Received: 27 December 2022 | Accepted: 18 May 2023

DOI: 10.1111/ddg.15153

REVIEW

Perioperative antibiotic prophylaxis in skin surgery – Position paper of the Antibiotic Stewardship working group of the German Society for Dermatologic Surgery (DGDC), Part 2: Special indications and situations

Galina Balakirski[1] | **Sören L. Becker**[2] | **Daniela Hartmann**[3] | **Lukas Kofler**[4] | **Christian Kunte**[5] | **Cornelia S. L. Müller**[6] | **Thomas Volz**[7] | **Benjamin Kendziora**[3] | **Justin Gabriel Schlager**[3] | **Christoph R. Löser**[8]

[1]Center for Dermatology, Allergology and Dermatosurgery, Helios University Hospital Wuppertal, University of Witten/Herdecke, Wuppertal, Germany

[2]Institute of Medical Microbiology and Hygiene, Saarland University, Homburg, Germany

[3]Department of Dermatology and Allergy, University Hospital, Ludwig Maximilian University Munich, Munich, Germany

[4]Department of Dermatology, University of Tübingen, Tübingen, Germany

[5]Department of Dermatologic Surgery and Dermatology, Artemed Clinic Munich, Munich, Germany

[6]Medical Supply Center for Histology, Cytology, and Molecular Diagnostics Trier, Trier, Germany

[7]Department of Dermatology and Allergology, University Medical Center, Technical University of Munich, Munich, Germany

[8]Department of Dermatology, Ludwigshafen City Hospital, Ludwigshafen, Germany

Correspondence
Dr. med. Galina Balakirski, Center for Dermatology, Allergology and Dermatosurgery, Helios University Hospital Wuppertal, University of Witten/Herdecke, Heusnerstraße 40, 42283 Wuppertal, Germany.
Email: galina.balakirski@helios-gesundheit.de

Summary

In addition to prevention of surgical site infections after skin surgery, perioperative antibiotic prophylaxis (PAP) aims to prevent the occurrence of other postoperative infectious complications, especially bacterial endocarditis and hematogenous joint prosthesis infections. This article discusses specific indications for the use of PAP. For example, patients who have undergone any type of heart valve replacement, including transcatheter valve replacement or use of prosthetic material to correct the heart valve, or patients who have experienced bacterial endocarditis, require PAP during skin surgery on mucosal membranes or ulcerated tumors.

The use of PAP in special situations such as secondary wound healing, septic dermatosurgery or ulcer surgery is also presented and discussed in detail in this paper based on the current scientific literature. This paper represents the second part of the position paper of the Antibiotic Stewardship Working Group of the German Society for Dermatologic Surgery (DGDC) and summarizes evidence-based recommendations for the administration of PAP during skin surgery for special indications and situations. This is particularly important because, as detailed in Part 1 of this position paper, PAP can and usually should be avoided in skin surgery.

KEYWORDS

Perioperative antibiotic prophylaxis, skin surgery, dermatologic surgery, surgical site infections, bacterial endocarditis, joint prosthesis infection

INTRODUCTION

Although perioperative antibiotic prophylaxis (PAP) is in most cases used for prevention of surgical site infections (SSIs), there are also other indications. The most important include endocarditis prophylaxis and prophylaxis of hematogenous joint prosthesis infections, given that these may be associated with serious health consequences.

In Part 1 of this position paper, we discussed procedure- and patient-related risk factors for the development of

