installation and use demands special knowledge on the part of the therapist and patient which in the authors' own experience is not generally found at present.

Much scientific evidence is available for the successful treatment of wounds with fly larvae. The use of maggots also requires special knowledge and should be reserved for special indications involving chronic wounds (23).

The chronic wound

If the wound healing processes last for longer than four weeks and no tendency to healing is apparent, the wound is by definition chronic (2). Now at the latest, the cause of the wound healing disorder must be established.

Incorrect wound treatment must always be ruled out as a primary factor. A differential diagnosis of the wound healing disorder should then be undertaken.

Wound closure

The goal of all wound management is to obtain a mechanically stable and aesthetically acceptable scar, because stable scar conditions protect the tissue most

effectively against wound dehiscence. Open wounds are unacceptable as a long-term situation. Depending on their extent and localization, they are a burden and hazard for the patient. The range of available closure options extends from conservative healing to coverage with free skin grafts which can be integrated by the vascular pedicle technique. General surgery, plastic and reconstructive surgery have now attained a standard that allows the closure of every defect (24) (box 4).

Documentation

Most of the relevant publications on wound dressings call for the wound and the type of dressing to be documented. While this may be considered desirable, the generation of objective findings and standardization of dressing types in an attempt to achieve comparability in scientific studies must be considered to have more or less failed (25). Digital photography, which offers the most information for little effort, would appear a simple and practicable solution.

Conclusions

Considering the great importance attached to the topic of "wounds" in daily medical practice, the lack of evidence based interdisciplinary guidelines is surprising. The reasons for this are the extreme complexity of the wound conditions, the difficulties involved in standardization and the proliferating range of therapeutic options.

The benefit of the standardized approach to wound management presented in this article lies in the fact that it can be successfully applied to all types of wounds. The complex subject matter is thereby simplified for practical use. Decubitus ulcers, arterial or venous ulcers, postoperative wound infections, and ulcers associated with diabetic foot syndrome undergo the same physiological processes and thus are subject to the same therapeutic principles of wound dressing. An underlying causative pathology, such as arterial occlusive disease, venous insufficiency or a sacral decubitus ulcer naturally also requires causal treatment.

Conflict of interest statement

The authors declare that they have no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

Manuscript received on 17 July 2007; revised version accepted on 31 October 2007.

Translated from the original German by mt-g.

REFERENCES

1. Friedrich PL: Das Verhältnis der experimentellen Bakteriologie zur Chirurgie, Antrittsvorlesung 10. Juli 1897 Leipzig: Verlag von Wilhelm Engelmann 1897.

Chronic wound

If no healing tendency is apparent over a period of four weeks, this condition is regarded as a chronic wound.

Guidelines

At present there are no evidence based interdisciplinary guidelines for "wound care."

2. Lippert H: Wundatlas, Kompendium der komplexen Wundbehandlung. Stuttgart, New York: Thieme Verlag 2006.
3. Hofstädter F: Pathologie der Wundheilung. Chirurg 1995; 66: 174–81.
4. Singer AJ, Clark RAF: Cutaneous wound healing, N Eng J Med 1999; 341: 738–9.
5. Fleischmann W, Russ MK, Moch D: Chirurgische Wundbehandlung Chirurg 1998; 69: 222–32.
6. Schäffer M, Becker HD: Immunregulation der Wundheilung. Chirurg 1999; 70: 897–908.
7. Agren MS, Jorgensen LN, Andersen M, Viljanto J, Gotttrup F: Matrix metalloproteinase 9 level predicts optimal collagen deposition during early wound repair in humans. Br J Surg 1998; 5: 68–72.
8. Gailit J, Clark RAF: Wound repair in the context of extracellular matrix. Curr Opin Cell Biol 1994; 6: 717–72.
9. Schwemmler K, Linder R: Prinzipien der primären und sekundären Wundversorgung. Chirurg 1995; 66: 182–7.
10. Nelson EA, Bradley MD: Dressings and topical agents for arterial leg ulcers. Cochrane Database of Systematic Reviews 2007, Issue 1. Art. No.: CD001836. DOI: 10.1002/14651858.CD001836.pub2
11. Swartz MN: Clinical practice, Cellulitis. N Engl J Med 2004; 350: 904–12.
12. Edwards R, Harding KH: Bacteria and wound healing. Curr Opin Infect Dis 2004; 17: 91–6.
13. Barre K, Leistner K, Vatterott N: Leitungswasser zur Wundreinigung: Eine sichere Alternative zu steriler Kochsalzlösung? EVIBAG-Übersichtsarbeit 2004, www.gesundheit.uni-hamburg.de.
14. Fernandez R, Griffiths R: Water for wound cleansing. Cochrane Database of Systematic Reviews 2008, Issue 1. Art. No.: CD003861. DOI: 10.1002/14651858.CD003861.pub2
15. Kramer A, Daeschlein G, Kammerlander G et al.: Konsensempfehlung Wundantiseptik, Konsensempfehlung zur Auswahl von Wirkstoffen für die Wundantiseptik. Zeitschrift für Wundheilung 2004; 9: 110–120.
16. Schmitt-Neuerburg KP, Bettag Ch, Schlickewei W, Fabry W, Hanke J, Renzing-Köhler K, Hirche H, Koch H-J: Wirksamkeit eines neuartigen Antisepticum in der Behandlung kontaminierter Weichteilwunden. Chirurg 2001; 72: 61–71.
17. Palfreyman SJ, Nelson EA, Lochiel R, Michaels JA: Dressings for healing venous leg ulcers. Cochrane Database of Systematic Reviews 2006. Issue 3 Art No: CD001103.
18. Bishop SM, Walker M, Rogers AA, Chen WY: Importance of moisture balance at the wound-dressing interface. J Wound Care 2003; 12/4: 125–28.
19. Voshege M, Wozniak G: Was ist evidenzbasiert in der Behandlung chronischer Wunden? Gefäßchirurgie 2003; 8: 269–276
20. Vassel-Biergans A: Wundauflagen 2. Auflage. Wissenschaftliche Verlagsgesellschaft mbH, Stuttgart 2006.
21. Horch R.E.: „Panta rhei“: Vakuumtherapie im Wandel – Ein Vorwort zum Supplement „Drei-Länder-Kongress“ Nürnberg 2006; Zentralbl Chir 2006; 131: 1–2
22. Tautenhahn J, Bürgen T, Lippert H: Der Stand der Vakuumversiegelung. Chirurg 2004; 75: 492–97.
23. Bonn D: Maggot therapy: an alternative of wound infection. Lancet 2000; 356: 1174.
24. Ziegler UE, Debus ES, Keller HP, Thiede A: Hautersatzverfahren bei chronischen Wunden. Zbl Chir 2001; 126: 71–4.
25. Panfil EM, Lenicle E: Kriterien zur Wunddokumentation. www.dgfw.de/pdfdata/wd_review_hessip.pdf.

