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Consensus on the treatment of second-degree burn wounds (2024 edition)

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Abstract

Second-degree burns are the most common type of burn in clinical practice and hard to manage. Their treatment requires not only a consideration of the different outcomes that may arise from the dressing changes or surgical therapies themselves but also an evaluation of factors such as the burn site, patient age and burn area. Meanwhile, special attention should be given to the fact that there is no unified standard or specification for the diagnosis, classification, surgical procedure, and infection diagnosis and grading of second-degree burn wounds. This not only poses great challenges to the formulation of clinical treatment plans but also significantly affects the consistency of clinical studies. Moreover, currently, there are relatively few guidelines or expert consensus for the management of second-degree burn wounds, and no comprehensive and systematic guidelines or specifications for the treatment of second-degree burns have been formed. Therefore, we developed the Consensus on the Treatment of Second-Degree Burn Wounds (2024 edition), based on evidence-based medicine and expert opinion. This consensus provides specific recommendations on prehospital first aid, nonsurgical treatment, surgical treatment and infection treatment for second-degree burns. The current consensus generated a total of 58 recommendations, aiming to form a standardized clinical treatment plan.

Key words: Burns, First aid, Infection, Wound management, Consensus, Surgical procedures, Operative, Debridement

Highlights

- This was the first clinical consensus on the treatment of second-degree burn wounds at home and abroad, covering the following four aspects: pre-hospital first aid treatment,non-surgical treatment, surgical treatment, and infection treatment of burn wounds. It aimed to form a standardized treatment plan for second-degree burns.
- This consensus clarified and standardized the terminology related to second-degree burn wounds, including for the first time further dividing deep second-degree burn wounds into shallow deep second-degree and profound deep second-degree burn wounds, which provided a decision-making basis for standardizing the relevant diagnosis, classification, and treatment of second-degree burn wounds.
- Based on the evidence-based medicine evidence, comprehensive consideration of the operative feasibility of the clinical practice, and the economic level of different geographic regions and cultural factors, a set of operable clinical practice guideline of second-degree burn wounds was formed.

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Background

Burns are the fourth leading cause of injury worldwide, following car accidents, falls and interpersonal violence [1]. In clinical practice, the most common type of burn is a second-degree burn. Our initial data indicated that second-degree burns account for 85.4% of all burn cases, of which 56.3% are burns of less than 10% of the total body surface area (TBSA) [2]. Second-degree burn wounds often exhibit dynamic changes in the early postburn period, which is not only determined by their pathophysiological characteristics but is also closely related to wound intervention and other factors. Timely and reasonable prehospital first aid and appropriate wound treatment after admission are essential in preventing wound deepening. However, many variations still exist in the treatment of deep second-degree burn wounds, including the manner of conservative dressing change, choice of external dressings or medications, and indication and timing of surgery, which requires not only consideration of the different outcomes that may arise from the dressing changes or surgical treatments themselves but also an evaluation of factors such as burn site, patient age and burn area.

Therefore, we aimed to develop clinical consensus for the treatment of small- to medium-sized burn wounds caused by thermal factors, combining evidence from evidence-based medicine and expert opinions to establish standardized clinical treatment plans and provide reference opinions for health care professionals involved in burn care. This consensus develops a set of operational clinical practice guidelines in four areas: pre-hospital first aid, non-surgical treatment, surgical treatment, and infection treatment. Notably, to further standardize clinical terminology and develop treatment plans, we have further graded deep second-degree burn wounds into shallow deep second-degree and profound deep second-degree burn wounds in the process of guideline formulation for the first time. In addition, we have established grading and diagnostic criteria for burn wound infection, classifying the severity of wound infection as mild, moderate or severe based on the local and systemic clinical manifestations of the burn wound or the invasion of tissue, developed a treatment protocol for second-degree burn wounds. Finally, we have integrated the content of the four sections and developed a treatment protocol for second-degree burn wounds. This provides a basis for decision-making with strong operability and practicability for standardizing the diagnosis, classification and treatment of second-degree burn wounds Figure 1.

Methods

Consensus working group

The Consensus Working Group consists of relevant experts of burns surgery, plastic surgery, wound repair, statistics, and epidemiology. Moreover, the Consensus Working Group consists of Cochair, Expert Committee Group, Methodology Expert Group, Clinical Problem Solicitation Expert Group, and Writing Group. The Writing Group was divided into four subgroups, who were responsible for compiling the contents on first aid, nonsurgical treatment, surgical treatment, and wound infection treatment, respectively.

Development process

The consensus was based on the evidence-based medicine. After 1 round of clinical questioning, 2 rounds of discussion at the expert meeting, and 3 rounds of expert review, the final expert recommendation was obtained.

Identification of clinically relevant questions The Writing Group wrote a proposal based on the results of the clinical question solicitation, and the clinical questions were identified in the form of PICO (P: Patient, I: Intervention, C: Comparison, O: Outcome) after a discussion with experts in the field of burns to formulate the corresponding clinical questions on what needed to be highlighted. All proposed clinical questions were further reviewed and discussed by the Writing Group, and after review and revision, all clinical questions were finalized.

Systematic literature review and level of evidence determination The Medline, Embase, and Cochrane databases were systematically searched with the terms "burns, scald, first aid, infection, surgical, surgery, debridement, skin grafting, dressing, wound, wound management, etc." The search period was from the establishment of the database to December 31, 2022. Systematic reviews, randomized controlled trials, observational studies (cohort studies, case-control studies, cross-sectional studies, case series reports, etc.) and expert opinion were included. Literature other than case series reports and expert opinion was systematically evaluated. The methodological quality (e.g. risk of bias) of the study designs of the included randomized controlled trials was evaluated using the Cochrane Risk of Bias tool, case-control studies and cohort studies using the Newcastle-Ottawa Scale, and cross-sectional studies, case series reports, and expert opinion using the Joanna Briggs Institute criteria. At least 2 members of the Writing Group independently completed the screening and quality assessment of the literature. Two methodologists were responsible for reviewing and evaluating each round of recommendations and their evidence, and then providing feedback to the Writing Group members for further revision. The quality of evidence was formally evaluated using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) system and was classified as high, moderate, or low (including very low) (Table 1) [3]. The quality of evidence can be reduced by the presence of risk of bias, inconsistency of study results, or publication bias, or it can be raised by significant efficacy or the presence of a clear dose–response relationship.

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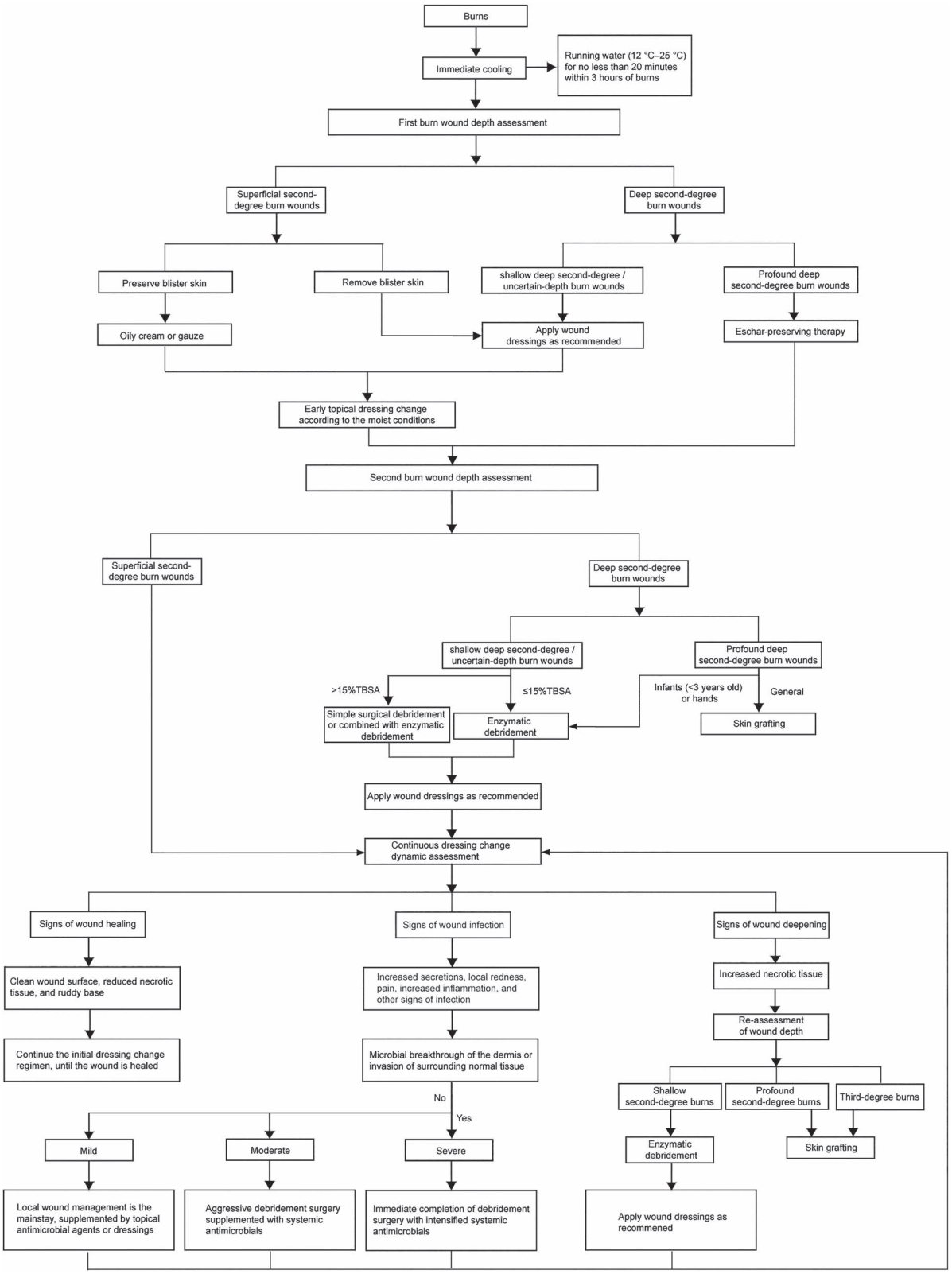

Figure 1. Treatment processs for second-degree burn wounds. *TBSA* total body surface area

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Table 1. Rating of the quality of evidence based on the GRADE system

Quality of evidence	Definition
High quality	Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Downgrading factors: risk of bias, inconsistency of results, publication bias.
Upgrading factors: the presence of a large effect size or evidence of a dose–response relationship.