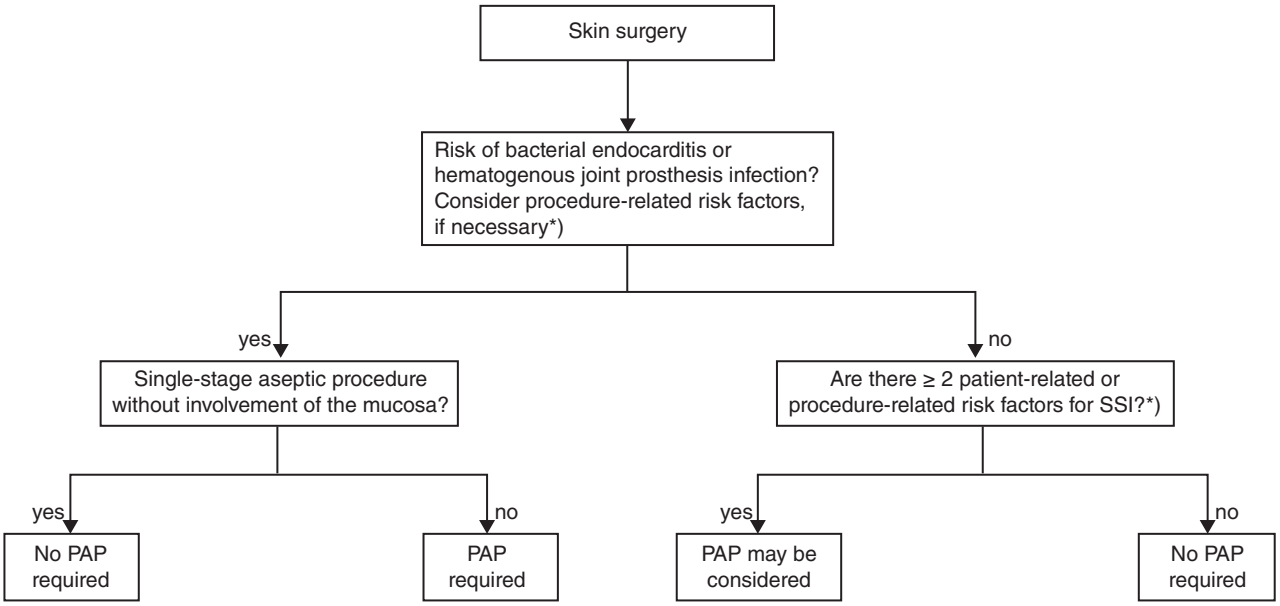

FIGURE 1 Recommendation for the use of perioperative antibiotic prophylaxis in skin surgery. In the first excision of clinically uninfected skin in a multi-stage procedure, PAP may be omitted for prophylaxis of bacterial endocarditis. For all further procedures or wound closure PAP is required. In contrast to endocarditis prophylaxis, the recommendation for the use of PAP for the prophylaxis of hematogenous joint prosthesis infections is a weaker one, so that considering the limited evidence, a choice against PAP for this indication can also be justified. *Abbr.:* SSI, surgical site infections; PAP, perioperative antibiotic prophylaxis. *) Patient-related risk factors relevant to the development of SSI: immunosuppression. Intervention-related risk factors relevant for the development of SSI: defect size > 4 cm^2, wound closure using skin flap, localization on the lower extremities or ears, surgery on ulcerated tumors.

SSI and the use of PAP for SSI prevention.[1] In general, PAP should be avoided in most elective skin surgeries. The exceptions are combinations of several relevant risk factors. PAP may, for example, be considered in individual cases for closure of large wound defects of > 4 cm^2 with skin flaps.[1,2] In addition, special localizations (such as lower leg or ear) have, in combination with other risk factors like immunosuppression, a tendency to develop SSIs and may justify the use of PAP (Figure 1).[1,2] In this second part, the authors discuss specific PAP indications, such as prophylaxis of bacterial endocarditis or hematogenous joint prosthesis infection, as well as PAP in special situations (for example, in the context of septic surgeries). An S3 guideline on the perioperative and peri-interventional antibiotic prophylaxis in collaboration with the German Dermatological Society (DDG) is already planned by the AWMF (Working Group of Scientific Medical Societies), but completion is not expected until December 2023.[3]

SPECIFIC INDICATIONS

Endocarditis prophylaxis

In the guidelines of the European Society of Cardiology (ESC) patients at an increased risk of developing bacterial endocarditis are defined as follows:[4]

- patients who have undergone any type of heart valve replacement, including transcatheter valve replacement, or use of prosthetic material to correct the heart valve,
- patients who have had bacterial endocarditis

or

- patients with congenital heart defects:
  - any cyanotic defect,
  - status after cardiac defect correction with prosthetic material irrespective of the technique in the first 6 months after the correction, or lifelong in case of persisting residual shunt or regurgitation.

Patients with other heart valve abnormalities or congenital heart defects are not defined as patients at risk.

In these exactly defined risk constellations (Table 1), the above-mentioned guidelines[4] recommend perioperative antibiotic prophylaxis for skin surgeries involving mucous membranes (oral or nasal mucosa) or in case of infected, inflamed, or ulcerated skin (Table 2). This should be performed 30 to 60 minutes before the procedure. Perioperative antibiotic prophylaxis is, therefore, not required in aseptic, single-stage skin surgeries with direct wound closure without mucous membrane involvement, provided

TABLE 1 Presentation of the risk populations that require perioperative antibiotic prophylaxis independent of the prevention of postoperative wound infections (based on[2,4,6]).

Risk factors for	
Development of bacterial endocarditis	***Development of hematogenous joint prosthesis infection after endoprosthesis implantation***
Status after any heart valve replacement, including transcatheter valve replacement (lifelong)	Status after any joint endoprosthesis implantation in the first 2 years after surgery or
Status after heart valve correction using prosthetic material (lifelong)	Status after any endoprosthesis implantation, irrespective of the time of implantation, and presence of one of the following risk factors: - immunosuppression (for example, due to immunosuppressive therapy or chemotherapy) - untreated of insufficiently treated HIV infection - extreme malnutrition - inflammatory joint diseases (for example, rheumatoid arthritis or systemic lupus erythematosus) - status after previous hematogenous joint prosthesis infection - diabetes mellitus type I - hemophilia
Status after previous bacterial endocarditis (lifelong)	
Presence of any congenital cyanotic heart defect (lifelong)	
Status after complete correction of cardiac defects with prosthetic material, irrespective of the technique (in the first 6 months after the correction)	
Status after incomplete correction of cardiac defects with prosthetic material with persistence of residual shunt or regurgitation, irrespective of the technique (lifelong)	

TABLE 2 Recommendations of perioperative antibiotic prophylaxis for endocarditis prophylaxis in patients at risk of bacterial endocarditis (adapted from[2,4]).

Situation	Recommended substances	As single dose 30–60 minutes before surgery	
		Adults	***Children***
No allergy to penicillin or ampicillin	Amoxicillin	2 g p.o.	50 mg/kg body weight p.o. or i.v.
	Ampicillin	2 g i.v.	
	Cefalexin	2 g p.o.	50 mg/kg body weight p.o.
	Cefazolin	2 g p.o. or i.v.	50 mg/kg body weight i.v.
Known allergy to penicillin or ampicillin	Clindamycin	600 mg p.o. or i.v.	20 mg/kg body weight p.o. or i.v.
	Cefazolin*	2 g p.o. or i.v.	50 mg/kg body weight p.o. or i.v.

*Use as an alternative after benign rashes due to penicillin, aminopenicillins (ampicillin, amoxicillin), or 1st generation cephalosporins (such as cefaclor, cefalexin, or cefadroxil) in the medical history is possible.

there are no procedure- or patient-related risk factors as defined in Part 1 of this position paper (Figure 1).

Currently, no recommendations are available on the implementation of PAP in two-stage or multi-stage skin surgeries for the prophylaxis of bacterial endocarditis in patients at risk. Even though PAP is not required for primary excisions on intact skin due to the sterile conditions, the authors recommend the appropriate PAP for each re-excision or during wound closure, given that potential colonization of the surgical site with resident skin flora after 24 hours cannot be excluded with certainty. Accordingly, the surgical site cannot be considered sterile.

