Received: 18 July 2024 | Accepted: 27 November 2024

DOI: 10.1111/ddg.15649

REVIEW

Systematics, diagnosis and treatment of wound infections in chronic wounds: A position paper from WundDACH

Joachim Dissemond[1] | **Julian-Dario Rembe**[2] | **Bernd Assenheimer**[3] | **Marjam Barysch-Bonderer**[4] | **Veronika Gerber**[5] | **Jan Kottner**[6] | **Peter Kurz**[7] | **Martin Motzkus**[8] | **Eva-Maria Panfil**[9] | **Sebastian Probst**[10] | **Robert Strohal**[11] | **Jürg Traber**[12] | **Andreas Schwarzkopf**[13]

[1]Department of Dermatology, Venereology and Allergology, University Hospital Essen, Essen, Germany

[2]Department for Vascular and Endovascular Surgery, University Hospital Düsseldorf, Düsseldorf, Germany

[3]Nursing School, University Hospital Tübingen, Tübingen, Germany

[4]Dermapraxis Wädenswil, Wädenswil, University of Zürich, Zürich, Switzerland

[5]Initiative Chronische Wunden e.V. (ICW), Quedlinburg, Germany

[6]Institute of Clinical Nursing Science, Charite – Universitatsmedizin Berlin, Berlin, Germany

[7]WPM Wound Care Management, Bad Pirawarth, Austria

[8]Central Wound Management, Evangelic Hospital, Mülheim an der Ruhr, Germany

[9]Practice Development and Research Department, Nursing / MTT, University Hospital Basel, Basel, Switzerland

[10]HES-SO Technical College West Switzerland, Geneva, Switzerland, University Hospital Geneva, Switzerland, Monash University, Melbourne, Australia, University of Galway, Galway, Ireland

[11]Department of Dermatology and Venereology, State Hospital Feldkirch, Feldkirch, Austria

[12]Vein Hospital Bellevue, Kreuzlingen, Switzerland

[13]Institute Schwarzkopf, Bad Bocklet, Germany

Correspondence
Prof. Dr. med. Joachim Dissemond, Department of Dermatology, Venereology and Allergology, University Hospital Essen, Hufelandstraße 55, 45122 Essen, Germany.
Email: joachim.dissemond@uk-essen.de

Summary

Wound infections are still an interdisciplinary and interprofessional challenge, because of numerous complications, particularly in people with chronic wounds. There are many different concepts and approaches in this field today. Therefore, WundDACH, the umbrella organization of the German-speaking wound healing societies, wrote a position paper on this important topic. An interdisciplinary and interprofessional group of experts from German-speaking countries developed definitions and procedures for nomenclature, diagnosis and treatment of wound infections in people with chronic wounds in a modified Delphi process.

The importance of correctly diagnosing wound infections is emphasized so that adequate treatment can be carried out as early and specifically as possible. For a differentiated assessment, a simplified continuum of wound infection with contamination, colonization, local and systemic infection and the corresponding therapeutic consequences was described. Most bacteria in wounds can be removed by repeated wound-irrigation and debridement. Local wound infections are diagnosed based on clinical signs of infection and TILI score. Treatment

Joachim Dissemond and Julian-Dario Rembe contributed equally to the publication.

is then usually exclusively local, for example with modern antiseptics such as polyhexanide. Systemic antibiotics should mostly be considered when signs of systemic infections appear. The indication for antimicrobial wound therapy should be critically reviewed after 10–14 days at the latest.

KEYWORDS
antiseptics, bacteria, chronic wounds, wound healing, wound infections

INTRODUCTION

The early diagnosis and adequate treatment of wound infections in people with chronic wounds remain a relevant interdisciplinary and interprofessional challenge. Especially older people with chronic wounds are at a particularly high risk of blood stream infections or sepsis, potentially with subsequent severe consequences due to underlying diseases, disturbed microcirculation, and age-related reduction of protein synthesis.[1,2] Moreover, it is argued that in up to 40 % of affected individuals, wound infection is the cause of a prolonged or chronic healing process.[3]

WundDACH, the umbrella organization of the German-speaking wound healing societies, has set itself the task of improving wound care in theory and practice in German-speaking countries. The board of WundDACH has, therefore, commissioned an interdisciplinary and interprofessional group of experts to summarize or revise the currently recommended definitions (Table 1) and procedures for nomenclature, diagnosis, and treatment of wound infections in patients with chronic wounds, or to develop new recommendations.

MICROORGANISMS

Microorganisms may affect the complex processes of wound healing in different ways. Only in rare cases, such as mycobacteriosis, are microorganisms the cause of chronic wounds; it is much more common that they cause complications, such as wound infections. While bacteria are usually responsible, wound infections may rarely also be caused by parasites or fungi. While viruses may penetrate the skin via injuries and cause skin changes, they are not considered as pathogens causing wound infection in the strict sense. Therefore, this position paper will focus primarily on wound infections caused by bacteria.

The entirety of microorganisms living on and in humans is referred to as a microbiome. Although not all interactions are yet known, it is known that the microbiome is important for the development and maintenance of the human immune system.[4] This applies also to the defense function of the skin.[5] Accordingly, the permanent and complete eradication of bacteria in wounds is not physiological. However, excessive proliferation of bacteria may cause the development of wound infections.[6,7] Various bacterial species may be responsible for this process (Table 2). A clinical study performed in Germany could show that the germ spectrum in patients with chronic wounds of different causes did not differ significantly.[8] This seems obvious, given that with the exception of *Pseudomonas aeruginosa* and other water and environmental germs, such as *Acinetobacter baumannii*, all bacteria mentioned are associated with humans and, therefore, almost always originate from the patients themselves.