Formation of Recommendation and Determination of Recommendation Strength The Writing Group initially determined the recommendations for each clinical question, and then all members of the Writing Group reviewed the full text and revised it to form the first draft of the consensus. The Expert Group discussed the draft in the first round of on-site meeting and proposed revisions. Then the Writing Group revised the draft according to the experts' suggestions. The revised consensus draft was submitted to the reviewing experts in the form of an electronic questionnaire, and was reviewed by 22 experts in the first round and 67 experts in the second round. Each recommendation had two options: recommended and not recommended. Each expert could cast one vote for each recommendation and provide additional suggestions for the recommendation. The Writing Group summarized the feedback from the experts and added and modified the recommendations after discussion. Subsequently, the Expert Group conducted the second round of on-site meeting discussion. Finally, the full text was submitted to a total of 89 experts in the first 2 rounds for the third round of review. Then the Writing Group revised the consensus again based on the experts' feedback and determined the strength of the recommendations. A modified consistency algorithm based on the Willy and Stellar method was used to determine the recommendation strength of the recommendations [4], which was classified into strong, moderate and weak recommendations according to the degree of consistency. If a recommendation is recommended by >95% of experts, it is highly recommended; if it is recommended by 75% to 95% of experts, it is a moderately recommended; if it is recommended by ≥50% and <75% of experts, it is a weakly recommended; and recommendations with a degree of consistency of <50% will not be included.

Clinical questions and recommendations

Recommendations for the treatment of prehospital first aid

Clinical question 1: Prehospital first aid for thermal burn wounds

Recommendation 1 (highly recommended). Immediately remove the victim from the heat source as soon as possible, and remove clothing and accessories from the wound surface (evidence level: low).

Rationale. Thermal burns primarily refer to burns caused by flames, hot liquids, etc. Their severity is mainly related to the temperature and the duration of contact between the heat source and the skin. Thus, the primary objective of prehospital first aid after a burn is to stop the injury process, remove the victim from the heat source and transfer them to a safe place as soon as possible while ensuring the safety of the rescue personnel [5]. In a flame-burn environment, flames tend to spread upwards. This poses a risk of flames spreading to the head, face and entire body. Therefore, the victim can adopt the 'stop, drop and roll' method to extinguish the flames on their body and avoid walking or running to prevent the spread of fire. Nearby water bodies such as lakes, running water or other nonflammable liquids can help extinguish the flames on the victim's clothing [6]. In addition, clothing that scorches or retains hot liquids on the skin's surface may act as a potential heat source, causing continuous damage to local tissues and potentially exacerbating tissue damage to the wound. Accessories on distal limbs (e.g. rings and bracelets) not only act as potential heat sources but also pose a risk of tissue ischaemic necrosis when exerting pressure on local soft tissues with oedema [7, 8].

It should be noted that if the victim's clothing has burned or adhered to the skin, it should be temporarily left in place until the arrival of professional medical personnel to avoid improper onsite operations that may lead to bleeding, enlargement and infection of the wound [9]. Furthermore, considering wound heat dissipation, changing into dry clothes or covering the wound with gauze or other coverings is not advisable before sufficient and effective local cooling is achieved. This avoids impeding local heat dissipation and aggravating tissue damage. It should be noted that regardless of whether the onsite rescue personnel are professional firefighters or medical personnel, they must be aware of the risk of being burned by the heat source and thus take self-protection measures as much as possible.

Recommendation 2 (highly recommended). Start cooling as soon as possible after the burn, and it is recommended to start no later than 3 h after the injury, with a cooling duration of no less than 20 min or until the pain in the wound is adequately relieved (evidence level: high).

Rationale. According to Jackson's classical theory, early burn wounds can be divided from the inside out into a

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central necrotic zone, a stasis zone and a peripheral congested oedema zone [10]. Importantly, the development of the zone of stasis is dynamic and reversible, and the tissues in this zone can gradually restore perfusion and turn towards healing if timely and effective intervention is taken. Otherwise, progressive necrosis may occur, deepening the burn wound [11]. Early cooling can lower the temperature of the wound tissue below the injury temperature, thereby stopping ongoing heat damage to the tissues. Furthermore, it can alleviate tissue oedema, reduce inflammatory reactions and improve wound perfusion through pathophysiological mechanisms, effectively inhibiting burn wound progression [12–14]. Several clinical studies have demonstrated that timely, adequate and proper cooling can effectively reduce the local temperature of burn wounds and the severity of burns, thereby reducing the probability of skin grafting, areas requiring skin grafting, patient admission to the ICU and length of hospital stay [15–17]. It should be noted that appropriate measures should be taken to keep the rest of the patient's body warm during cooling to avoid the risk of hypothermia [7].

The starting and duration of cooling are two crucial factors affecting its effectiveness. Theoretically, the earlier cooling is initiated after removal from the heat source, the better the outcome. However, the latest time to start cooling and the duration of its application remain controversial. Recent studies have shown that using running water to cool the wound for at least 20 min within 3 h after the burn significantly reduced the severity of burns and the need for skin grafting, thereby reducing mortality, shortening wound healing time and reducing the length of hospital stay [16, 18, 19]. However, another recently published systematic review reported that cooling for a duration of no less than 20 min did not exhibit significant advantages over cooling for <20 min in terms of burn size, depth, re-epithelialization and skin grafting outcomes [20]. However, this review included four observational studies and superficial second-degree burns with an average surface area of <5% TBSA. It is also important to specifically highlight that there is no evidence to suggest that cold therapy more than 3 h after a burn is non-beneficial in preventing deepening of the wound, and more high-quality RCTs are still needed to further validate this.

In summary, according to the current evidence, clear conclusions regarding the duration of cooling cannot yet be drawn. Based on existing evidence and expert opinions, we recommend starting cooling as soon as possible after the burn, no later than 3 h after the injury, with a duration of no less than 20 min. In addition, considering the analgesic value of cooling for early acute burns, the relief of local pain after stopping cooling can be considered as the duration of cooling in prehospital first aid.

Recommendation 3 (moderately recommended). For the mode and temperature of cooling, the use of running water (12–25°C) appropriate for the patient's body temperature is recommended for wounds (evidence level: moderate).

Rationale. The use of cooling for emergency treatment of burn wounds has a long history, including cold water immersion, irrigation and spraying as well as wet towel application [6]. In theory, any method that can lower the temperature of burn wounds can be used as a form of cooling. However, the treatment effects of other liquids, such as vegetable oil, are unclear, and oily liquids have insulation properties, which may ultimately exert a counterproductive effect. Furthermore, ice cubes, which have a lower temperature, can cause vasoconstriction of the wound blood vessels, leading to ischaemic necrosis, and may also carry the risk of frostbite and hypothermia [21]; thus, they are not recommended for cooling burn wounds. Previous clinical research has reported that continuous irrigation with running water for 20 min results in a more obvious reduction in skin surface temperature and exerts a more certain analgesic effect than tea tree oil and burn cooling spray [22]. Compared with other cooling modalities, cold water irrigation can significantly reduce tissue damage and promote wound healing [23]. At present, evidence regarding the optimal temperature for cooling is insufficient, but existing studies and guidelines suggest controlling the cooling temperature between 12 and 25°C [21, 24–26]. Considering the simplicity, availability and low cost of running water, this consensus recommends using running water (12–25°C) as the first choice for the wound cooling in burn patients. In the absence of a sufficient running water source, distilled water or physiological saline can be used as alternatives.

Recommendation 4 (moderately recommended). In the absence of sufficient running water for cooling, it is recommended that wound cooling measures be taken whenever possible, including wet towel application, cold water spraying and hydrogel dressings with cooling effects (evidence level: moderate).

Rationale. The results of a clinical trial involving healthy volunteers indicated that spraying 1 l of cold water on the skin could achieve similar cooling effects to irrigation with 5 l of cold water, which lowers the risk of hypothermia due to the reduced use of water for cooling [27]. Hydrogel dressings with cooling effects have both cooling and wound-covering functions and can be applied to all body areas. Nearly 80% of fire departments in the UK reportedly use these hydrogel dressing with cold therapy effects as dressings and/or cooling agents [28]. In the UK and Australia, hydrogel dressings have been used as prehospital emergency cooling measures for many years [28–30]. However, there is a lack of supportive evidence from relevant clinical studies on the effectiveness of hydrogel dressings as first aid for burn wounds. The results of a clinical study showed that hydrogel dressings did not provide significant benefits compared with traditional polyvinyl chloride films as adjunctive analgesic treatment for acute paediatric burns [31]. Nevertheless, The 2018 International Society for Burn Injuries (ISBI) *Practice Guidelines for Burn Care* recommend using hydrogel dressings as alternative first aid for burn wounds without running water sources [5]. Considering the dual role of hydrogel dressings with cooling effects in wound cooling and covering, this consensus suggests that they can be

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used as alternative first aid without sufficient running water.