Prophylaxis of hematogenous joint prosthesis infections

The question of prophylaxis for prevention of hematogenous joint infections is a topic intensely discussed among experts. Until recently, there was no convincing national or international consensus due to the lack of sufficient data. The American Dental Association, for example, argues against the general use of PAP in patients with joint prostheses prior to dental interventions while leaving room for case-by-case decisions, if risk factors are present (such as immunosuppression or a history of joint prosthesis infection that required surgical treatment).[5] Recently, however, new recommendations based on new findings[7,8] have been released by the German Society for Endoprosthetics on January 23, 2022.[6] It has been shown in two retrospective cohorts with 106 and 132 analyzed hematogenous joint prosthesis infections that *Staphylococcus aureus or Streptococcus spp.* represented the causal pathogens in the majority of cases and that in approximately 13% and 11% of the infections skin and mucosa acted as entry points.[7,8] Therefore, the German Society for Endoprosthetics recommends for all individuals with a joint endoprosthesis the single use of 2 g amoxicillin 1 hour before an invasive (bleeding) dental procedure irrespective of the time of primary implantation of the prosthesis.[6] Dermatologic surgeries are, however, not specifically addressed. Future prospective studies will show whether the new recommendation can effectively reduce the rate of hematogenous joint prosthesis infections.

TABLE 3 Recommendations for perioperative antibiotic prophylaxis for the prophylaxis of hematogenous joint prosthesis infection in patients at increased risk (adapted from[2]).

Situation	Recommended substances (as single dose 60 minutes before surgery)	
	Surgery involving the mucosa	***Surgery not involving the mucosa***
No allergy to penicillin or ampicillin	Amoxicillin 2 g p.o.	Amoxicillin 2 g p.o.
		Cefalexin 2 g p.o.
		Cefazolin 2 g p.o. or i.v.
Known allergy to penicillin or ampicillin	Clindamycin 600 mg p.o. or i.v.	Clindamycin 600 mg p.o. or i.v.
	Cefazolin* 2 g p.o. or i.v.	Cefazolin* 2 g p.o. or i.v.
In case of known MRSA colonization	Consultation with microbiology/infectiology is recommended. For community acquired MRSA strains, combination of cotrimoxazole 960 mg is often possible, eventually also in combination with another effective substance	

*Use as an alternative after benign rashes due to penicillin, aminopenicillins (ampicillin, amoxicillin), or 1st generation cephalosporins (such as cefaclor, cefalexin, or cefadroxil) in the medical history is possible.

The US-American statement on perioperative antibiotic prophylaxis in skin surgery also defines patient groups at increased risk of postoperative hematogenous joint prosthesis infections.[2] These include patients with joint endoprostheses in the first 2 years after endoprosthesis implantation, history of hematogenous joint prosthesis infection, presence of inflammatory joint diseases (for example, rheumatoid arthritis, systemic lupus erythematosus), or immunosuppression (for example, due to immunosuppressive therapy or chemotherapy). However, no procedure-specific risk factors have been defined.

Based on the current recommendation of the German Society for Endoprosthetics from January 23, 2022,[6] PAP may, therefore, be performed in the indications mentioned above (Table 1). Whether this recommendation will prevail in the long term can only be assessed on the basis of evidence when prospective clinical studies demonstrate a measurable benefit of this procedure. In the meantime, other strategies concerning the indication of PAP in these patients also appear justifiable. If the use of PAP is indicated, patients should receive perioperative antibiotic prophylaxis, similar to patients at risk for developing of bacterial endocarditis, 30 to 60 minutes before skin surgery on mucous membranes (oral or nasal mucosa) or on infected, inflamed, or ulcerated skin (Table 3). Again, any two-stage or multi-stage intervention in the above-mentioned patient collective may be classified as high-risk procedures. Given the sterile conditions, PAP is not required for primary excisions on intact skin. Based on current data, PAP may, however, be considered for each re-excision or while wound closure due to the potential colonization of the surgical site by resident skin flora after 24 hours. Perioperative antibiotic prophylaxis is not required for aseptic, single-stage skin surgery with direct wound closure without mucous membrane involvement, especially if there is no procedure- or patient-related risk factor according to Part 1 of this position paper (Figure 1).

SPECIAL SITUATIONS

Ulcer surgery

Ulcer surgery (referring to dermatosurgical procedures for chronic ulcers) predominantly involves the diagnosis of chronic leg ulcers. This represents the most common dermatologically treated chronic wound.[9,10] However, the recommendations can be applied to chronic ulcers at other sites.

A Cochrane review from 2014 concluded that systemic antibiotic therapy in venous leg ulcer provides no benefits in terms of healing of the ulcer.[11] This applies also for chronic ulcers of different etiology.[12] Accordingly, systemic antibiotic therapies are not required in chronic ulcers in the absence of clinically manifest wound infection. Chronic wounds are, however, colonized by bacterial pathogens known to form biofilms.[13] Although *Staphylococcus aureus* is the most common pathogen found in chronic venous leg ulcer, the pathogen spectrum of chronic wounds has changed in recent years towards gram-negative pathogens.[14] In individual cases, it is, however, very difficult to distinguish between mere colonization and a causative infectious agent by microbiological analysis when detecting certain bacteria. According to current knowledge, *Staphylococcus aureus* will generally remain the primarily responsible pathogen of wound infections, irrespective of the isolation of other, for example gram-negative, bacteria from the wound swab.[15]

In general, causal treatment is recommended for chronic ulcers.[10] Skin surgery is, therefore, always used as supplemental therapy. Surgical wound cleansing (surgical debridement) is the most important surgical method for adjuvant therapy of venous leg ulcer. It is also incorporated in the AWMF guidelines on local therapy of chronic wounds.[16]

Surgical debridement is the radical removal of non-vital tissue together with biofilm, coatings, and necroses from a wound down to vital tissue. Depending on surface, depth, and condition, various instruments including a sharp spoon, ring curette, sterile brush, scalpel, scissors, and dermatome may be used.[16,17] Subsequent to surgical removal of the avital tissue colonized by bacteria, the development of transient bacteremia is possible.[18] For this reason, PAP is indicated in patients at increased risk of bacterial endocarditis (see section "Endocarditis prophylaxis") or hematogenous joint prosthesis infection (see section "Prophylaxis of hematogenous joint prosthesis infection"). In the absence of these risk factors, there is currently no evidence for PAP in surgical debridement of chronic wounds with or without subsequent use of negative-pressure therapy (vacuum pumps).