Usually, one bacterium is primarily responsible for wound infection.[9] Especially the role of anaerobic bacteria, which are able to survive in an oxygen-free environment, in wounds is largely unresolved.[10] Multidrug-resistant organisms (MDROs) are a relevant problem in daily clinical practice. This term refers collectively to bacteria with pronounced resistance to antibiotics. Worldwide, approximately 1.2 million people die every year due to resistance to antibiotics.[11] In the context of treatment of patients with chronic wounds, methicillin-resistant *Staphylococcus (S.) aureus* (MRSA) are of major clinical relevance, in particular as a causative factor of nosocomial infections.[12] In humans, the nasopharyngeal region is predominantly colonized by MRSA. Recently, it has been shown that individuals with diabetic foot ulcer (DFU) and detection of MRSA have longer healing duration of wounds, longer hospitalization times, and incur higher hospital costs compared to individuals with DFU and exclusive detection of methicillin-sensitive *S. aureus* (MSSA).[13] Moreover, a new classification for multidrug-resistant gram-negative bacteria (MRGN) was introduced in Germany in 2012. In MRGN, bacteria resistant to four (4MRGN) or three (3MRGN) groups of defined antibiotics are differentiated. Since 2019, carbapenemase-producing bacteria are also included in the 4MRGN group. In humans, the intestines as well as perianal and inguinal regions are predominantly colonized by 3MRGN or 4MRGN.[14]

CONTINUUM OF WOUND INFECTION

The term infection continuum has been coined and internationally established by the *International Wound Infection Institute* (IWII). It describes the various stages from generally harmless bacterial contamination to potentially life-threatening systemic infection in a differentiated manner.

TABLE 1 Definitions of important terms in the context of wound infections.

Term	Definition
Antibiotics	Antibiotics target specifically bacteria and are, therefore, intended for treatment of infections caused by bacteria. In contrast to antiseptics, antibiotics have always a spectrum of activity; therefore, they do not act equally on all bacteria.
Anti-infectives	Collective term for antimicrobials, antiseptics, and antibiotics.
Antimicrobial stewardship	Concepts for the rational and responsible use of antibiotics and antimicrobial substances in appropriate medical indications. It is the aim to provide people with the optimum treatment while minimizing selection processes and resistances in microorganisms.
Antimicrobials	Antimicrobial substances or physical therapies acting against microorganisms by either destroying them or inhibiting their growth, without, however, achieving the reduction factor required of antiseptics. Accordingly, more germs survive compared to the use of antiseptics.
Antisepsis	Hygienic measures eliminating or reducing potential pathogens either actively or passively, thus reducing the infection risk or treating an existing infection. This includes both substance-based measures like antiseptics and physical therapies like debridement.
Antiseptics	Substances approved according to the German Medicinal Products Act with the primary purpose of antisepsis and/or disinfection and sold as such. The designation may only be assigned, if a defined germ reduction of various test germs has been achieved in vitro.
Biofilm	Biofilms are communities of microorganisms adhering to surfaces where the grow and proliferate. They form a protective layer of mucus (matrix) where they embed and organize themselves. Microorganisms organized in biofilms are adapted to the respective environment and have a higher resistance to environmental factors than free-living planktonic microorganisms. Biofilms may contain individual species or consist of mixed populations.
Debridement	Removal of adherent dead tissue, crusts, microbial or fibrinous coatings, biofilm, or foreign material from wounds. Debridement is an important component of decontamination and antisepsis.
Decontamination	Hygienic measure to remove hazardous substances, contaminations, or coatings, or to reduce them to a non-harmful amount.
Disinfection	Hygienic measures to kill or inactivate potential pathogens. Due to the significant reduction of their quantity on or in wounds, infection occurs less often.
Inflammation	Inflammatory reaction of the organism to harmful stimuli. Clinical cardinal symptoms are erythema, warmth, swelling, pain, and impaired function.
Colonization	Colonization of the wound with proliferation of microorganisms without typical clinical signs of infection. Adhesion to the wound surface has occurred; the removal by irrigation alone is impeded. While formation of a biofilm is common, this per se presents no infection.
Contamination	Potential pathogens of wound infection adhere to the wound surface, initially without proliferation. In this physiological stage, the removal of a large fraction of germs is still possible, e. g., by irrigation even without antimicrobial activity.
Wound infection	*Local*: Immunologic host reaction with clinical signs of infection. *Systemic*: In addition to local signs of an inflammatory reaction, there are systemic immunological host reactions, such as leukocytosis, increase of CRP, and fever.
Wound irrigation	Removal of non-adherent components by sterile solutions. Apart from remnants of dressings, this will often remove (dried) wound exudates, but also microbial toxins and other components. Main aim of wound irrigation is decontamination, not disinfection in the primary sense.
Wound irrigation solution	Substance with the primary purpose of mechanical wound irrigation and/or decontamination approved according to the German Medical Device Law Implementation Act (*Medizinprodukterecht-Durchführungsgesetz*, MPDG) or the *Medical Device Regulation* (MDR, authorization regulation at EU level) and sold as such. Wound irrigation solutions may be preserved or non-preserved. Substances with antimicrobial efficacy are often used for preservation resulting in product stability, whereas no specific antimicrobial effect may be assumed. The use of wound irrigation solutions is subject to the German Medical Devices Operator Ordinance (*Medizinprodukte-Betreiberverordnung, MPBetreibV*).