Recommendation 5 (moderately recommended). Considering the specificity of the burn site, it is recommended to use running water irrigation for limb burns, whereas alternate cold compresses with wet towels may be applied to burn sites on the head, face, trunk and groin as appropriate (evidence level: low).

Rationale. Due to the uniqueness of different body parts, running water irrigation should not be used for all burn sites. For limb burns, running water irrigation is simple, easy to operate and has a better overall cooling effect. For burns on the head and face, considering the special nature of facial organs such as the mouth and nose, patients need to maintain breathing and may develop the risk of aspiration and choking cough. In such cases where repeated cooling water irrigation is inconvenient, an alternate cold compress with wet towels to the wound is recommended. Continuous cooling on the trunk, groin and other areas can easily decrease body temperature, particularly as large skin areas are exposed, increasing the risk of hypothermia. In addition, cooling on the anterior chest area may cause complications such as reflex bradycardia and arrhythmia. Thus, considering the overall factors, it is recommended to use water irrigation for limb burns and to exercise caution in cooling for trunk and groin burns. In such cases, the possibility of hypothermia should be assessed, proper insulation measures should be provided and alternate cold compresses with wet towels should be applied to appropriately cool the wound.

Recommendation 6 (moderately recommended). Considering the risk of heat loss and concurrent hypothermia due to extensive wound exposure during cooling, caution should be exercised in patients with large burns, infants and children, elderly and frail individuals, and burn patients with shock and under cold environmental conditions (evidence level: low).

Rationale. Due to damage to the physiological structure and function of the dermis, burn wounds lose their ability to regulate skin temperature. Combined with the uncontrolled heat loss from the exposed wound surface, there is an increased risk of hypothermia in patients, particularly those with extensive burns [32]. Although some studies have demonstrated that cooling is also beneficial for patients with extensive burns [33], it may pose a higher risk of hypothermia and exacerbating shock, considering that these patients often experience hypovolemic shock and extensive wound exposure, as well as uncontrolled heat loss from the wound surface. Furthermore, infants, young children, and elderly and frail patients have weaker heat production and insulation capabilities and poorer temperature regulation abilities, making them more prone to hypothermia with prolonged irrigation or cooling [6]. It has been suggested that cooling should be used with caution in children with extensive burns [34]. Meanwhile, for paediatric patients the total burn area is greater than 10% TBSA, cooling was identified as a risk factor for hypothermia [35]. However, other clinical studies have demonstrated no significant correlation between prehospital cooling and hypothermia [36–38]. Based on the available evidence, the association between TBSA and the risk of hypothermia due to cooling remains unclear. In one study of severe burns, the experts suggested that even in the absence of shock, cooling should not be administered to paediatric patients with the total burn area greater than 10%TBSA and adult patients with the total burn area greater than 20%TBSA [39]. The ISBI *Practice Guidelines for Burn Care*, and other guidelines also suggest cautious cooling for patients with extensive burns, infants and young children, and elderly and frail patients in prehospital first aid [5, 40–42]. In addition, under cold conditions, skin heat loss is accelerated, increasing the risk of hypothermia for patients, cooling for wounds is not advisable.

Recommendation 7 (highly recommended). Based on the protective effect of the blister skin on burn wounds, it is recommended to preserve it as intact as possible during early prehospital first aid (evidence level: low).

Rationale. Blisters are the most common clinical manifestation of second degree burn wounds. In second-degree burns, inflammation occurs due to heat conduction to the dermis, leading to increased vascular permeability and severe tissue exudation. A large amount of exudate accumulates in the gap between the epidermis and the dermis, forming blisters [43]. Whether to remove blister skin has been a disputed focus in clinical practice. Blisters naturally provide a physical barrier that protects the wound and prevents bacterial colonization, thereby reducing the risk of wound infection [44]. They also provide pain relief by covering exposed skin nerves in the wound and provide a moist wound environment, thus potentially playing a role in promoting wound healing and preventing deepening of the wound [45–48]. Furthermore, casual removal of blister skin in prehospital settings may expose the wound bed, increasing the risk of wound infection and damage. Therefore, considering all these factors, this consensus recommends the preservation of blister skin as intact as possible in early prehospital emergency care.

Recommendation 8 (moderately recommended). It is recommended to use sterile or clean nonadherent dressings as temporary dressings to cover and protect the wound surface after cooling (evidence level: low).

Rationale. Second-degree burn wounds are characterized by epidermal loss and partial dermal damage, destroying the skin's physical barrier and physiological structure and leaving the wound completely exposed to external pathogens. This leads to increased loss of body fluids through exudation and increases the risk of infection [49], which, combined with dry skin exposure, also tends to exacerbate tissue damage and leads to further wound deepening. Timely and effective covering with dressings after cooling can provide a temporary skin barrier, reducing the risk of trauma infection and hypothermia and alleviating pain due to nerve exposure. Several relevant guidelines, including the 2018 ISBI *Practice Guidelines for Burn Care* all recommend the use of clean, low-adherent dressings, such as clean cloths, to cover the wound after cooling [41]. Furthermore, nonprofessionals are not

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recommended to perform special wound handling, including the application of cream, butter, milk or toothpaste [14]. Coloured agents such as methyl violet solution should also be avoided on the wound surface to avoid affecting the subsequent wound evaluation after admission.

In light of the limited medical resources available in prehospital first aid, it is recommended to use any clean, low-adherence dressings, fabrics etc. as a temporary wound covering, and the patient should then be promptly transferred to the nearest hospital for further treatment.

Clinical question 2: Prehospital first aid for chemical burn wounds

Chemical burns include burns caused by acids, alkalis and other chemical substance burns. Unlike thermal burns caused by heat sources, the main mechanism of injury in chemical burns is the continuous corrosive effect of substances on the skin or mucous membranes and the thermal damage caused by chemical reactions. Acid burns can cause denaturation of skin tissue proteins and formation of scabs, presenting as coagulative necrosis, which can prevent continued penetration of acid into the skin tissue, and is thus potentially beneficial in stopping further tissue damage. Alkaline chemicals mainly cause denaturation of skin tissue proteins and saponification of lipid membranes, presenting as liquefaction necrosis. This type of necrosis consistently penetrates deep tissues and usually results in more severe damage than acid burns. On the other hand, organic solutions damage the skin by dissolving cellular lipid membranes [50]. Failure to take effective first-aid measures for chemical burns can often result in severe injury. The main factors that determine the severity of the injury are the type, character, concentration and duration of contact between the chemical substance and the skin. Thus, the general principle for prehospital first aid for chemical burns is the prompt removal of contaminated clothing and rinsing with abundant running water. In addition, based on the different properties of chemical substances, the disposal methods for chemical wounds vary and are described in more detail below.

Recommendation 9 (highly recommended). For burn wounds caused by acids, alkalis and other chemicals, it is recommended to immediately remove contaminated clothing, clear the chemical substances from the wound surface and rinse the wound as soon as possible with running water for 30 min to 2 h (evidence level: moderate).

Rationale. The nature, concentration and duration of contact between the chemical substance and the skin are the main factors that determine the severity of chemical burns. Prompt removal or dilution of chemical substances is crucial for the treatment of chemical burns. Thus, in the absence of specific information about the type of chemical substance in prehospital settings, in addition to immediate removal of chemical-contaminated clothing, the chemical substances on the wound surface should also be cleared as soon as possible to prevent further tissue damage. Studies have shown that rinsing with plenty of cold water can dilute and remove residual chemical substances on the skin surface and neutralize the dehydrating effect of chemical substances on tissues [51]. Previous systematic reviews and clinical studies have also demonstrated that early and adequate running water irrigation can effectively reduce the severity of chemical burns and shorten the hospitalization time, thus facilitating early recovery [52–55]. However, there is currently no definite standard for the optimal duration of running water irrigation. Taking into account comprehensive considerations, we recommend continuous running water irrigation for 30 min to 2 h after chemical burns, and the pH from the effluent can be monitored to judge the adequacy of irrigation if conditions permit [56]. In addition, the results of previous clinical studies have indicated that diphoterine, an amphoteric, polyvalent, chelating sterile solution, is more effective for rinsing than cold water after chemical burns [57–59]. However, this study still has limitations, such as poor methodology, small study population and heterogeneity of measurements. Taking into account comprehensive considerations, this consensus suggests that diphoterine can be used as an auxiliary first-aid measure in cases where running water is insufficient in chemical burns.

In addition to conventional chemicals, some chemicals release a large amount of heat when in contact with water or are insoluble in water. In these cases, thorough irrigation of the wound with running water should not be performed until the chemical substances are effectively cleared. Dried alkali deposits should be brushed away first, followed by rinsing with abundant running water. Hydrochloric acid and concentrated sulfuric acid also release a large amount of heat when in contact with water. After removing the remaining acid on the surface using soapy or lime water, the wound should be rinsed with abundant running water. In addition, because phenol is insoluble in water and may be more readily absorbed when diluted in a small amount of water, it should be removed using a sponge soaked in 50% polyethylene glycol or vegetable oil for prehospital first aid; if it cannot be accessed in time before rinsing, dipping a clean cloth to remove the chemical residue can be used as an alternative, followed by immediate rinsing with plenty of running water [60]. When rinsing chemicals from the skin surface, care should be taken to avoid spreading them to adjacent unburned areas, e.g. placing the patient in a bathtub for rinsing or immersion may worsen the injury. Personal protective measures should also be taken, such as wearing gloves, gowns, masks and protective goggles.

Based on the above evidence and considering the inability to clearly determine the specific type of chemical substance or the lack of corresponding emergency testing reagents in prehospital settings, this consensus recommends removing contaminated clothing immediately after chemical burns, wiping or brushing off chemical substances, promptly rinsing the burn wound with running water for 30 min to 2 h, and then immediately transferring the patient to the hospital for further treatment.