Another dermatosurgical procedure is closure of chronic wounds by split-skin grafting (for example, mesh graft).[17,19] For healing and integration of the graft, the quality of the wound bed is just as important as it is for wound defect closure by skin grafts after tumor surgery. For this reason, extensive surgical debridement or fasciectomy is recommended for preparing the wound bed.[19,20]

Although wound defect coverage in venous leg ulcers by split-skin grafting (especially mesh graft with subsequent vacuum therapy) is an established procedure, current literature (both reviews and clinical studies) provides no information on whether PAP should be performed before the intervention.[21] It is, however, assumed that bacterial colonization or infection of the wound contributes to impaired graft integration.[22] In a retrospective work, an SSI rate of 16% was demonstrated after full-thickness skin grafting on the lower leg, which could be reduced to 2% by PAP with flucloxacillin 250 mg or 500 mg once daily for 7 days.[23] However, this study assessed defect closure after excision of skin tumors, not closure of chronic leg ulcers. To the authors' knowledge, there is no scientific evidence that single administration of an antibiotic improves graft integration in venous leg ulcer surgery or reduces the rate of surgical site infections. In most large studies, antibiotic administration in skin grafting after ulcer coverage was performed for one week, which corresponds to "preventive therapy" and not to PAP. However, such a "preventive therapy" is now viewed critically due to the resulting selection for resistance as well as effects on the (skin) microbiome.

With rigorous mechanical cleansing and disinfection of the wound prior to split-skin grafting, there is no need for PAP to reduce bacterial pathogens. This was also confirmed in a recently published prospective study. Surgical debridement alone, without the use of antiseptic agents, can already ensure a reduction of bacterial colonization in the wound bed by more than 99%.[24] According to currently available information, the only indications requiring PAP prior to skin grafting in chronic ulcers are prophylaxis of bacterial endocarditis or hematogenous joint prosthesis infections (Table 1). For clinically infected wounds, therapy of the infection prior to scheduled skin grafting is recommended instead of surgery with PAP. However, for split-skin graft coverage in cases of venous leg ulcers, the localization-related risk factor of the lower extremity should be noted. Accordingly, PAP may be considered in the presence of other relevant procedure-related risk factors (Figure 1).

Septic skin surgery

Septic skin surgery deals with the surgical treatment of infections of the skin and soft tissue, including, for example, abscess incision or excision. In addition, surgical debridement may be required in the context of an acute infection. One example is the removal of necroses in complicated necrotizing erysipelas. Surgical treatment of hidradenitis suppurativa can also be assumed as a septic procedure, as the inflammatory lesions in this chronic inflammatory disease are usually colonized by multiple bacterial pathogens.[25,26]

In septic procedures, endocarditis prophylaxis is generally recommended for patients at risk for bacterial endocarditis (see section "Endocarditis prophylaxis"), while PAP is recommended for the corresponding population at risk to prevent hematogenous joint prosthesis infections (see section "Prophylaxis of hematogenous joint prosthesis infections").

There is no evidence to support the general use of PAP for abscess incision in uncomplicated infections. An abscess with accompanying phlegmon or lesions in visible or functionally important areas (like face and hands) must be treated with systemic antibiotics.[27,28] However, this is not PAP but the actual treatment of the infection.

Similarly, during surgical debridement in the context of erysipelas or other complicated skin or soft tissue infections, treatment primarily involves the required antibiotic therapy of the acute infection, but not PAP.[27]

There is also no evidence that PAP improves the therapeutic success of surgical treatment of hidradenitis suppurativa. Guideline-based oral antibiotic therapy with a combination of clindamycin and rifampicin may be initiated (several weeks) prior to excision of the affected areas. This is used to stabilize the clinical finding, but is not a PAP.[29,30]

To conclude, for skin surgery in the context of infections (septic skin surgery), PAP is indicated only in individual cases for prophylaxis of endocarditis or hematogenous joint prosthesis infection. An antibiotic therapy that is performed during the infection is not a PAP but the actual therapy of the disease. Based on current knowledge, PAP is not necessary if antibiotic therapy of the disease is not required and there is no increased risk of bacterial endocarditis or hematogenous infection of the joint prosthesis.

Use of wound drainage

Wound drainage is used in all surgical fields to remove blood and wound secretions from the wound cavity. It is hoped that this reduces hematoma formation and the associated risk of wound infections, as well as improve wound healing. There is little evidence for indications concerning the use of drainages in dermatology. A survey performed among members of the German Society for Dermatologic Surgery several years ago showed that wound drainages are used predominantly in deep and complex dermatologic surgeries.[31] These include large advancement flaps and rotation flaps, excisions of sentinel lymph nodes, as well as excisions of subcutaneous processes or larger lipomas. Drainages may also be applied in cases of excessive intraoperative bleeding. Another indication reported for the use of wound drainages is curettage of sweat glands (for hyperhidrosis surgery). In this survey, approximately 10% of the respondents reported wound infections as drainage-associated complications. The frequency of wound infections could not be derived from the survey.[31] Although wound drainages represent foreign objects and are therefore generally considered as risk factors for SSIs, especially the quality of the drainage system, the position of the penetration site, and the duration of placement influence the development of SSIs.[32] Accordingly, the Commission for Hospital Hygiene and Infection Prevention at the Robert Koch Institute recommends avoiding open drainages, and that drainages should be placed using a separate incision rather than the surgical wound.[32] Since 89.8% of all respondents of the above-mentioned survey use redon drainages, which belong to the conditionally closed systems, and usually remove them after 1–3 days,[31] the risk of SSIs associated with wound drainages in skin surgery is considered to be relatively low. Furthermore, data from 495 patients receiving wound drainage in the context of skin surgery were evaluated in a retrospective study. The complication rates of surgical interventions with or without drainage did not differ significantly ($p = 0.118$).[33] Therefore, the mere application of wound drainage during skin surgery does not justify PAP. Rather, factors decisive for the use of drainage, such as size and depth of the surgical site or the complexity of wound closure, may already contribute to the risk of developing wound infarction. These factors have been addressed in Part 1 of this position paper.