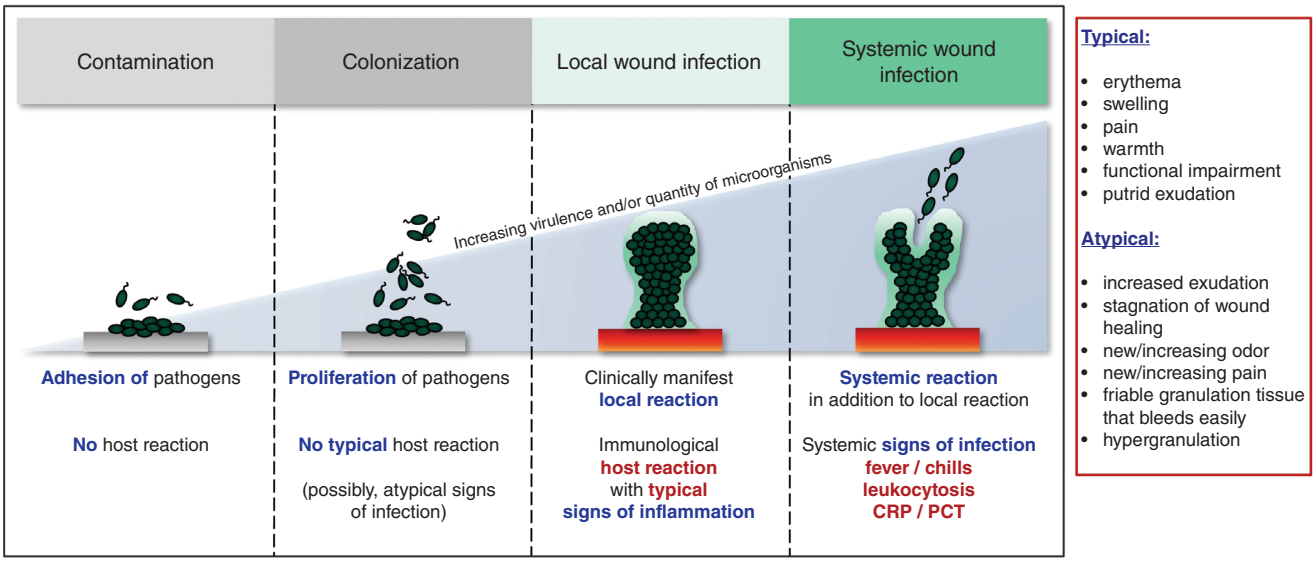

FIGURE 1 Continuum of wound infection and possible typical and atypical clinical signs. *Abbr.*: CRP, C-reactive protein; PCT, procalcitonin

TABLE 2 Most common bacterial species in chronic wounds in Germany.[8,14,47]

Species	Frequency (%)
Staphylococcus aureus	37–70
Pseudomonas aeruginosa	17–39
Proteus mirabilis	10–17
Escherichia coli	6–14

Last revised in 2022, this international consensus specifies the various clinical conditions and their treatment.[6]

In the context of this position paper, the experts for the German-speaking area have agreed on a simplified classification in contamination, colonization, local and systemic wound infection (Figure 1). In each wound, whether acute or chronic, microorganisms of the skin microbiome can be found; this is referred to as contamination. With increasing proliferation and/or increased virulence of the predominant microorganisms, colonies are formed, a process referred to as colonization. With uncontrolled progression of colonization, increasing evidence for a developing local wound infection may be observed. Clinical signs for this development include exudate increase, stagnation or delay of wound healing, as well as newly emerging or increasing pain and wound odor. In case of progressive increase of the microbial load with associated local reaction, this condition has been referred to as critical colonization in the past.[6] In the context of this position paper it is recommended to no longer use the term of critical colonization, given that the exact transition point when a colonization should be considered as critical cannot be specified with sufficient reliability.[15] There are numerous potential influencing factors that may affect the progression of local wound infection. Important factors include amount and virulence of the pathogens, immune competence of the host, and wound localization.[16]

In the international version of the wound infection continuum updated in 2022, local wound infection was subdivided into *overt* and *covert* forms, while *spreading infection* was newly introduced.[6] The background for this differentiation was the fact that an incipient local wound infection will often not present with the full extent of typical, apparent clinical signs of infection. This applies in particular to people with impaired or disturbed immune response and to chronic, recurrent infections associated with biofilms. Spreading infection is another subdivision intended to present the next step from local to systemic infection, if no adequate treatment measures are taken.[6] Given that the further subdivision of local wound infection has no specific therapeutic consequence and may rather lead to confusion, the use of this term was excluded in this consensus.

Local wound infections can be diagnosed based on clinical signs of infection, which may be supported by the therapeutic index for local infections (TILI) score.[17] Systemic signs, such as fever, chills, or general feeling of exhaustion, may be symptoms of systemic infection.[1,6] In this case, serological parameters, such as white blood cell differential, C-reactive protein (CRP), or procalcitonin (PCT), should be determined, and blood cultures should be taken for further diagnostic workup. While these content-related considerations, especially concerning the transition thresholds between colonization and local wound infection as well as local infection and systemic infection are of essential importance for correct treatment and assessment, it is the opinion of the experts of WundDACH that a classification within the wound continuum should be as simple as possible and suitable for daily life. Accordingly, they consider a simplified overview without loss of content-related relevance as the most reasonable approach.

TABLE 3 Bacterial diagnostics in chronic wounds.[48]

Indication	Method	Remarks
MDRO search	Swab using Essen Rotary technique without prior cleansing	Using a spiraling motion and applying slight pressure, load swab with material from the periphery to the center of the wound. *Lab requirements*: Screening, co-examination of other sites, if necessary
Pathogenic organisms	Swab using Levine technique with prior cleansing	Applying slight pressure, load swab with material from the area that appears clinically infected (approx. 1 cm^2). *Lab requirements*: Pathogenic organisms with antibiogram
DFU, deep wounds, suspected rare pathogens, such as mycobacteria, Leishmania etc.	Biopsy after prior cleansing	Give biopsy with droplets of Ringer's solution into sterile tube. *Lab requirements*: Pathogenic organisms, record suspicion of mycobacteria etc., if necessary
Fistulas	Collect content of fistula with canula	Give content of fistula into sterile tube or blood culture flask. *Lab requirements*: Pathogenic organisms, record suspicion of mycobacteria etc., if necessary