Corresponding author

Prof. Dr. med. Peter Kujath
Universitätsklinikum Schleswig-Holstein
Campus Lübeck
Ratzeburger Allee 160
23538 Lübeck, Germany
peter.kujath@chirurgie.uni-luebeck.de

For a case report please refer to:
www.aerzteblatt-international.de/cme/0804

Further information

This article has been certified by the North Rhine Academy for Postgraduate and Continuing Medical Education.

Deutsches Ärzteblatt provides certified continuing medical education (CME) in accordance with the requirements of the Chambers of Physicians of the German federal states (Länder). CME points of the Chambers of Physicians can be acquired only through the Internet by the use of the German version of the CME questionnaire within 6 weeks of publication of the article. See the following website: www.aerzteblatt.de/cme

Participants in the CME program can manage their CME points with their 15-digit "uniform CME number" (einheitliche Fortbildungsnummer, EFN). The EFN must be entered in the appropriate field in the www.aerzteblatt.de website under "meine Daten" ("my data"), or upon registration. The EFN appears on each participant's CME certificate.

The solutions to the following questions will be published in Volume 21/2008. The CME unit "Basic Knowledge of Refractive Surgery" (volume 9/2007) can be accessed until 11 April 2008.

For volume 17/2008 we plan to offer the topic "Epilepsy in Childhood and Adolescence".

Solutions to the CME questionnaire in volume 5/2008:

Bieker E, Sauerbruch T: Diagnosis and Management of Upper Gastrointestinal Bleeding: 1/c, 2/a, 3/a, 4/c, 5/a, 6/a, 7/b, 8/a, 9/d, 10/b

Please answer the following questions to participate in our certified Continuing Medical Education program. Only one answer is possible per question. Please select the answer that is most appropriate.

Question 1:

How is a simple wound defined?

- a) As any disruption of the integrity of skin tissue
- b) As a venous leg ulcer
- c) As a perforating ulcer in diabetic foot syndrome
- d) As a bite injury
- e) As a stick injury from an injection needle

Question 2:

What happens during the resorptive phase of wound healing?

- a) A clot of fibrin, platelets, and various cytokines forms.
- b) The matrix metalloproteinases (MMP) induce remodeling of the extracellular matrix.
- c) Chemotaxis is activated and leukocytes and macrophages migrate into the wound.
- d) From this time onwards, budding capillaries supply the wound with oxygen.
- e) Scar formation begins, characterized by the maturation of collagen.

Question 3:

A patient attends the practice with a primary healing (pp) wound. From what point onwards can the wound be cleansed?

- a) Immediately postoperatively
- b) Postoperatively after 24 hours
- c) Postoperatively after 48 hours
- d) Before removing the wound sutures
- e) After removing the wound sutures

Question 4:

What is the current wisdom regarding the use of drinking water to cleanse wounds?