Exposed bones and periosteum

Dermatologic surgeries are usually performed on skin and subcutaneous tissue. Exceptions are scalp and distal phalanges of toes and fingers, given that these are often affected by multi-layer defects reaching beyond the soft tissue coverage.[34] The complication feared in these wound defects is necrosis due to dehydration of the bone rather than SSI.[30] Currently, there is no evidence that wound defects with exposed bones closed by simple wound closure or flap have a higher risk of wound infection than those without exposed bones. Several types of wound closure are available for particularly large surgical wounds with exposed bones. In case of stage-adapted wound care, successful secondary wound healing without increased risk of SSI is described in 90% of cases.[35] This may, however, take several months. Another possibility is the application of dermal substitutes to prepare the wound bed prior to skin grafting and to protect the bone against dehydration. Here, SSI is a relevant risk factor for the loss of transplant.[36] In a retrospective work with 68 wound defects, however, this approach had an SSI rate of only 4%.[37] In summary, it remains unclear whether exposed bone contributes to the risk of SSI. Rather, wound size and type of wound closure are relevant factors (see chapter "Procedure-related risk factors" in Part 1). The mere presence of exposed periosteum or exposed bones should, therefore, present no indication for PAP.

Secondary wound healing

Secondary wound healing allows for defect healing after surgical removal of malignant or benign skin lesions in skin surgery and may be used as an alternative to other wound closure techniques in suitable cases.[38–41] A survey among members of the American College of Mohs Surgery conducted in 2015 showed that secondary wound healing following microscopically controlled skin surgery is widely used with good results.[38] Both superficial wound defects and deep wounds after skin surgery are left open for secondary wound healing. This procedure is primarily used for relatively small wound defects (< 2 cm) on concave localizations (temple, inner canthus, nasolabial area). In addition, secondary wound healing is commonly used after wound dehiscence or flap necrosis. For large wound defects or in elderly patients where elaborate procedures may be associated with risk of complications, or in very aggressive tumors prone to recurrence, secondary wound healing presents an option provided that rigorous wound care is ensured.[42]

Overall, complication rates in secondary wound healing are low in case of good postoperative wound care. SSI is rarely observed in secondary wound healing. In recent studies, SSI rates of up to 6.8% are described, with SSIs occurring more often on the lower extremities than on other localizations.[43–47]

Given that the skin barrier is absent, it can be assumed that any wound undergoing secondary healing is colonized by bacteria of the resident skin flora.[48,49] Nevertheless, these wounds do not require antibiotic prophylaxis or therapy if there are no signs of infection.[43–47] Routine topical application of ointments containing antibiotics should also be avoided because of the potential of sensitization in the absence of a skin barrier and the unknown concentration of

TABLE 4 Recommendations for perioperative antibiotic prophylaxis to prevent postoperative wound infections.

Situation	Recommended substances (as single dose 30–60 minutes before surgery)	
	Administration i.v.	***Administration p.o.***
No allergy to penicillin or ampicillin	Ampicillin 2 g Cefazolin 2 g	Amoxicillin 2 g Cefalexin 2 g
Known allergy to penicillin or ampicillin	Clindamycin 600 mg Cefazolin* 2 g p.o. or i.v.	Clindamycin 600 mg Cefazolin* 2 g p.o. or i.v.
In case of known MRSA colonization	For hospital acquired MRSA, vancomycin 1 g, eventually also in combination with another effective substance	Consultation with microbiology/infectiology is recommended. For community acquired MRSA, combination of cotrimoxazole 960 mg is often possible, eventually also in combination with another effective substance

*Use as an alternative after benign rashes due to penicillin, aminopenicillins (ampicillin, amoxicillin), or 1st generation cephalosporins (such as cefaclor, cefalexin, or cefadroxil) in the medical history is possible.

antibiotic in the wound, which would result in questionable effects.[50,51] Overall, there is insufficient evidence to support a benefit of perioperative antibiotic prophylaxis (PAP) and especially of topical application of antibiotics on dermatosurgical wounds undergoing secondary healing.[52,53] Similar to chronic wounds, surgical wounds should be treated in a stage-adapted manner dependent on their depth. The frequency of dressing change is dependent on wound secretion. In case of clinical signs of wound infection, initiation of an appropriate therapy is required.

The literature search revealed no scientific entries analyzing the course of secondary wound healing after skin surgery in patients at increased risk of bacterial endocarditis or hematogenous joint prosthesis infection. However, it has been reported that chronic wounds colonized by bacteria may cause bacteremia.[49] Therefore, it cannot be excluded that wounds colonized by bacteria that undergo secondary healing after skin surgery present a risk factor for bacterial endocarditis or hematogenous joint prosthesis infection in susceptible patients. In this patient collective, secondary wound healing after skin surgery should therefore only be considered after risk assessment, and efforts should be made to achieve a rapid closure of the wound defect, if possible. For these wounds, no recommendation is made concerning the (routine) use of antibiotic prophylaxis, if procedures, such as joint prosthesis surgeries, are performed in a timely manner.