INFLAMMATION VERSUS INFECTION

While it is not always possible to strictly differentiate unequivocally between inflammation and wound infection in individuals with chronic wounds, this differentiation is important because of the therapeutic consequences. Inflammation describes a reaction of the organism to a potentially harmful stimulus. Causes may be bacterial infections, but also non-infectious factors. Non-infectious causes may include autoimmune diseases, such as vasculitis and vasculopathies, or eczemas. Biopsies are often important for their diagnosis. In contrast to wound infections diagnosed by, for example, vital parameters and serology, their therapy involves rheologic or immunosuppressive drugs.[18] For the treatment of wound infections, however, antimicrobial, locally applied substances like antiseptics or, if appropriate, systemic antibiotics are usually important. Moreover, additional measures, such as wound irrigation and debridement, are useful to reduce the number of microorganisms.[19]

DIAGNOSTIC WORKUP

Depending on the indication, different procedures and approaches can be used for the detection of bacteria (Table 3).[20]

Swab

In chronic wounds, a bacteriologic swab from the wound surface is usually sufficient for the detection of bacteria in routine care. When screening for MDROs, no wound cleansing should be performed prior to swabbing in order to detect the spectrum of pathogen species in the wound as representative as possible. The swab can be taken according to the Essen Rotary technique with a spiraling motion from the periphery to the center of the wound while applying slight pressure. If, however, wound infection is clinically suspected, wound cleansing should be performed prior to bacteriological diagnosis using sterile wound irrigation solution without active substance and, if necessary, cotton gauze. By this means, clinically irrelevant contaminants can be removed from the wound surface. Subsequently, the bacteriologic swab should be taken with the so-called Levine technique from the area of approximately 1 cm^2 that appears clinically infected while applying slight pressure.[20] Swabs from wounds should be taken from the wound bed, if possible, to provide clinically relevant results. Subsequently, these swabs should be sent as fast as possible to the lab for appropriate analysis. If there is a delay of more than 24 hours, storage at room temperature will result in proliferation of pathogens and thus in a shift of the microbiological picture in favor of faster-growing species. Storage in a refrigerator will cause the loss of anaerobes, given that these germs are often less tolerant to low temperatures and die. Facultative anaerobes may, however, survive in the refrigerator for a significantly longer time. Taking the above considerations into account, however, qualitative evaluation with loss of anaerobes is still possible after 48 hours.[20]

Biopsy

In most individuals with chronic wounds, no routine biopsies should be taken for pathogen diagnostics. Only in case of deep ulcerations, DFU, severe soft tissue infection, fistula tissue, or if specific pathogens are suspected, such as

mycobacteria, Leishmania, or molds, are biopsies required for pathogen detection.[20,21]

Serology

The spread of infections in skin, lymphatic system, or bloodstream are complications requiring systemic antibiotic therapy. However, some people require systemic antibiotic therapy, due to malnutrition, exsiccation, immunosuppressive therapy, or diabetes mellitus, without relevant signs of inflammation. In these cases, the decision should be made based on the clinical presentation, with coatings, odor, discoloration, and general condition of those affected. Apart from this, the diagnosis of systemic infection may be confirmed by lab results, such as CRP, erythrocyte sedimentation rate (ESR), and leukocytosis. PCT is another sensitive biomarker for infections caused by bacteria that can be determined, in particular, if incipient sepsis is suspected.[22]

Fluorescence

Biofilm or bacterial colonization in wounds with more than 10^4 CFU/mm^2 can often be made visible to the human eye with near-UV light. Light of a wavelength around 450 nm allows for detection of areas with high bacterial metabolic activity due to fluorescence of bacterial metabolites. Porphyrins are, for example, responsible for red fluorescence indicating the presence of *Staphylococcus spp*. and enterobacteria. In contrast, cyan-blue fluorescence is an indicator for the presence of *Pseudomonas spp*. secreting pyoverdine.[23]

Scores

Specific scores have been developed as an aid for clinical diagnosis.

Wound-At-Risk (W.A.R.) score

It is often difficult to identify people that may have no clinical manifest wound infection yet but are at an enhanced risk of developing wound infection. This status is also called risk wound or *Wound-At-Risk* (W.A.R.).[24] An international interdisciplinary and interprofessional group of experts has devised the W.A.R. score to enable the determination of the infection risk based on risk points (Table 4).[25] In individuals with an increased risk of infection, it may be useful to perform antimicrobial wound treatment earlier and, if necessary, even for a longer period. The W.A.R. score is used for early detection of an infection risk based on patient-specific characteristics and risk factors of the wound. Accordingly, the score supports the individual assessment whether antimicrobial wound therapy is justified.

TABLE 4 Wound-At-Risk (W.A.R.) score to estimate the risk of infection for people with wounds. Local antimicrobial wound treatment is recommended from a total score of ≥ 3 points.[25]

1 risk point
Acquired immunosuppressive disease, e. g., diabetes mellitus
Acquired immune deficiency due to medical therapy, e. g., ciclosporin, methotrexate, glucocorticoids, antibodies
Diseases with solid tumors
Hematological systemic disease
Postsurgical wound healing disorder resulting in (unplanned) secondary healing
Wounds with particularly high germ load due to localization, e. g., perineum, genitals
Problematic hygienic conditions, due to social or occupational environment, e. g., farmers, truck drivers
Age ≥ 80
Younger age, e. g., premature babies, babies, infants
Existence of wounds > 1 year
Wound size ≥ 10 cm^2
Chronic wounds of all causalities with a depth of > 1.5 cm
Long-term hospitalization > 3 weeks
2 risk points
Severe acquired immune deficiencies, e. g., HIV infection
Highly contaminated acute wounds
Bite, stab, and bullet wounds with a depth of 1.5 to 3.5 cm
3 risk points
Burn wounds with an involvement of > 15 % body surface area
Wounds that have a direct connection to organs or functional structures, e.g., joints, or contain exogenous material
Extremely serious inherited immune deficiencies, e. g., agammaglobulinemia, severe combined immune deficiency (SCID)
Bite, stab, and bullet wounds with a depth of > 3.5 cm