- a) It is no longer generally used for chronic wounds.
- b) According to the guidelines, irrigation of the wound with drinking water is obsolete.
- c) Wounds may safely be cleansed with drinking water.
- d) It should be used under hospital conditions.
- e) Wound cleansing with drinking water in the outpatient setting is irresponsible.

Question 5:

When is antibiotic treatment of wounds indicated?

- a) For primary healing wounds
- b) For irritation-free wounds and mild leukocytosis
- c) On infiltration of the subcutaneous tissue (phlegmons)
- d) In open wound treatment
- e) For painful wounds

Question 6:

What is the most important aspect in the treatment of secondary wounds?

- a) The use of disinfectant dyes
- b) The use of silver-containing dressing pads
- c) Maintaining the moist environment
- d) Use of conventional dressing pads
- e) Administration of growth factors

Question 7:

What scientific knowledge is available regarding the quality of different wound dressings?

- a) A randomized study showed that alginates are to be preferred.
- b) According to a meta-analysis, hydrogels provide more rapid wound closure.
- c) A postmarketing surveillance study showed that the use of hydrocolloids results in more stable scars.
- d) Foam dressings are preferable, based on a selective literature search.
- e) A Cochrane analysis showed no advantages for any particular preparation.

Question 8:

Which wound antiseptic is relatively tissue sparing and can be used for wound disinfection?

- a) Boric acid
- b) Ethacridine lactate
- c) Potassium permanganate
- d) Polyhexanide
- e) H₂O₂

Question 9:

What happens in the vacuum sealing of wounds?

- a) Wound cleansing is performed by periodic drainage.
- b) Complete disinfection of the wound is thereby assured.
- c) The conditions for moist wound treatment are fulfilled.
- d) In vacuum sealing, previously introduced fly larvae that promote the healing process survive.
- e) The course of physiological wound healing is accelerated.

Question 10:

What is the best protection against wound dehiscence?

- a) A stable scar
- b) Wound dressings
- c) Fibrin layers
- d) Wound pain
- e) A compact compression bandage

CONTINUING MEDICAL EDUCATION

Wounds – From Physiology to Wound Dressing

Peter Kujath, Angela Michelsen

Case

Wound Care

A 57-year old patient had an open venous ulcer on the right lower leg for 15 years. The wound was treated by the patient's GP and the patient himself. The wound was always covered with a dry dressing, using a variety of agents including dye solutions and powder. The patient suddenly developed an exacerbation of his symptoms accompanied by extreme pain. Fever 38.5 °C, leukocytosis 12 300/μL, CRP 180 mg/L (normal up to 5 mg/L). The external aspect showed a deep ulceration covered with layers of blackish material (*figure 1*).

A phlegmonous erythema and swelling of the skin had developed in the peri-wound area. The microbiological swab specimen taken from the wound showed a mixed culture of group A streptococci, *Bacterioides* spp, and *Clostridium perfringens*.

Surgical debridement was performed in this patient, revealing full-blown necrotizing fasciitis. All ventral fascial coats of the lower leg had to be removed. The incision extended as far as the knee joint. After surgically eliminating the source of infection, daily dressing changes were performed. The wound was irrigated without addition of a disinfectant (Ringer's lactate). The first postoperative dressing changes showed that the exudative phase of wound healing was in progress. The wound bed was clean due to the surgical debridement. During the first five postoperative days the patient received antibiotic therapy with an acylaminopenicillin combined with a beta lactamase inhibitor. The wound was dressed with simple gauze compresses.

Since the wound showed a marked tendency to desiccation during the exudative phase and at the beginning of the resorptive phase of wound healing, the daily dressing change with renewed irrigation was performed every eight hours to maintain a moist wound environment. No

Figure 1

Figure 2

Figure 3

Figure 4

vacuum dressing was applied, but would have been a possible, although more expensive alternative. At the beginning of the proliferative phase the moist environment was maintained using hydrocolloid dressings.

This treatment resulted in very good formation of granulation tissue (*figure 2*). With decreasing exudation and completed granulation (*figure 3*), mesh graft coverage was performed on the 18th postoperative day after harvesting skin from the right thigh (*figure 4*). Only after 5 days was the first dressing change performed, which showed that the mesh graft transplant had taken completely (*figure 5*). The graft was treated in the open manner with a greasy ointment, which led to complete epithelization of the entire wound during the further course.

Ten years after this wound care the patient attended again for the treatment of a different disease. The venous leg ulcer had healed completely and a stable scar had formed. The patient showed good lower leg function and was symptom free (*figure 6*).

It can be concluded from this case report that correctly timed surgical remediation of the infection was decisive for the success of healing. Treatment of *Clostridium perfringens* was unnecessary because the contamination was only superficial (Weinstein's "simple contamination"). The principles of moist wound treatment were followed and the wound underwent surgical plastic coverage. This treatment concept allowed complete, relapse-free healing of the venous leg ulcer.

Figure 5

Figure 6