SELECTION OF SUITABLE ANTIMICOBIAL SUBSTANCES

If PAP is indicated, the question of suitable antimicrobial substances arises. Suitable antibiotics for PAP for prophylaxis of bacterial endocarditis and prevention of hematogenous infection of joint prostheses in patients at risk are presented in Tables 1 and 2.

Given that the pathogens responsible for SSIs are predominantly gram-positive (especially *Staphylococcus aureus*, beta-hemolytic streptococci),[53] antibiotics with appropriate efficacy should be chosen for SSI prophylaxis. Betalactam antibiotics such as amoxicillin 2 g p.o. are suitable for this purpose. Cefalexin 2 g is a potential oral alternative. If intravenous administration of PAP is preferred, cefazolin 2 g, a first-generation cephalosporin, may be used.[2] Cefuroxime (1.5 g), a second-generation cephalosporin, may be administered intravenously as an alternative. Its oral use for PAP is, however, not recommended because of the poor bioavailability.[54] In case of known penicillin allergy, switching to clindamycin 600 mg is possible. Given that PAP based on clindamycin is less effective than PAP with one of the substances mentioned above and that clindamycin has a more negative side effect profile, it should be discussed and checked with the patients whether they indeed suffer from a "true" penicillin allergy. In the case of mild benign drug reactions in the medical history (drug eruption) after use of penicillin, aminopenicillins (ampicillin, amoxicillin), or amino-cephalosporins (first-generation cephalosporins, such as cefaclor, cefalexin, cefadroxil), perioperative antibiotic prophylaxis may be performed with 2 g cefazolin (orally or intravenously) as an alternative.[55] Since hypersensitivity reactions to beta-lactam antibiotics recorded in the medical history can be confirmed in only 2%–7% of cases by targeted allergologic history and diagnosis in adults, an allergologic diagnosis including drug provocation testing of potential alternative substances, if necessary, should be recommended and offered to all patients with allergic reactions (including immediate-type hypersensitivity) after use of betalactam antibiotics.[55] This is also in line with current efforts to resolve erroneously suspected penicillin allergies by *delabeling*.[56]

The selection of PAP in case of colonization with methicillin-resistant *Staphylococcus aureus* (MRSA) should be made after antibiotic sensitivity testing or after consultation with the microbiology/infectiology department, given that the local epidemiology and resistance situation may vary considerably. For community-acquired MRSA (CA-MRSA) strains susceptible to cotrimoxazole, use of cot-

rimoxazole 960 mg is recommended, in combination therapy, if necessary.[2] For colonization with a hospital-acquired MRSA (HA-MRSA) strain, administration of vancomycin 1 g i.v. in addition to cefazolin or clindamycin is recommended (Table 4). For elective surgeries in presence of confirmed MRSA colonization, however, efforts should be made to achieve bacterial decolonization prior to surgery. The current US-American recommendations prefer oral administration of PAP 30–60 minutes before surgery; intravenous administration is also possible, if oral intake is not feasible (for example, in case of dysphagia).[2] Given that no comparative studies on this topic exist, the authors agree with this recommendation.

CONCLUSION

In the second part of the position paper, specific indications for PAP and the use of PAP in special situations are addressed. In patients at increased risk of bacterial endocarditis, PAP should be performed in all two-stage surgeries. Moreover, these patients should receive PAP while ulcer surgery, interventions on ulcerates tumors, septic interventions, or surgeries involving mucosa.

Another indication for PAP is prevention of hematogenous joint prosthesis infection. Based on currently available evidence, it appears reasonable to perform PAP in patients who are at increased risk of hematogenous joint prosthesis infection due to additional factors while two-stage surgeries with delayed wound closure, ulcer surgery, ulcerated tumors, septic interventions, and surgeries involving mucosa.

PAP is not required for ulcer surgery, secondary wound healing, septic interventions, use of drainages, or surgery on exposed periosteum or bone in abcence of the relevant risk factors. Patient- and/or procedure-related risk factors should be included in the decision regarding the use of PAP (Figure 1).

ACKNOWLEDGEMENTS

Open access funding enabled and organized by Projekt DEAL.

CONFLICT OF INTEREST

None.