Therapeutic Index for Local Infections (TILI) score

The therapeutic index for local infections (TILI) score for the diagnosis of local wound infections was developed by an interdisciplinary and interprofessional group of experts in Germany, translated into several languages, and validated in an international study.[26] The current, updated German version of the TILI score was then devised in cooperation with WundDACH (Table 5).[17] While, individually, the respective clinical symptoms are important, they are no proof of wound infection. Therefore, the TILI score will only provide an indication for antimicrobial wound treatment, for example with antiseptics, if at least five of the six non-specific symptoms (indirect criteria) are present. There are, however, also individual aspects, here referred to as direct criteria,

TABLE 5 Therapeutic Index for Local Infections (TILI) score for the diagnosis of local wound infections and indication of local antimicrobial therapy.[17] An indication for antimicrobial wound treatment exists if at least five of the six non-specific symptoms or one of the direct criteria is present.

No direct indication
- Erythema to surounding skin
- Heat
- oedema, induration, or swelling
- Spontaneous pain or pressure pain*
- Sta wound healing
- Increase and/or change of colour or smell of exudate
Direct indication
- Presence of wound pathogens**
- Surgical septic wound
- Presence of free pus

*Caution for people with polyneuropathy or when using painkillers.
**This can be very different in different countries and institutions. One example is the detection of MRSA.

TABLE 6 M.O.I.S.T. concept of local therapy for chronic wounds.[27]

M: Moisture balance
O: Oxygen balance
I: Infection control
S: Support (of healing process)
T: Tissue management

that justify antimicrobial wound therapy. Implementation of the TILI score has the aim to improve the indication and reduce non-indicated antimicrobial wound therapy.

CONCEPT OF MODERN WOUND THERAPY

Today, a modern treatment plan of chronic wounds can be guided by M.O.I.S.T. or other concepts, such as TIME or TIMERS (Table 6).[27] In these concepts, the letter "T" describes the tissue management. Key aspects of these concepts are wound irrigation and debridement.

Wound irrigation and debridement

In contaminated wounds without signs of infection, regular use of neutral irrigation solutions combined with mechanical debridement and wound cleansing is usually sufficient to prevent an unphysiological increase of microorganisms.[19] Sterile physiological saline and Ringer solution may, for example, be used for wound irrigation. These are, however, not preserved and can therefore only be used once. Preserved wound irrigation solutions are increasingly used especially for wound treatment in the out-patient setting, given that they can be used for 6–10 weeks after opening. Common preservatives include the colorless substances polyhexanide, octenidine, sodium hypochlorite, or hypochlorous acids. Sodium hypochlorite or hypochlorous acids are well-tolerated chlorine-releasing agents. The antimicrobial effect is primarily based on oxidative reactions. In combination with salt solutions, they show osmotic potential on the eroded bacterial cell membrane. In contrast to most antiseptics, they can also be used on exposed bone or cartilage.[28] The current recommendations of the Commission for Hospital Hygiene and Infection Prevention (KRINKO) in Germany point out that tap water may only be used for wound treatment, if it is filtered with terminal sterile filters with a pore size of 0.2 µm.[29]

TABLE 7 Indication-dependent selection of antimicrobial wound therapies.[28]

Indication	Antimicrobial agent	
	1st choice	2nd choice
Wounds at risk of infection	Polyhexanide	NaOCl, HOCl, hypochlorite, silver, OCT/PE
Wounds with evidence of multidrug-resistant organisms (MDROs)	OCT/PE	OCT, polyhexanide, silver
Wounds without drainage opportunity	NaOCl, HOCl	-

Abbr.: NaOCl, sodium hypochlorite; HOCl, hypochlorous acid; OCT, octenidine dihydrochloride; OCT/PE, octenidine dihydrochloride/phenoxyethanol; MDRO, multidrug-resistant organisms

Debridement has the aim of removing adherent, dead tissue, crusts, and foreign material from the wounds.[30] This will also eliminate already a large fraction of the bacteria from wounds. Mechanical and sharp or surgical debridement are predominantly used for the therapy of wound infections. Sharp or surgical debridement reduces bacterial colonization and load very effectively,[31] but only for a short period. Accordingly, it should be performed repeatedly in intervals of maximally 48–72 hours to exert its antimicrobial effect.[32] An alternative for wound treatment with medicinal larvae grown under sterile conditions is referred to as biosurgery. Extracorporeal digestion and secretion of, among others, antimicrobial peptides by medicinal larvae results in highly selective lysis of necrotic tissue and bacteria.[33]

Antimicrobial wound therapy

In the treatment concepts for chronic wounds, therapeutic measures for infection control are described with the letter "I". Various therapeutic options can be used for antimicrobial wound therapy including wound irrigation, gel, or wound dressing/pads. The different indications are, among other factors, the result of the used active substance, respective concentration, spectrum of activity, and potential cytotoxicity (Table 7).[28] The correct indication and selection of the respective antimicrobial substance is based on several aspects, such as potency, cytotoxicity, intention of treatment (therapeutic/preventive), the relation between microbial load and resilience of the tissue,

TABLE 8 Exposure times of antimicrobial agents.[48]