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Recommendation 10 (highly recommended). It is not recommended to routinely use neutralizing agents for chemical burn wounds (evidence level: low).

Rationale. Theoretically, neutralizing agents can quickly neutralize chemical substances on the wound surface to reduce tissue damage. However, there is currently no reliable clinical research confirming that the use of neutralizing agents is more effective than cold water irrigation. In addition, most neutralizing agents are toxic and release a large amount of heat during the neutralization reaction, which can further aggravate tissue damage. For example, copper sulfate is a neutralizing agent for phosphoric acid, which can prevent oxidation of phosphorus and phosphoric acid burn and can also blacken its particles, thus facilitating the identification and removal of residual phosphorus particles on the skin. However, a systematic review showed that copper sulfate did not effectively improve tissue damage in burn wounds compared with running water [61], and copper sulfate has systemic toxicity, which may further exacerbate the patient's condition [62]. Thus, it is not recommended to use neutralizing agents as the first choice for first aid in chemical burn wounds [61–64].

It should be noted that the use of neutralizing agents is suitable for professional laboratories and chemical plants where corresponding emergency neutralizing agents and professional personnel are available. Regarding first aid for chemical burn injuries at home, immediately irrigating the burn wound with a large amount of running water and urgently transporting the patient to the hospital for treatment are recommended, considering the generally low concentration of chemical substances as well as the lack of corresponding neutralizing agents and professional personnel.

Recommendation 11 (moderately recommended). Based on the specific mechanism of hydrofluoric acid burns, it is recommended to apply topical, subcutaneous, arterial or intravenous calcium gluconate medication after adequate water rinsing, depending on its concentration, to stop the continued damage of the chemical to the wound tissue (evidence level: low).

Rationale. In addition to its corrosive properties, hydrofluoric acid exhibits metabolic toxicity. It can quickly penetrate the skin, infiltrate deeper tissues and cause liquefaction necrosis of deep tissues and systemic toxic symptoms. In particular, fluoride ions can chelate with positively charged ions, such as calcium and magnesium, leading to systemic hypocalcaemia and hypomagnesemia [65]. The key to its salvage is neutralizing and inhibiting hydrogen ion and fluoride ion uptake [66]. According to *Total Burn Care*, for hydrofluoric acid burns with a concentration less than 20%, thorough irrigation with running water for 30 min should be the preferred prehospital first aid, whereas for hydrofluoric acid burns with a concentration greater than 20%, after rinsing with running water for 30 min as before, the burns were further treated by topical application or subcutaneous, arterial or intravenous injection of glucose [67] to neutralize fluoride ions and prevent further damage [66].

Clinical question 3: Prehospital first aid for electrical burn wounds

Electrical burns primarily include electrical contact burns, arc and flame burns caused by clothing or environmental fires. Electrical contact burns are direct tissue injuries caused by electric current passing through the body, which can cause damage to tissues through various mechanisms, such as electric perforation and electrochemical effects on proteins, cell membranes and other biomolecular structures, as well as tissue damage caused by heat generation [68]. Electrical contact burns are usually more severe and can affect deep tissues, muscles and even bones. Arc burns result from momentary high-temperature electric sparks burning the skin, which is similar to thermal burns. Based on the nature and severity of electrical burns, the management of these wounds also varies. Electrical burns are also the most dangerous among the burns, as the electrical current not only flows through the victim but can also be transmitted to the rescuers who come into contact with the victim, causing severe consequences such as cardiac arrest and respiratory failure. Therefore, before providing first aid for the wound, the safety of both the rescuer and the patient should be the primary concern.

Recommendation 12 (highly reommended). Ensure the safety of rescuers themselves and promptly disconnect the casualty from the power source (evidence level: low).

Rationale. The severity of the injury is determined by the intensity and nature of the current (alternating or direct current), duration of contact with the skin and resistance at the contact point [69]. Therefore, the primary principle of first aid is the prompt disconnection of the casualty from the power source. Considering that the electric current can pass from the casualty to the rescuers, direct contact with the casualty is prohibited. To minimize the continuous harm caused by the power source, prompt disconnection of the casualty from the source should be carried out while ensuring the safety of the rescuers [70]. If the injury is caused by high-voltage electricity, the power source should be turned off before approaching the casualty, emergency medical assistance should be called for immediately and help from professionals should be sought. If the injury is caused by low-voltage electricity, the power can be turned off, or nonconductive objects such as wooden sticks can be used to disconnect the casualty from the power source to prevent continuous harm caused by the electric current [6]. In addition, the burned or smoking clothing and all metal objects (jewelry or equipment) in contact with the skin of the casualty should be immediately removed [5].

Unlike other types of burns, electrical burns are particularly dangerous, as the current can easily pass through the heart, leading to arrhythmia, respiratory problems, cardiac arrest and other serious complications. Thus, after ensuring the safety of the scene, it is important to first assess the victim's consciousness, breathing and circulation. If the victim is unconscious or experiencing respiratory or cardiac arrest, immediate CPR and emergency assistance should be provided. In the case of multiple victims, those with respiratory and cardiac arrest should be prioritized [71]. Notably,

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lightning injuries do not cause the spread of electricity; thus, immediate first aid can be administered. The first-aid measures can be consistent with those for electrocution, including assessment of the level of consciousness and immediate CPR if the injured person is unresponsive [69].

Recommendation 13 (highly recommended). For arc burn wounds or their secondary flame burn wounds, early first aid, the same as for thermal burn wounds described above, is recommended (evidence level: low).

Rationale. Arc burns are caused by the passage of electric current through ionized gases generated by an enormous electric field, which does not require mechanical contact, and the current can be transmitted to the victim only through the air and burns the skin through instantaneous high-temperature electric sparks [70], first-aid measures for thermal burns are typically applicable. In addition, an electrical current can cause clothing or the environment to catch fire, resulting in flame burns, which may be treated similarly to thermal burns.

Recommendation 14 (moderately recommended). For electrical contact burns, routine cooling is not recommended. Instead, the wound should be covered and protected, and the victim should be promptly transported to a hospital for treatment (evidence level: low).

Rationale. Electrical contact burns include low- and high-voltage electrical burns. Low-voltage electrical burns usually occur in household electrical accidents, resulting in localized carbonization and tissue necrosis at the contact point on the skin. High-voltage electrical burns are typically more severe, with a smaller zone of injury on the surface but a larger zone internally, spreading to the deep tissues, blood vessels, muscles and even bones; this makes judgement of the injury severity based on surface damage difficult [72]. Wounds international guidelines for wound care state that electrical burns usually affect deep tissues and should not be washed with cold water [73]. Therefore, considering the available evidence, this consensus does not recommend routine cooling for electrical contact burns. Instead, it recommends covering the wound with sterile gauze, plastic wrap or clean fabric and immediately transporting the victim to a hospital for emergency treatment. In addition, regardless of whether electrical burn patients show obvious symptoms, they should seek urgent medical attention for further examination.

Recommendations for the nonsurgical treatment of second-degree burn wounds

Clinical question 4: Diagnosis and evaluation of second-degree burn wounds

The in-depth diagnosis and area assessment of burn wounds are the cornerstone of clinical treatment decisions. Accurate depth and area diagnosis are crucial for evaluating patient conditions and formulating clinical treatment plans. Currently, second-degree burns are mainly classified into superficial and deep second-degree burns depending on the dermal involvement. This classification is significant in differentiating the pathological levels of burn injuries and guiding clinical treatment. However, the current clinical diagnosis of second-degree burns mainly relies on the physician's subjective evaluation of the local manifestations of the wound, lacking more objective assessment tools. Additionally, for deep second-degree burns, significant differences in their healing potential and scar formation depending on the level of dermal involvement exist, thereby leading to uncertainty in clinical decision-making regarding the choice between conservative dressing changes or surgical treatment. Considering these reasons, this consensus comprehensively considers the diagnosis and assessment methods for second-degree burn wounds and further classifies the depth of deep second-degree burns, aiming to provide better guidance for clinical practice.

Recommendation 15 (moderately recommended). The depth diagnosis of second-degree burn wounds mainly relies on the local clinical manifestations of the wound, and noncontact diagnostic techniques can be used as adjunct diagnostic tools (evidence level: moderate).

Rationale. Currently, the diagnosis of burn depth is primarily based on distinguishing the involvement of different anatomical layers of the skin, and histopathological examination is the gold standard for objective diagnosis. However, histopathological examination requires consecutive skin tissue biopsies, which have drawbacks, including further damage and increased patient pain. Therefore, the current clinical diagnosis of burn depth mainly relies on the local clinical manifestations of the wound [74, 75], including wound appearance, capillary refill, sensitivity to light touch, and needle puncture [76, 77] which is known as clinical evaluation. Therefore, the development of objective diagnostic techniques or tools for the assessment of burn depth has become the main research direction in the field of burns in recent years. Some studies have reported that the accuracy rate is only between 60 and 75% [78]. The development of objective evaluation and diagnostic techniques or tools has become a major research direction. In recent years, various new auxiliary diagnostic techniques, such as laser Doppler imaging (LDI) [79, 80], harmonic ultrasound imaging [81], optical coherence tomography [82] and high-resolution infrared thermography [83], have been successively reported. However, most of them remain at the clinical research stage, and only LDI has been approved by the FDA for clinical practice. LDI has the advantages of being non-invasive and having a fast response, high sensitivity and accuracy in evaluation [84, 85]. However, disadvantages, including being affected by factors such as blistering and infection, and high equipment costs, still exist. Currently, it is used only as an auxiliary technique for burn-depth diagnosis and cannot replace a clinical evaluation.