REFERENCES

1. Löser CR, Becker SL, Hartmann D, et al. Perioperative antibiotic prophylaxis in skin surgery – Position paper of the Antibiotic Stewardship working group of the German Society for Dermatologic Surgery (DGDC), Part 1: Procedure- and patient-related risk factors. *J Dtsch Dermatol Ges*. 2023;21(9):949-956.
2. Wright TI, Baddour LM, Berbari EF, et al. Antibiotic prophylaxis in dermatologic surgery: advisory statement 2008. *J Am Acad Dermatol*. 2008;59(3):464-473.
3. Anmeldung: S3-Leitlinie Perioperative und Periinterventionelle Antibiotikaprophylaxe. Available from: https://www.awmf.org/leitlinien/detail/anmeldung/1/ll/067-009.html [Last accessed March 23, 2023].
4. Habib G, Lancellotti P, Antunes MJ, et al. 2015 ESC Guidelines for the management of infective endocarditis: The Task Force for the Management of Infective Endocarditis of the European Society of Cardiology (ESC). Endorsed by: European Association for Cardio-Thoracic Surgery (EACTS), the European Association of Nuclear Medicine (EANM). *Eur Heart J*. 2015;36(44):3075-3128.
5. American Dental Association – Appointed Members of the Expert Writing and Voting Panels Contributing to the Development of American Academy of Orthopedic Surgeons Appropriate Use Criteria. American Dental Association guidance for utilizing appropriate use criteria in the management of the care of patients with orthopedic implants undergoing dental procedures. *J Am Dent Assoc*. 2017;148(2):57-59.
6. Antibiotikaprophylaxe bei zahnmedizinischen Eingriffen – ein Update –23.01.2022 Empfehlung der AE – Deutschen Gesellschaft für Endoprothetik. Available from: https://www.ae-germany.com/images/ae/oeffentlich/pdf-handlungsanweisungen/Handlungsempfehlung_AB_Prophylaxe_Update_Januar_2022.pdf [Last accessed December 6, 2022].
7. Rakow A, Perka C, Trampuz A, Renz N. Origin and characteristics of haematogenous periprosthetic joint infection. *Clin Microbiol Infect*. 2019;25(7):845-850.
8. Renz N, Trampuz A, Perka C, Rakow A. Outcome and failure analysis of 132 episodes of hematogenous periprosthetic joint infections: A cohort study. *Open Forum Infect Dis*. 2022;9(4):ofac094.
9. Jockenhöfer F, Gollnick H, Herberger K, et al. Aetiology, comorbidities and cofactors of chronic leg ulcers: retrospective evaluation of 1000 patients from 10 specialised dermatological wound care centers in Germany. *Int Wound J*. 2016;13(5):821-828.
10. Dissemond J. Chronic leg ulcers. *Hautarzt*. 2017;68(8):614-620.
11. O'Meara S, Al-Kurdi D, Ologun Y, et al. Antibiotics and antiseptics for venous leg ulcers. *Cochrane Database Syst Rev*. 2014;(1):CD003557.
12. Norman G, Dumville JC, Moore ZE, et al. Antibiotics and antiseptics for pressure ulcers. *Cochrane Database Syst Rev*. 2016;4(4):CD011586.
13. Attinger C, Wolcott R. Clinically addressing biofilm in chronic wounds. *Adv Wound Care*. 2012;1(3):127-132.
14. Jockenhöfer F, Chapot V, Stoffels-Weindorf M, et al. Bacterial spectrum colonizing chronic leg ulcers: a 10-year comparison from a German wound care center. *J Dtsch Dermatol Ges*. 2014;12(12):1121-1127.
15. Sunderkötter C, Becker K. Frequent bacterial skin and soft tissue infections: diagnostic signs and treatment. *J Dtsch Dermatol Ges*. 2015;13(6):501-524.
16. AWMF-Leitlinie "Lokaltherapie chronischer Wunden bei Patienten mit den Risiken periphere arterielle Verschlusskrankheit, Diabetes mellitus, chronisch venöse Insuffizienz" Available from: https://www.awmf.org/uploads/tx_szleitlinien/091-001l_S3_Lokaltherapie_chronischer_Wunden_2012-ungueltig.pdf [Last accessed December 6, 2022].
17. Stoffels I, Alt C, Bekeschus S, Klode J. Modern ulcer surgery: Invasive treatment options using the example of therapy-resistant venous leg ulcers. *Hautarzt*. 2020;71(11):843-849.
18. Mozingo D, McManus A, Kim S, Pruitt S Jr. Incidence of bacteraemia after wound manipulation in the early post-burn period. *J Trauma*. 1997;42:1006-1011.
19. Schmeller W, Gaber Y. Surgical removal of ulcer and lipodermatosclerosis followed by split-skin grafting (shave therapy) yields good long-term results in "non-healing" venous leg ulcers. *Acta Derm Venereol*. 2000;80(4):267-271.
20. Serra R, Rizzuto A, Rossi A, et al. Skin grafting for the treatment of chronic leg ulcers – a systematic review in evidence-based medicine. *Int Wound J*. 2017;14(1):149-157.
21. Yin Y, Zhang R, Li S, et al. Negative-pressure therapy versus conventional therapy on split-thickness skin graft: a systematic review and meta-analysis. *Int J Surg*. 2018;50:43-48.