Agent	Concentration (%)	Exposure time (min.)
Octenidine + phenoxyethanol	0.1–1	1–2
Polyhexanide	0.01–0.04	10–20
Sodium hypochlorite	0.08	3–5
PVP iodine	1–11	3–5

as well as wound stage.[34] In case of contamination or colonization, the primary goal is to prevent the increase of microbial load to a critical level or to achieve its reduction without compromising tissue regeneration due to cytotoxic effects. For an already existing local wound infection, the cytotoxic effects of antimicrobial treatment strategies may temporarily be considered of lesser relevance. In addition, product-specific limitations should be considered for the use on exposed tissue structures, such as tendons, vessels, CNS structures, and peritoneum. The same applies to the different exposure times (Table 8).[28]

Polyhexanide or polyhexamethylene biguanide (PHMB) kills microorganisms by binding to and damaging their cell walls. The combined use with betaine surfactants can improve the physical properties of PHMB, thus increasing its antimicrobial activity.[35]

Octenidine is a cationic antiseptic agent mostly used in combination with phenoxyethanol for wound treatment. It exerts its antimicrobial effect by destroying the outer membrane of microorganisms. Preparations with octenidine should not by introduced with pressure deeply into tissue without drainage opportunity, since this may result in edema and necrosis.[36]

Silver is usually used for wound treatment in the form of wound dressings. However, the broad bactericidal activity of silver only takes effect when the silver atoms become positively charged silver ions (Ag^+).[37] The antimicrobial effect of silver is exerted via several mechanisms and on various target sites of the bacterial cell. The risk of resistance development has only rarely been described in vitro or in animal experiments, and is, to date, without clinical relevance.[38] For the therapy of wounds with biofilm, antimicrobial wound dressings with silver, EDTA, and benzethonium chloride have proven to be effective.[39] Despite the large number of good clinical studies, the large heterogeneity of products and study designs impedes the unambiguous assessment of silver in wound treatment.[40]

Due to its brown color, the risk of thyroid disorders, a comparatively higher cytotoxicity, and the high potential of contact sensitization, povidone (PVP) iodine is nowadays viewed critically with respect to treatment of individuals with chronic wounds. It remains an approved drug that is predominantly recommended for acute wounds with bacterial spores, for example, in bullet or bite injuries.[41] Cadexomer iodine was effective both on biofilms in in vitro experiments[42] and in clinical trials on patients with chronic wounds.[43]

Generally, wound dressings with antimicrobial activity may also be used for the treatment of wound infections. In this context, various dressing or carrier materials exist, such as polyurethane (PU) foams, alginates, or hydrofibers that are combined with an antimicrobial agent. Moreover, wound dressings without active substance are available with an antimicrobial activity based primarily on the physical binding of microorganisms. Especially for wound dressings coated with dialkylcarbamoyl chloride (DACC), it is postulated that bacteria and fungi adhere irreversibly to the hydrophobic surfaces and are thus removed from the wound during dressing change.[44] In addition, other hydroactive products with high retention capacity, such as superabsorbers, can bind germs irreversibly in a physical manner.[45] Accordingly, there is generally no risk of tolerance development or cytotoxicity (Figure 2). Additional antimicrobial strategies for wound treatment include physical treatment options like cold atmospheric plasma, laser, or ultrasound.[46]

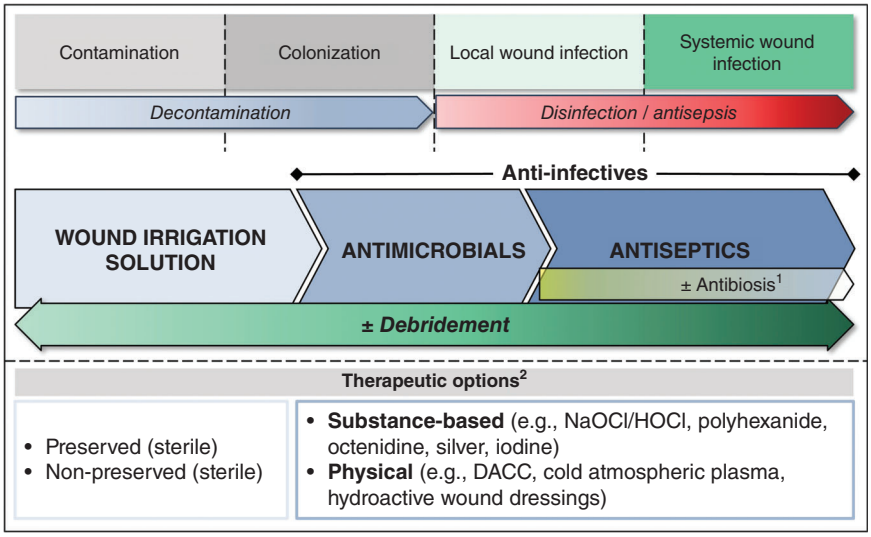

FIGURE 2 Therapeutic procedure for different stages of wound infection. *Abbr.*: NaOCl, sodium hypochlorite; HOCl, hypochlorous acid; DACC, dialkylcarbamoyl chloride. [1]The indication for the use of systemic antibiotics is a situation-based decision and depends on several factors such as underlying disease, severity of infection, immune status, etc. [2]This is a generic overview for clarification purposes and does not claim to be exhaustive.

Although various effective wound therapeutics with antimicrobial activity and minor cytotoxicity are now available, this does not justify their non-selective long-term use. Accordingly, the group of experts recommends an individual and targeted use of antimicrobial wound therapeutics for a limited period. A maximum therapy duration of 10–14 days is recommended. After this time, the indication should be critically reviewed and the information of the manufacturer concerning the maximum therapy duration should be considered.

For systemic therapies with antibiotics, we refer to the relevant medical guidelines.

CONCLUSIONS FOR CLINICAL PRACTICE

Especially in people with chronic wounds, wound infections may cause numerous complications. Therefore, important objectives of modern wound therapy concepts are the prompt diagnosis of wound infections and their adequate treatment. Therapeutically, many bacteria in wounds can already be removed by repeated wound cleansing with wound irrigation and debridement. Today, numerous effective substances and wound therapeutics with antimicrobial activity are available that may be selected and used on an individual basis. However, the indication of antimicrobial wound therapy should be critically reviewed after 10–14 days at the latest.