Recommendation 16 (moderately recommended). Based on the consideration of the involved dermal pathological levels and wound healing time, it is recommended to classify second-degree burn wounds into superficial second-degree burn wounds, shallow deep second-degree burn wounds, profound deep second-degree burn wounds, and those with indeterminate depth as uncertain-depth burn wounds (evidence level: low).

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Table 2. Diagnostic classification of depth of second-degree burn wounds

Burn depth	Damaged tissue level	Wound appearance	Tactile feature	Healing time	Scar
Superficial second-degree burn wounds	Epidermis and upper dermis	Erythema, blisters, moist wound base, exudation.	Significant pain and whitening of the wound base on pressure.	<2 weeks	Generally no scar.
Shallow deep second-degree burn wounds	Epidermis and middle dermis	Deep pink, blisters, wet or dry wound base.	Pain or nociception absent, no whitening of the wound base on pressure.	2–3 weeks	The incidence of scars is about 30%.
Profound deep second-degree burn wounds	Epidermis and deep dermis	Red and white alternating, blisters may be present, and the wound base may be wet or dry.	Pain or pain sensation disappears, and the wound base does not turn white on pressure.	Mostly >3 weeks	The incidence of scars ranges from 70% to 80%.

Rationale. A large number of clinical practices have shown that there are great differences in the incidence of scar after healing of deep second-degree burn wounds. Some deep second-degree burn wounds involve a relatively shallow dermal level and can heal within 14–21 days with a scar formation probability of only 30%. Conversely, other second-degree burn wounds have less residual normal dermis and frequently take >3 weeks to re-epithelialize, with the risk of hypertrophic scarring increasing to 70–80% [86, 87]. Pathologically, the former usually damages the middle layer of the dermis, while the latter reaches the deep layer of the dermis. Therefore, the current diagnostic criteria of diagnosing all burn wounds with damage to the reticular layer of dermis as deep second-degree burns may lead to inappropriate clinical treatment decisions. Combined with expert opinions, this consensus classifies deep second-degree burn wounds into shallow deep second-degree burn wounds and deep second-degree burn wounds according to the pathological level of injury and wound healing time (Table 2), in order to further evaluate the healing potential and prognosis of deep second-degree burn wounds, so as to make the best clinical treatment decisions.

The literature reports that the accuracy rate of wound healing within 3 weeks assessed by experienced specialists is only 50–70% [74, 87]. Therefore, for this kind of deep second-degree burn wounds that cannot be determined temporarily, which is recommended by the consensus to be defined as 'uncertain-depth wound', continuous dynamic assessment is needed during later treatment to determine their specific depth.

Recommendation 17 (moderately recommended). It is recommended to use the 'nine-point scale', palm method and Lund–Browder chart method for the assessment of the wound area of second-degree burn wounds. Computerized 3D visual-assisted technology can be used as an auxiliary assessment tool (evidence level: moderate).

Rationale. To date, the 'nine-point scale' and the palm method are widely used wound area assessment methods. The 'nine-point scale' is based on the normal-sized population, which is generally applicable to adults and adolescents >9 years of age [88,89]. The new 'nine-point scale' developed in China extends its applicability to children <9 years of age (including). Although a large margin of error in burn area assessment for female patients with extreme and different body shapes (e.g. pear and apple shapes) exists [89, 90], the 'nine-point scale' remains the most widely used and quickest method of rough assessment for burn area in clinical practice [91]. The palm method utilizes the projecting area of the patient's whole hand (five fingers together) of ~1% TBSA as a scale for burn area assessment, and it can be applied to assess the percentage area of irregular anatomical sites in both children and adults, such as the hip and female breast [92]. The Lund–Browder chart method is a 2D evaluation method of the body surface area distribution of the normal population based on a large amount of data, which incorporates a more detailed delineation of the characteristics of children's growth and development at different times and is an accurate and less costly method of assessing the body surface area of both adult and paediatric patients [93].

Computerized 3D visual-assisted technology incorporates several factors, including gender, weight, height and body type, in the assessment of a patient's TBSA; therefore, the results may be more accurate and individualized [94]. Some studies have reported that the median difference between the 3D assessment system and the Lund–Browder chart method is 1.3% [95]. However, the accuracy of computerized 3D visual-assisted technology relies on a large number of data model training, and the application also requires special equipment and network support. The operability and convenience of computerized 3D visual-assisted technology are not as good as those of traditional two-dimensional evaluation methods such as "nine-point method" and palm method. Therefore, this consensus believes that the computer three-dimensional visual assistance technology is only suitable as an auxiliary tool for assessing burn area at present, and its further promotion and application still needs to be studied.

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Clinical question 5: Wound blister management

Blisters are the most common clinical manifestation of second degree burn wounds. The composition of blister fluid formed by burns varies depending on the level of dermis involved. The pain on the superficial second degree burn wound is usually more obvious, and the blister fluid formed is often a light yellow clear liquid. However, the pain sensation on the deep second degree burn wound is relatively dull, and the blister fluid formed is thicker, with thicker blister walls [47]. Multiple experiments and clinical studies have shown that preserving the blister skin on the wound can maintain a moist environment, promote wound healing, and significantly reduce discomfort for patients when changing dressings [45, 46].

Recommendation 18 (weakly recommended). Based on the possibility of blister rupture and the risk of infection, it is recommended to remove the skin of blisters that have been damaged or, although not damaged, are large size, have thin walls, are prone to damage, or have severe surface contamination (evidence level: low).

Rationale. Several studies have confirmed that intact blister skin can still serve as a physical barrier to protect the wound while forming a moist microenvironment to promote wound healing [45, 46]. However, most of the wound base is exposed when the blister skin of the wound is severely ruptured and loosely piled up, and in such cases, the blister skin can hardly play a role in wound protection and may even become a tissue that is prone to bacterial growth and leads to wound infection. Therefore, for large blister skins and blister skins that are thin, easily damaged or have severe surface contamination, there is a higher risk of rupture defects, wound exposure or wound infection. In clinical practice, it is generally recommended to retain the blister skin of burn wounds under special circumstances such as no serious contamination of the wound. This consensus recommends that the blister fluid be drained in the early burn stage while preserving the blister skin integrity as much as possible, and several factors, including the size, location and formation of the blister, should be considered before blister skin removal [45, 96–99]. Some studies have suggested that blisters with a diameter >6 mm or blisters with thin walls and a tendency to rupture should be removed to minimize the risk of wound infection [45].

It should be noted that the blister skin in different parts of the body is not completely the same. The blister skin on the dorsum of the hand and the dorsum of the foot is usually thinner, and the larger blister skin has a higher risk of rupture and defect. However, the cuticle of the palm or sole and other parts is thicker, and the blister skin of the blister that appears after the burn is generally thicker. Therefore, compared with other parts of the skin, the risk of blister skin rupture on the palm or sole is lower, and the large blister skin can still be intact. For the wound after removal of blister skin, more reliable wound covering should be selected to cover and protect the exposed wound base. Simultaneously, it is necessary to emphasize that the medical resources of local hospitals (availability of more suitable wound coverings) must be considered; otherwise, a comprehensive consideration of benefits and risks is needed.

Recommendation 19 (moderately recommended). Regarding injury factors, removing blister skin from low-heat scald wounds is recommended (evidence level: low).

Rationale. The causes of blister formation are varied and heat is the main common factor. A low-heat scald is generally defined as a progressive thermal injury to the epidermis, superficial dermis to deeper dermis, and subcutaneous tissues caused by prolonged exposure of the skin to a heat source with a temperature of ~50°C [100]. Owing to the small temperature difference between the heat source and the skin, patients frequently have no obvious discomfort because the skin has felt and contacted the heat source for too long, and most of the burn sites are locally compressed due to close contact, the blood circulation is blocked, the heat dissipation effect of blood flow is weakened, and a large amount of heat energy is accumulated and conducted to the deep layer of skin, thus deepening the wound surface. The immediate wound surface of patients with a low-heat scald may not be serious, showing only local erythema accompanied by small blisters with no obvious pain, which leads patients or inexperienced doctors to ignore the true depth of second-degree or even third-degree burns, which need surgical treatment to heal. Currently, the existence of blisters on the wound surface during low-heat scalding hinders the accurate evaluation of burn depth, interferes with the correct decision-making of physicians on wound treatment, often causes delayed wound treatment and affects therapeutic effects.

Clinical question 6: Wound cleaning and disinfection treatment

Wound disinfection is crucial for keeping the wound clean and preventing wound infections, and it is a basic procedure performed during regular dressing changes. To reduce the cell or tissue toxicity of disinfectants to the wound as much as possible, low toxicity and mild local disinfectants are preferred to be used for the disinfection of burn wounds, so as to ensure the prevention of wound infection and minimize the risk of delayed wound healing caused by the toxicity of disinfectants. This section primarily focuses on recommended disinfectants for routine dressing changes of noninfected burn wounds.

Recommendation 20 (moderately recommended). Low-toxicity and mild topical disinfectants, including chlorhexidine acetate solution and hypochlorous acid solution, are recommended for disinfecting second-degree burn wounds (evidence level: moderate).