22. Drerup C, Schlarb D. Surgical treatment for chronic leg ulcer. *Hautarzt*. 2020;71(9):715-723.
23. Audrain H, Bray A, De Berker D. Full-thickness skin grafts for lower leg defects: An effective repair option. *Dermatol Surg*. 2015;41(4): 493-498.
24. Moelleken M, Jockenhöfer F, Benson S, Dissemond J. Prospective clinical study on the efficacy of bacterial removal with mechanical debridement in and around chronic leg ulcers assessed with fluorescence imaging. *Int Wound J*. 2020;17(4):1011-1018.
25. Ring HC, Riis Mikkelsen P, Miller IM, et al. The bacteriology of hidradenitis suppurativa: a systematic review. *Exp Dermatol*. 2015;24(10):727-731.
26. Ring HC, Thorsen J, Saunte DM, et al. The follicular skin microbiome in patients with hidradenitis suppurativa and healthy controls. *JAMA Dermatol*. 2017;153(9):897-905.
27. Sunderkötter C, Becker K, Eckmann C, et al. S2k guidelines for skin and soft tissue infections Excerpts from the S2k guidelines for "calculated initial parenteral treatment of bacterial infections in adults – update 2018". *J Dtsch Dermatol Ges*. 2019;17(3):345-369.
28. Daum RS, Miller LG, Immergluck L, et al. A placebo-controlled trial of antibiotics for smaller skin abscesses. *N Engl J Med*. 2017;376(26):2545-2555.
29. Zouboulis CC, Desai N, Emtestam L, et al. European S1 guideline for the treatment of hidradenitis suppurativa/acne inversa. *J Eur Acad Dermatol Venereol*. 2015;29(4):619-644.
30. Pinter A, Mrowietz U, Volz T. Systemic treatment of moderate/severe hidradenitis suppurativa. *Hautarzt*. 2021;72(8):686-691.
31. Ruers SS, Wagenpfeil S, Gauglitz G, et al. Persönliche Präferenz, Erfahrung, Intuition und operative Schule dominieren die Verwendung postoperativer Wunddrainagen in der Dermatochirurgie. *Hautarzt*. 2021;72(2):115-124.
32. Prevention of postoperative surgical wound infection: recommendations of the hospital hygiene and infection prevention committee of the Robert Koch institute. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz*. 2007;50(3):377-393.
33. Simgen J, Gräber S, Vogt T, Müller CSL. Retrospektive 4-Jahres-Analyse geschlossener Drainagesysteme an einem dermatochirurgischen Zentrum - Notwendigkeit einer individualisierten Anwendung. *Akt Dermatol*. 2019;45:386-397.
34. Koenen W, Kunte C. Dermatologic surgery on the scalp. *Hautarzt*. 2014;65(12):1037-1042.
35. Wong N, Zloty D. Secondary intention healing over exposed bone on the scalp, forehead, and temple following Mohs micrographic surgery. *J Cutan Med Surg*. 2022;26(3):274-279.
36. Othman S, Lukowiak T, Shakir S, et al. Bilayer wound matrix-based cutaneous scalp reconstruction: A multidisciplinary case control analysis of factors associated with reconstructive success and failure. *J Plast Reconstr Aesthet Surg*. 2021;74(11):3008-3014.
37. Benecke J, Koenen W, Mager L, et al. Reconstruction of full thickness defects on the scalp with artificial dermal regeneration template: Analysis of long-term results in 68 cases. *Dermatol Surg*. 2021;47(1):e1-e4.
38. Schwartzman G, Cartron AM, Khachemoune A. Review and reappraisal of assessment parameters of second intention healing after Mohs micrographic surgery. *Arch Dermatol Res*. 2022;314(1):17-23.
39. Liu KY, Silvestri B, Marquez J, Huston TL. Secondary intention healing after Mohs surgical excision as an alternative to surgical repair: Evaluation of wound characteristics and esthetic outcomes. *Ann Plast Surg*. 2020;85(1):28-32.
40. Lam TK, Lowe C, Johnson R, Marquart JD. Secondary intention healing and purse-string closures. *Dermatol Surg*. 2015;41(10):178-186.
41. Moreno-Arias GA, Izento-Menezes CM, Carrasco MA, Camps-Fresneda A. Second intention healing after Mohs micrographic surgery. *J Eur Acad Dermatol Venereol*. 2000;14(3):159-165.
42. Vedvyas C, Cummings PL, Geronemus RG, Brauer JA. Broader practice indications for mohs surgical defect healing by secondary intention: a survey study. *Dermatol Surg*. 2017;43(3):415-423.
43. Ruiz-Salas V, Sanmartin-Jiménez O, Garcés JR, et al. Complications associated with Mohs micrographic surgery: Data from the nationwide prospective cohort REGESMOHS. *Dermatology*. 2022;238(2):320-328.
44. Schimmel J, Belcher M, Vieira C, et al. Incidence of surgical site infections in second intention healing after dermatologic surgery. *Dermatol Surg*. 2020;46(12):1492-1497.
45. Molina GE, Yu SH, Neel VA. Observations regarding infection risk in lower-extremity wound healing by second intention. *Dermatol Surg*. 2020;46(10):1342-1344.
46. Hochwalt PC, Christensen KN, Cantwell SR, et al. Comparison of full-thickness skin grafts versus second-intention healing for Mohs defects of the helix. *Dermatol Surg*. 2015;41(1):69-77.
47. Gloster Jr HM. The use of second-intention healing for partial-thickness Mohs defects involving the vermilion and/or mucosal surfaces of the lip. *J Am Acad Dermatol*. 2002;47(6):893-897.
48. Natarajan S, Williamson D, Stiltz AJ, Harding K. Advances in wound care and healing technology. *Am J Clin Dermatol*. 2000;1(5):269-275.
49. Braga IA, Pirett CCNS, Ribas RM, et al. Bacterial colonization of pressure ulcers: assessment of risk for bloodstream infection and impact on patient outcomes. *J Hosp Infect*. 2013;83(4):314-320.
50. Gilissen L, Goossens A. Frequency and trends of contact allergy to and iatrogenic contact dermatitis caused by topical drugs over a 25-year period. *Contact Dermatitis*. 2016;75(5):290-302.
51. Dixon AJ, Dixon MP, Dixon JB. Randomized clinical trial of the effect of applying ointment to surgical wounds before occlusive dressing. *Br J Surg*. 2006;93(8):937-943.
52. Norman G, Dumville JC, Mohapatra DP, et al. Antibiotics and antiseptics for surgical wounds healing by secondary intention. *Cochrane Database Syst Rev*. 2016;3(3):CD011712.
53. Saleh K, Schmidtchen A. Surgical site infections in dermatologic surgery: etiology, pathogenesis, and current preventative measures. *Dermatol Surg*. 2015;41(5):537-549.
54. Gatermann S, Kresken M, Kern WV. Antibiotika-Empfindlichkeit: Grenzwerte sind hilfreich. *Dtsch Arztebl*. 2017;114(26):A-1314/B-1094/C-1072.
55. Wurpts G, Aberer W, Dickel H, et al. S2k Guideline: Diagnostics for suspected hypersensitivity to beta-lactam antibiotics. Guideline of the German Society for Allergology and Clinical Immunology (DGAKI) in collaboration with the Medical Association of German Allergologists (AeDA), German Society for Pediatric Allergology and Environmental Medicine (GPA), the Austrian Society for Allergology and Immunology (ÖGAI), and the Paul-Ehrlich Society for Chemotherapy (PEG). *Allergo J Int*. 2019;28:121-151.
56. Klimek L, Merk HF, Dickel H, Brockow K. Vermutete Penicillinallergie: De-Labeling als wichtige Aufgabe für das Antibiotika-Stewardship. *Dtsch Arztebl*. 2022;119(19):A-868/B-717.

How to cite this article: Balakirski G, Becker SL, Hartmann D, et al. Perioperative antibiotic prophylaxis in skin surgery – Position paper of the Antibiotic Stewardship working group of the German Society for Dermatologic Surgery (DGDC), Part 2: Special indications and situations. *JDDG: Journal der Deutschen Dermatologischen Gesellschaft*. 2023;21:1109–1117.
https://doi.org/10.1111/ddg.15153