ACKNOWLEDGMENTS

This position paper was supported by unrestricted grants from the following companies: B. Braun Austria, ConvaTec Germany, Essity/BSN medical, Paul Hartmann AG, Lohmann & Rauscher, Smith & Nephew, and Urgo.

Open access funding enabled and organized by Projekt DEAL.

CONFLICT OF INTEREST STATEMENT

The following authors have received honoraria for consulting activities, lectures/training courses, and/or studies potentially related to the topic presented here.

Dissemond: Aurealis, Biomonde, Coloplast, Convatec, Curea, Flen Pharma, Hartmann, Lohmann & Rauscher, Mölnlycke, Urgo, Piomic; Rembe: Serag-Wiessner, DEBx medical; Assenheimer: none; Barysch-Bonderer: none; Gerber: none; Kottner: none; Kurz: Essity, Coloplast, Convatec, Mölnlycke, Sorbion Austria, Publicare, Fidiapharma; Motzkus: Serag Wiessner, Coloplast, Mölnlycke, Hartmann; Panfil: none; Probst: Curea, Hartmann, Convatec, Solventum, Smith&Nephew, Polaroid Therapeutics, Urgo; Strohal: Urgo; Traber: Urgo, Piomic; Schwarzkopf: none.

ORCID

Joachim Dissemond https://orcid.org/0000-0003-3893-328X

Eva-Maria Panfil https://orcid.org/0000-0003-1112-7763

REFERENCES

1. Malone M, Schultz G. Challenges in the diagnosis and management of wound infection. *Br J Dermatol*. 2022;187:159-166.
2. Maheswary T, Nurul AA, Fauzi MB. The insights of microbes' roles in wound healing: A comprehensive review. *Pharmaceutics*. 2021;13:981.
3. Yao Z, Niu J, Cheng B. Prevalence of chronic skin wounds and their risk factors in an inpatient hospital setting in northern China. *Adv Skin Wound Care*. 2020;33:1-10.
4. Manos J. The human microbiome in disease and pathology. *APMIS*. 2022;130:690-705.
5. Byrd AL, Belkaid Y, Segre JA. The human skin microbiome. *Nat Rev Microbiol*. 2018;16:143-155.
6. Swanson T, Ousey K, Haesler E, et al. IWII Wound Infection in Clinical Practice consensus document: 2022 update. *J Wound Care*. 2022;31(Suppl. 12):10-21.
7. Leaper D, Assadian O, Edmiston CE. Approach to chronic wound infections. *Br J Dermatol*. 2015;173:351-358.
8. Schmidt K., Debus ES, Jessberger S, et al. Bacterial population of chronic crural ulcers: Is there a difference between the diabetic, the venous, and the arterial ulcer? *VASA*. 2000;29:62-70.
9. Puca V, Marulli RZ, Grande R, et al. Microbial species isolated from infected wounds and antimicrobial resistance analysis: Data emerging from a three-years retrospective study. *Antibiotics*. 2021;10:1162.
10. Percival SL, Malone M, Mayer D, et al. Role of anaerobes in polymicrobial communities and biofilms complicating diabetic foot ulcers. *Int Wound J*. 2018;15:776-782.
11. Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *Lancet*. 2022;39:629-655.
12. Simonetti O, Marasca S, Candelora M, et al. Methicillin-resistant Staphylococcus aureus as a cause of chronic wound infections: Alternative strategies for management. *AIMS Microbiol*. 2022;8:125-137.
13. Chen Y, Yang J, Wang Y, et al. Community-associated methicillin-resistant Staphylococcus aureus infection of diabetic foot ulcers in an eastern diabetic foot center in a tertiary hospital in China: a retrospective study. *BMC Infect Dis*. 2023;23:652.
14. Jockenhöfer F, Gollnick H, Herberger K, et al. Bacteriological pathogen spectrum of chronic leg ulcers: Results of a multicenter trial in dermatologic wound care centers differentiated by regions. *J Dtsch Dermatol Ges*. 2013;11:1057-1063.
15. Schwarzkopf A. Kritische Betrachtung zur kritischen Kolonisation. *WUNDmanagement*. 2023;17:44-45.
16. Williams M. Wound infections: An overview. *Br J Community Nurs*. 2021;26 (Suppl. 6):22-25.
17. Dissemond J, Gerber V, Lobmann R, et al. Therapeutischer Index für Lokale Infektionen: TILI-Score Version 2.0. *WUNDmanagement*. 2021;15:123-126.
18. Dissemond J, Romanelli M. Inflammatory skin diseases and wounds. *Br J Dermatol*. 2022;187:167-177.
19. Mayer DO, Tettelbach WH, Ciprandi G, et al. Best practice for wound debridement. *J Wound Care*. 2024;33(Suppl. 6b):1-32.
20. Schwarzkopf A, Dissemond J. Indikation und praktische Durchführung mikrobiologischer Diagnostik bei Menschen mit chronischen Wunden. *J Dtsch Dermatol Ges*. 2015;13:203-210.
21. Erfurt-Berge C, Bültemann A, Gerber V, et al. Stellenwert der Biopsie in der Diagnostik chronischer Wunden – ein Positionspapier der Initiative Chronische Wunden (ICW) e. V. *Dermatologie*. 2024;75:163-169.
22. Cecconi M, Evans L, Levy M, Rhodes A. Sepsis and septic shock. *Lancet*. 2018;392:75-87.
23. Stürmer EK. Wound biofilm: a bacterial success story. *J Wound Manage*. 2023;24:6-13.
24. Dissemond J, Assadian O, Gerber V, et al. Classification of wounds at risk and their antimicrobial treatment with polihexanide: A practice-oriented expert recommendation. *Skin Pharmacol Physiol*. 2011;24:245-255.