Rationale. Following a second-degree burn, the epidermal barrier is disrupted and the dermis is exposed. The wound becomes sensitive and wound disinfectant penetrates easily into the normally active dermal tissue. Therefore, the cleaning and disinfection of second-degree burn wounds differ from the disinfection treatment of normal skin. The disinfectant should have a broad-spectrum antibacterial effect that covers common clinical infection-causing microorganisms while

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having low cell toxicity to minimize damage to normal tissues and reduce the risk of delayed wound healing. Furthermore, to avoid interfering with the clinician's judgement of the wound condition and reduce pain and discomfort during dressing changes, the disinfectant should be colourless, transparent, mild and nonirritating. Currently, iodine, alcohol, phenol, peroxide, guanidine, quaternary ammonium salts and acidic oxidative potential water are the clinically used wound disinfectants. Of these, the widely used disinfectants for burn wounds include povidone-iodine, chlorhexidine gluconate solution and hypochlorous acid solution, which have a generally broad spectrum of bactericidal properties. Different kinds of disinfectants have varying physicochemical characteristics suitable for treating different types of burn wound infections. In addition, the above disinfectants also have obvious differences in wound irritation and cytotoxicity. For example, silver-containing disinfectants have obvious cytotoxicity to keratinocytes and fibroblasts, which may have the risk of delaying wound healing [101–102]. Iodine-containing disinfectants (iodophor and povidone iodine) are easy to stain the wound, which affects the doctor's assessment of the depth of the wound, and has great irritation on the wound, which is easy to cause obvious wound pain. However, low concentration chlorhexidine acetate solution (mass fraction 0.05%) and hypochlorous acid solution (mass fraction 0.25%-0.125%) are colorless liquids, with lower toxicity and less wound irritation. New types of guanidine disinfectants, including polyhexamethylene biguanide hydrochloride and polyhexamethylene guanidine hydrochloride, have been rapidly developed in recent years, with good bactericidal effects, low irritability and low toxicity [103, 104]; however, the high application cost limits its wide application. During early burn care, some clinical guidelines currently recommend the use of mild soap solution and potable tap water for wound disinfection [5, 105, 106]. However, based on the global differences in water quality safety and the continuous increase in infection risk caused by bacterial contamination and colonization caused by long-term exposure of the wound surface in the late stage of burn, simple decontamination or tap water cleaning of the wound surface cannot achieve the desired microbial bactericidal effect. Therefore, this consensus recommends that mild soap solution or tap water can be used for cleaning the wound surface in the early stage of acute contamination, and low-toxicity and mild skin disinfectants, including chlorhexidine acetate solution and hypochlorous acid solution, are recommended for wound surface disinfection in subsequent routine cleaning and dressing changes.

Clinical question 7: Coverage and management of wounds

Superficial second-degree burn wounds

Recommendation 21 (moderately recommended). For superficial second-degree burn wounds with an intact preserved blister skin, an oil-based cream or gauze coverage is recommended following cleaning of the wound (evidence level: low).

Rationale. The principles of non-surgical treatment of superficial second-degree burn wounds are to keep the wound moist, prevent the wound from deepening, and prevent the wound from infection. For superficial second degree burn wounds with intact preserved blister skin, it is recommended to cover them with non adhesive dressings, which can protect the blister skin while absorbing exudate, and maintain a moist local environment. An oil-based cream or gauze can reduce the adhesion of the dressing to the wound surface and play a role in wound protection. An oil-based cream is beneficial for maintaining a moist wound environment and promoting re-epithelialization [5, 107, 108]. However, notably, a long replacement cycle will cause the oily substance to dry, and the challenge of dressing adhesion to the wound surface remains inevitable.

Recommendation 22 (moderately recommended). For superficial second-degree burn wounds with removed blister skin, it is recommended to prioritize the use of biological dressings such as allogeneic/xenogeneic skin, amniotic membrane, or artificial synthetic temporary skin substitutes for coverage. Secondly, foam dressings, hydrocolloid dressings and other dressings with good absorption, exudation and moisturizing functions are recommended, as well as oily cream and gauze. (evidence level: high).

Rationale. Following blister skin removal, the base of the wound is exposed. An ideal wound dressing should not only reconstruct a physical barrier to protect the wound from microorganisms such as bacteria but also maintain wound moisture, promote wound epithelialization and increase patient comfort. Several RCTs and case–control trials have shown that biological dressings, including allogeneic/xenogeneic skin and amniotic membrane, provide a temporary skin substitute for second-degree burn wounds in children and adults during early wound exposure, and have advantages over traditional dressings and modern synthetic dressings in terms of anti-infection, reducing wound pain and increasing comfort [109–114]. Allogeneic skins possess better wound adhesion, and xenogeneic skins may be repelled from the patient's wound owing to the presence of heterologous proteins; moreover, there is no clear evidence of a significant difference in wound epithelialization promotion for the treatment of small- to medium-sized superficial second-degree burns [115]. Synthetic temporary skin substitutes, including silicone-based materials (Biobrane® and Mepitel®) and cellulosic materials (Aquacell®, Suprathel® and Epicite^{hydro}), can mimic the human epidermis to act as a certain physical barrier with moisturizing effects and can further mimic the dermal structure when combined with collagen loading. Studies have shown that a synthetic temporary skin substitute has a greater advantage in terms of reducing the length of hospitalization, shortening healing time, and decreasing the pain of traumatic injuries and other aspects than a variety of creams, antimicrobial ointments and 1% (mass fraction) silver sulfadiazine (SSD) cream [114, 116–124].

Multiple clinical studies have shown that using modern synthetic dressings can shorten the length of hospital stay,

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decrease the number of dressing changes, reduce wound pain and have a better cost–effectiveness ratio than using traditional dressings, including gauze [125–130]. Foam dressings are suitable for wounds with moderate to severe exudation due to their high absorbency, whereas hydrocolloid dressings containing hydrophilic polymer matrix are suitable for wounds with mild to moderate exudation. Foam and hydrocolloid dressings can maintain a certain humidity for the wound after absorbing wound exudates [131–134]. Traditional fabric dressings, including gauze, will gradually dry and adhere to the wound; however, they have the advantages of being simple and easy to obtain, have low requirements for medical resources, can can be added materials and modified at multiple levels, such as antibacterial ointment and cream, to minimize adhesion, control infection and further adapt to the healing state of the wound [5]. Of note, the skin barrier function of the burn wound is disrupted, and the absorption of silver-containing preparations (e.g. SSD) through the wound is increased; however, delayed wound healing or even wound deepening have been observed in several studies [135–137]. Furthermore, silver-containing preparations may be toxic to the liver, kidney and central nervous system [138]. Therefore, this consensus does not recommend SSD for superficial second-degree burn wounds.

Shallow deep second-degree burn wounds

The injury of shallow deep second-degree burn wounds reaches the middle dermis. While the wound has a certain healing potential, the necrotic tissue attached to the surface also increases the risk of wound deepening and infection [139]. Therefore, providing a good healing microenvironment, preventing wound deepening and early regression of tissues from the stasis area to the necrotic area in the early stage of the wound, promptly removing necrotic tissues and promoting spontaneous wound epithelialization are the basic principles of the treatment of shallow deep second-degree burn wounds.

Recommendation 23 (moderately recommended). For early shallow deep second-degree burn wounds (within 24–48 h), dressings with good exudate absorption and moisturizing function are preferentially recommeded, including foam and hydrocolloid dressings. Gauze containing oil-based creams, such as SSD, are secondly recommended (evidence level: moderate).

Rationale. The main factors leading to progressive wound deepening include inadequate local tissue perfusion, persistent inflammatory response, and infection [140]. Although necrotic tissues are also present on the surface of shallow deep second-degree burn wounds, the tissues are thinner, unlike those of profound deep second-degree burn wounds; using good dressing coverage may be significant for preventing the transformation of interstitial ecological tissues. Therefore, early wound management of shallow deep second-degree burn wounds aims to improve the wound microenvironment and reduce local inflammatory reactions to prevent progressive wound deepening. Foam and hydrocolloid dressings not only have good exudate absorption capacity but can also form a moist healing microenvironment [129, 130]. Additionally, the closed microenvironment formed by these dressings may play a role in promoting autolytic debridement of necrotic tissues. Several studies have confirmed that compared with traditional gauze, foam and hydrocolloid dressings have significant advantages in preventing wound deepening and promoting wound healing and can significantly improve the comfort of dressing change [141–145].

Oil-based gauze and ointments are readily available. Owing to their higher oil content than water, they are beneficial for maintaining a moist wound environment, promoting re-epithelialization [5] and reducing the adhesion of dressings to the wound over time. SSD ointment has a broad spectrum of bactericidal properties and has shown certain advantages in reducing wound infection [124, 132, 135]. However, several clinical studies have reported that it has certain cytotoxicity, which may deepen wounds or delay wound healing [135–137]. After applying ointments, including oil-based and SSD ointments, to wounds, thorough cleaning is needed to adequately evaluate wound healing during each dressing change. This frequently leads to discomfort and pain in patients, and frequent dressing changes may damage the new fragile epidermis. Therefore, such ointments are recommended only as a last choice.

Recommendation 24 (weakly recommended). After the wound depth is stable (48–72 h), enzymatic debridement with collagenase, bromelain, papain or other enzymes is preferred for removing necrotic tissues, followed by autolytic debridement with hydrogels and ointments. For large wounds, enzymatic debridement combined with surgical debridement can be used (evidence level: moderate).

Rationale. Following the early shock phase, the systemic inflammatory response of the body tends to stabilize and the wound depth becomes relatively stable. Removing necrotic tissues as soon as possible and promoting spontaneous epithelialization for wound healing while preserving the remaining normal dermal tissues are the main treatment principles for shallow deep second-degree burns. The methods of debridement for necrotic tissue removal include surgical, enzymatic, autolytic and biological debridement. Currently, surgical debridement cannot accurately distinguish the interface between necrotic and normal dermal tissues and is prone to damage normal dermal tissues, especially in cases of mixed-degree burns or superficial interval burns. Owing to the risk of infection and the subjective discomfort of the patient, biological debridement with maggots and other organisms is not routinely performed in clinical practice. However, enzymatic debridement with collagenase, bromelain, papain and other enzymes can efficiently remove necrotic tissues while maximally preserving normal dermal tissues. Several studies have confirmed the effectiveness of enzymatic debridement in removing necrotic tissues, preserving viable tissues, and reducing the wound care costs, surgical debridement rate and

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skin grafting rate [146, 147]. European guideline on enzymatic debridement (2019) [148] stated that bromelain-based enzymatic debridement is best indicated for small superficial to deep-dermal burns (≤15% TBSA) with mixed patterns and facial burns, and can be performed on an outpatient basis. For patients with large burns, enzymatic debridement for eschar removal is formally limited to 15% treated TBSA per application. Although there have been reports of enzymatic debridement applied to burn wounds of > 15%TBSA in a single dose, this application still lacks high-quality evidence such as prospective controlled studies, and it has a high risk of causing a large amount of fluid loss of patients and resulting in hemodynamic changes. Therefore, this consensus preferentially recommends enzymatic debridement for small superficial and deep second-degree burn wounds, and enzymatic combined surgical debridement for larger burn wounds.

Autolytic debridement is a debridement technique guided by the theory of moist wound healing, which is based on the principle of applying a moisture-retentive dressing to the wound and removing inactivated or necrotic tissues through the processes of softening, hydrolysis and autolysis [49, 149]. Autolytic debridement has a longer cycle and a relatively slower speed than enzymatic debridement. Hydrogel dressings are commonly used for autolytic debridement. The combination of hydrogel and exudate can promote autolytic debridement by rehydrating inactivated and necrotic tissues, thereby accelerating wound healing [110, 111]. Hydrocolloid dressings, transparent film dressings, and ointment preparations, including debridement creams and SSD, are other commonly used products for autolytic debridement.

Profound deep second-degree burn wounds

Recommendation 25 (weakly recommended). For infants and young children (<3 years old) with profound deep second-degree burn wounds, it is recommended to prioritize the use of collagenase ointment, bromelain, or other enzymes for enzymatic debridement (evidence level: low).

Rationale. Infants and young children have special characteristics: their skin is relatively thin, the depth of burns is often deep, and their immune system is incomplete, leading to secondary infection and even sepsis complications. However, infants and young children have the characteristics of rapid growth and development and strong skin-healing ability, and even deep burns have a strong potential to achieve self-epithelialization and healing through conservative treatment. Clinical studies have shown that for deep second degree burn wounds in young children, including infants and young children (<3 years old), enzymatic debridement using collagenase ointment, bromelain, or other enzymes can significantly shorten hospital stay, reduce the need for subsequent surgery and blood transfusion, and cause less discomfort compared to mechanical debridement. Therefore, enzymatic debridement is also suitable for outpatient small area burn wounds in pediatric patients [150–152].

Recommendation 26 (weakly recommended). For profound deep second-degree burn wounds on the hands, it is recommended to prioritize the use of collagenase ointment, bromelain, or other enzymes for enzymatic debridement (evidence level: moderate).

Rationale. The nerves and blood vessels in the hands are concentrated, with complex routing and loose subcutaneous tissue, low subcutaneous fat content, and uneven distribution, which cannot provide sufficient protection. Deep burns on the hands often lead to severe hand deformities. Although surgical debridement accelerates the healing of deep burn wounds in the hands, surgical procedures often require anesthesia, skilled physicians, and sophisticated medical equipment, and often damage normal tissues. A study on deep hand burns reported that compared with standard surgical debridement, enzymatic debridement significantly reduced the time and number of treatments needed for overall debridement following admission to hospital, and the outcomes of scarring following healing were almost equivalent [153]. European guideline on enzymatic debridement (2019) recommend the use of enzymatic debridement for deep burn wounds in the hands. The dermis is thicker in areas such as the head, back, and soles of the feet, and the positions of skin appendages are relatively deep. For deep second degree burns with the same level of injury, there will be more residual normal dermal tissue in the back and soles of the feet, with relatively greater healing potential, and thicker necrotic tissue on the surface. The application of enzymatic debridement in these areas can not only quickly remove necrotic tissue, reduce the risk of wound infection, but also facilitate accurate assessment of burn depth. Therefore, European guideline on enzymatic debridement (2019) also recommend the application of enzymatic debridement in these special areas of deep burn wounds. However, considering that there is currently no clear clinical research evidence to support the application of enzymatic debridement in these areas, this consensus does not recommend it.

Uncertain-depth wounds

The early treatment of uncertain-depth wounds mainly includes moisturization and anti-infective measures to avoid wound deepening. Continuous dynamic evaluations should be performed during subsequent wound treatments, and appropriate wound disposals should be implemented after the specific wound depth is determined.

Recommendation 27 (moderately recommended). For wounds with uncertain depth, it is recommended to perform treatment in the same manner as the early management of shallow deep second-degree wounds until the depth is determined (evidence level: low).

Rationale. In clinical practice, the assessment can be influenced by an atypical wound appearance or the presence of thick necrotic tissues, making determining whether the wound is a shallow or a profound deep second-degree burn temporarily difficult. For wounds with uncertain depth, continuous dynamic evaluation is recommended during the treatment process, and the healing potential often needs to be determined in later stages. To avoid misjudgment of wound depth and excessive surgical intervention for wounds that can promote epithelial healing through routine dressing changes,

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this consensus recommends continuous depth assessment for wounds with uncertain depth. Before determining their depth, refer to the treatment plan for early shallow deep second-degree burn wounds to maintain a good healing microenvironment as much as possible. After the depth is determined, a new treatment plan is formulated.

Management of dressing change for second-degree burn wounds

Changes in burn wounds is a dynamic pathological process, and wound deepening throughout the treatment process is possible. In the early stages, progressive wound deepening may occur owing to thermal factors, local tissue ischaemia and persistent inflammatory reactions, which generally last for 48–72 h following injury [9, 79, 154, 155]. In the later stage of burns, poor wound management may also lead to wound infection, imbalance of local microenvironment, and ultimately deepen the wound, further delaying healing.

Recommendation 28 (strongly recommended). Second-degree burn wounds should undergo a continuous dynamic evaluation, including assessments for wound improvement, presence of infection, increase in necrotic tissues and wound deepening (evidence level: low).

Rationale. Second-degree burn wounds may have a dynamic deepening due to its own physiological and pathological changes, therefore continuous dynamic evaluation of the wound is necessary. If the wound is clean, necrotic tissue is reduced, and there are no signs of infection, the current treatment plan can continue to be implemented until the wound is epithelialized and healed. If there are signs of infection such as increased secretion and redness and swelling around the wound, it is necessary to carefully evaluate the wound infection situation. Based on the degree of wound infection, strengthen local wound treatment, apply antibacterial dressings locally, and if necessary, perform debridement surgery or systemic antibiotic treatment; If there is a significant increase in necrotic tissue on the wound, after ruling out wound infection, the depth of the wound can be reevaluated and corresponding treatment plans can be formulated based on the specific depth of the wound.

Application of growth factors

Numerous studies have reported that various growth factors have broad prospects for regulating immune–inflammatory responses and promoting tissue repair and regeneration. To date, fibroblast growth factor (FGF), epidermal growth factor (EGF), recombinant human granulocyte–macrophage colony-stimulating factor (rhGM-CSF) and other growth factors are widely used to treat various acute and chronic wounds, with good results.

Recommendation 29 (moderately recommended). The adjunctive use of growth factors, including FGF, EGF and rhGM-CSF, is recommended in the treatment of deep second-degree burn wounds (evidence level: moderate).

Rationale. FGF, EGF, rhGM-CSF and other growth factors play important roles not only in promoting keratinocyte formation, fibroblast proliferation, differentiation and migration but also in regulating cell apoptosis, extracellular matrix secretion and glycolysis [152]. Several studies have demonstrated that these growth factors can significantly shorten the healing time of second-degree burn wounds and show good effects in reducing or improving scar hyperplasia after healing [156]. A systematic review that included 12 clinical RCTs showed that FGF, EGF, and rhGM-CSF as adjunctive treatments for second degree burn wounds can significantly promote wound healing, shorten wound healing time, and improve the degree of scar hyperplasia after wound healing [157]. Another meta-analysis also showed that FGF and EGF shorten the healing time of superficial and deep-dermal burn wounds and improve the appearance of scars, such as pigmentation and scar thickness [158]. This consensus considers that superficial second-degree burn wounds heal faster and have a lower risk of scar hyperplasia after healing, and the cost-effectiveness of using growth factor preparations for patients is not significant. Therefore, it is recommended to use external growth factor preparations such as FGF, EGF, rhGM-CSF as auxiliary treatment for deep second-degree burn wounds.

Recommendations for the surgical treatment of second-degree burn wounds

Surgery is a key treatment for second-degree burns; however, there is currently no uniform clinical standard for surgical treatment. The Writing Group classified the surgical methods for deep second-degree burns into two types: simple surgical debridement and skin grafting, based on whether debridement is performed to facilitate spontaneous healing of the wound or autologous skin grafting after debridement. The former involves removal of necrotic tissue from the surface of the wound and covering it with different types of dressings to promote spontaneous epithelialization of the wound, while the latter involves complete removal of necrotic tissue to a clean base, followed by autologous skin grafting to close the wound and promote healing.

Burn depth is an essential factor affecting wound healing, and profound deep second-degree burns' healing are often associated with a scarring prognosis. Therefore, skin grafting is often recommended for profound deep second-degree burns. However, the specific treatment still needs to be combined with the patient's burn area, the patient's age, the burn site and other factors, and there may be different treatment tendencies. Besides, the choice of specific treatment method should also be considered jointly with the hospital's medical resource conditions, doctor's experience level, and patient and family's willingness and acceptance.

Clinical question 8: Indication for skin grafting of second-degree burn wounds

Recommendation 30 (moderately recommended). Based on the consideration of burn depth, skin grafting is recommended for profound deep second-degree burn wounds (evidence level: high).