25. Dissemond J, Eberlein T, Strohal R, Wild T. Die Checkliste „infektionsgefährdete Wunde" als Ergänzung zum W.A.R. Score (Wound-At-Risk). *WUNDmanagement*. 2011;5(Suppl. 2):19-20.
26. Dissemond J, Strohal R, Mastronicola D, et al. Therapeutic Index for Local Infections score validity: a retrospective European analysis. *J Wound Care*. 2020;29:726-734.
27. Dissemond J, Assenheimer B, Gerber V, et al. Lokaltherapie chronischer Wunden: Das M.O.I.S.T. Konzept. *Dtsch Med Wochenschr*. 2023;148:400-405.
28. Kramer A, Dissemond J, Willy C, et al. Auswahl von Wundantiseptika: Aktualisierung des Expertenkonsensus 2018. *WUNDmanagement*. 2019;13(Suppl.):3-23.
29. KRINKO - Kommission für Krankenhaushygiene und Infektionsprävention. Prävention postoperativer Wundinfektionen. *Bundesgesundheitsbl*. 2018;61:448-473.
30. Dissemond J, Bültemann A, Gerber V, et al. Positionspapier der Initiative Chronische Wunde (ICW) e. V. zur Nomenklatur des Débridements chronischer Wunden. *Hautarzt*. 2022;73:369-375.
31. Moelleken M, Krimphove SH, Krefting F, et al. How effective is simple mechanical wound debridement in reducing bacterial colonisation? Results of a prospective clinical study. *Int Wound J*. 2024;21:14824.
32. Schultz G, Bjarnsholt T, James GA, et al. Consensus guidelines for the identification and treatment of biofilms in chronic nonhealing wounds. *Wound Repair Regen*. 2017;25:744-757.
33. Gieroń M, Słowik-Rylska M, Kucharczyk M, et al. The influence of maggot debridement therapy on the bacterial flora of hard-to-heal wounds. *J Wound Care*. 2024;33:778-787.
34. Rembe JD, Stürmer EK. Die Moderne Wundantiseptik - Indikationen und Limitationen, zwischen Wissen, Wunsch und Unsicherheit. *Gefäßchirurgie*. 2020;25:272-276.
35. Klasinc R, Augustin LA, Below H, et al. Evaluation of three experimental in vitro models for the assessment of the mechanical cleansing efficacy of wound irrigation solutions. *Int Wound J*. 2018;15:140-147.
36. Babalska ZŁ, Korbecka-Paczkowska M, Karpiński TM. Wound antiseptics and european guidelines for antiseptic application in wound treatment. *Pharmaceuticals*. 2021;14:1253.
37. Lazareth I, Meaume S, Sigal-Grinberg ML, et al. Efficacy of a silver lipidocolloid dressing on heavily colonised wounds: a republished RCT. *J Wound Care*. 2012;21:96-102.
38. Braunwarth H, Steinmann J, Klock H, Brill FHH. Keine in-vitro-Hinweise auf die Entstehung von bakteriellen Resistenzen gegenüber einem Silberionen-Komplex. *WUNDmanagement*. 2019;13:177-181.
39. Metcalf DG, Parsons D, Bowler PG. Clinical safety and effectiveness evaluation of a new antimicrobial wound dressing designed to manage exudate, infection and biofilm. *Int Wound J*. 2017;14:203-213.
40. Dissemond J, Böttrich JG, Braunwarth H, et al. Evidenz von Silber in der Wundbehandlung - Meta-Analyse der klinischen Studien von 2000–2015. *J Dtsch Dermatol Ges*. 2017;15:524-536.
41. Barreto R, Barrois B, Lambert J, et al. Addressing the challenges in antisepsis: focus on povidone iodine. *Int J Antimicrob Agents*. 2020;56:106064.
42. Stürmer EK, Plattfaut I, Dietrich M, et al. In vitro activity of antimicrobial wound dressings on P. aeruginosa wound biofilm. *Front Microbiol*. 2021;12:664030.
43. Raju R, Kethavath SN, Sangavarapu SM, Kanjarla P. Efficacy of cadexomer iodine in the treatment of chronic ulcers: A randomized, multicenter, controlled trial. *Wounds*. 2019;31:85-90.
44. Mosti G, Magliaro A, Mattaliano V, et al. Comparative study of two antimicrobial dressings in infected leg ulcers: a pilot study. *J Wound Care*. 2015;24:121-127.
45. Rippon MG, Rogers AA, Sellars L, et al. Effectiveness of a non-medicated wound dressing on attached and biofilm encased bacteria: laboratory and clinical evidence. *J Wound Care*. 2018;27:146-155.
46. Assadian O, Ousey KJ, Daeschlein G, et al. Effects and safety of atmospheric low-temperature plasma on bacterial reduction in chronic wounds and wound size reduction: A systematic review and meta-analysis. *Int Wound J*. 2019;16(1):103-111.
47. Bessa LJ, Fazii P, Di Giulio M, Cellini L. Bacterial isolates from infected wounds and their antibiotic susceptibility pattern: some remarks about wound infection. *Int Wound J*. 2015;12:47-52.
48. Schwarzkopf C., Schwarzkopf A, Stürmer E, et al. ICW-Leitfaden: Infektionsprävention und Hygiene in der Wundversorgung. 5. Auflage, 2022.

How to cite this article: Dissemond J, Rembe J-D, Assenheimer B, et al. Systematics, diagnosis and treatment of wound infections in chronic wounds: A position paper from WundDACH. *JDDG: Journal der Deutschen Dermatologischen Gesellschaft*. 2025;23:565–574.
https://doi.org/10.1111/ddg.15649