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Rationale. Shallow deep second-degree burn wounds with a relatively superficial level often require conservative treatment or simple surgical debridement to achieve wound healing. On the other hand, profound deep second-degree burn wounds have extensive necrotic tissue on the wound surface and severe damage to the dermal layer, often requiring surgical removal of necrotic tissue and autografting for wound healing.

It is generally accepted that wounds that take longer than 21 days to heal usually lead to proliferative scarring or even dysfunction. According to *Total Burn Care*, almost all deep burns that fail to heal within 21 days require skin grafting to reduce the wound-healing time and the length of hospital stay, alleviate infection, and improve functional outcomes of burn sites and scar formation after wound healing [159]. Skin grafts can protect the wound bed from the environmental temperature, pathogens, etc., thus improving the wound microenvironment and promoting wound healing. Furthermore, several RCTs and one meta-analysis based on RCTs demonstrated that early removal of necrotic tissue, formation of a clean wound bed and autologous skin transplantation can not only reduce the rate of wound infection, accelerate wound healing, and decrease the length of hospital stay [160–162], but also improve long-term cosmetic appearance, sensory and motor function, and scar formation [161, 163–168]. However, a few studies have also concluded that there is no significant difference between skin grafting and conservative treatment in terms of hand function restoration in deep second-degree burn wounds on the hand [169–171]. The Writing Group believes that the bias in burn depth may be an important reason for the different studies which have produced different outcomes, with a greater prognostic difference between profound and shallow deep second-degree burn wounds. Therefore, skin grafting is preferred for profound deep second-degree burn wounds because it promotes wound healing and improves healing outcomes. However, autologous skin grafting is associated with great damage to the donor area and is susceptible to limitations such as the inadequacy of the skin source in the donor area. Although skin grafting is the primary treatment for profound deep second-degree burn wounds, thorough consideration should be given to each patient's situation.

Recommendation 31 (moderately recommended). Based on the consideration of patient age, active skin grafting is not recommended for deep second-degree burn wounds in infants and children younger than 3 years old (evidence level: moderate).

Rationale. Infants and young children are unique; their skin is relatively thin, and their burn wounds are often deeper. They commonly develop proliferative scar formation after healing. In addition, their immune system is not yet fully developed, thus increasing their risk for secondary wound infections and even sepsis. It is theorized that autologous skin grafting after surgical removal of necrotic tissue can minimize the risk of infection and promote better wound healing. However, infants and young children are characterized by rapid growth and development as well as strong skin-healing ability. Therefore, the need for skin grafting of them is relatively low. At the same time, they have a weak tolerance to anaesthesia, and their central nervous system is not yet well developed, so the risks brought by general anaesthesia must be fully considered. Several studies have shown the effectiveness of conservative treatment of deep second-degree burns in children. A prospective RCT demonstrated that for indeterminant-depth scald burns in infants younger than 3 years old, early conservative dressing changes can reduce the need for skin grafting, minimize the surgical site, and reduce the surgical time and blood loss in the later stages of treatment, compared with early skin grafting [172]. A case-control study found that in children with deep second-degree burns of less than 20% TBSA, skin grafting and conservative treatment yielded similar results in terms of healing time and prognostic scar score, whereas for burns of less than 10% TBSA, conservative treatment had significantly better outcomes than skin grafting[173]. In addition, a retrospective study involving 725 children with indeterminant-depth burns also showed the safety and effectiveness of conservative treatment [174]. Thus, based on the physiological characteristics and healing ability of the children themselves, as well as the possible anaesthesia risks of surgery, active skin grafting is not recommended for deep second-degree burns in children. Moreover, it must be pointed out that this recommendation is mainly based on the consideration of small and medium-sized second-degree burn wounds; for special burn sites such as functional parts and for large second-degree burn areas, skin grafting can be considered according to the specific situation of the wounds.

Recommendation 32 (moderately recommended). Based on the consideration of the burn site, active skin grafting is not recommended for deep second-degree burn wounds in areas with thicker skin, such as the back, palm, sole and head (evidence level: low).

Rationale. Skin thickness varies throughout the body, with the dermal layer being thicker on the back, palm, sole, head and other areas and the skin appendage being relatively deeper. Therefore, second-degree burn wounds of the same depth at these sites have more residual normal dermal tissue, with relatively greater healing potential, so that self-healing can be achieved in most clinical cases and skin grafting is rarely needed. A clinical study retrospectively analyzed the unit's 10-year experience with palm burns, and found that 87% of palm burns healed without surgery; it recommended that active skin grafting should be avoided [175] but emphasized the need for active physiotherapy after wound healing to prevent contracture [176]. The face is a cosmetic area with high aesthetic requirements. To date, the surgical treatment of facial profound deep second-degree burn wounds remains controversial, and many clinicians prefer to manage such wounds with conservative dressing changes. Available evidence suggests that conservative treatment can promote

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wound healing and have little influence on cosmetic and functional outcomes in patients with facial shallow deep second-degree burn wounds (healing within 21 days). In contrast, for facial profound deep second-degree burn wounds (healing over 21 days), skin grafting reduces scarring and achieves better cosmetic outcomes without increasing the incidence of complications (e.g. micrognathia, eyelid ectropion) compared with conservative treatment [163]. A 20-year study at the University of Washington Harbourview Medical Center reported that skin grafting is suitable for facial burns that do not spontaneously heal within 3 weeks and can help patients reintegrate into society more quickly [177]. Therefore, skin grafting is recommended for facial profound deep second-degree burn wounds.

Clinical question 9: Specific protocol for skin grafting on second-degree burn wounds

Recommendation 33 (moderately recommended). When skin grafting is determined, it is generally recommended to perform the procedure within 7 to 10 days after burn injury; facial skin grafting is recommended to be performed 10 to 14 days after burn injury (evidence level: moderate).

Rationale. At present, there is no clear boundary on the timing of early and delayed skin grafting for burn wounds. The 2016 ISBI *Practice Guidelines for Burn Care* stipulate that early surgery is generally performed within 7 to 10 days after the burn, whereas delayed surgery is often performed 10 to 21 days after the burn [178]. Multiple clinical controlled studies about second-degree burn wounds have demonstrated that early surgery can reduce the length of hospital stay, alleviate wound infection and decrease the incidence of complications such as sepsis compared with delayed surgery [179–184]. Furthermore, wound healing time is strongly associated with the risk of scar formation. Therefore, theoretically, early skin grafting can accelerate wound healing, reduce hypertrophic scar formation, and decrease the contracture rate. However, relevant studies are scarce, with only one article reporting on the subject thus far [185].

For burns in functional areas such as the hand, several clinically controlled studies have concluded that early skin grafting reduces the risk of readmission and the need for scar reconstruction surgery and is superior to delayed skin grafting in terms of the restoration of hand aesthetics and function (e.g. grasping and pressing) [166, 167, 186, 187]. Meanwhile, two recent RCTs have found that although early skin grafting can reduce the length of hospital stay, functional recovery is not associated with the timing of surgery [188, 189]. The Writing Group believes that the outcome of hand functional recovery is not only related to the timing of surgery but also closely related to the depth of burns on the patient's hand, level of surgical scab cutting, graft thickness, postoperative functional rehabilitation, anti-scarring treatment etc. These factors may have contributed to the inconsistency of findings between studies. To validate this finding, more high-quality RCTs are warranted. Therefore, this finding indicates that in terms of reducing the length of hospital stay and accelerating wound healing, early skin grafting is generally recommended for hand deep second-degree burn wounds. In addition, for neck deep second-degree and third-degree burns, early skin grafting has a significant advantage over delayed surgery in terms of reducing the length of hospital stay and long-term scar contracture [162].

The face is an important aesthetic part of the human body and facial burns have unique characteristics compared with burns in other areas. On the one hand, the face has a rich blood supply and relatively strong healing ability. On the other hand, it has a more complex tissue structure, thus requiring more excellent surgical skills and more delicate surgery. In addition, the current skin grafting method cannot achieve the ideal recovery state, as it cannot fully restore facial expressions and local features despite its ability to prevent scar hypertrophy in the later stages. Therefore, the conditions and timing of surgery for facial burns must be carefully considered. The commonly accepted view is that a continuous observation and evaluation period of 10 to 14 days is needed after facial burns to determine whether skin grafting is needed. If the wound healing time is longer than 21 days, skin grafting should be conducted. Therefore, the 2016 ISBI *Practice Guidelines for Burn Care* recommend performing the procedure 10 to 14 days after the burn [178].

For the above reasons, we recommend that for deep second-degree burn wounds requiring skin grafting, regardless of whether they are located in important aesthetic and functional areas, such as the neck, hands and joints, or in other areas, surgery should be performed within 7 to 10 days after the burn. Meanwhile, depending on the patient's condition, the surgery can be performed early but generally not earlier than 72 h. For facial deep second-degree burns, skin grafting is generally recommended to be performed 10 to 14 days after the injury.

Recommendation 34 (moderately recommended). For deep second-degree burn wounds subject to skin grafting, complete removal of necrotic tissue is recommended while preserving the normal dermal tissue as much as possible (evidence level: low).

Rationale. For burn wounds requiring autologous skin grafting after debridement, the goal of debridement is to completely remove all necrotic tissues and ensure good blood supply to the wound bed for autologous skin grafting [190]. However, residual dermal tissue is closely associated with the prognosis of scar formation; the more dermal tissue is preserved, the lower the risk of poor scar formation. Therefore, for wounds subjected to autologous skin grafting after debridement, preservation of normal dermal tissue is essential to ensure a satisfactory aesthetic appearance and functional requirements after wound healing.

Recommendation 35 (moderately recommended). Based on the adequacy of the donor skin area, the most recommended graft for second-degree burn wounds is a sheet, followed by a meshed, stamped and then particulate graft (evidence level: moderate).

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Rationale. Depending on the size, skin grafts can be categorized as sheet, meshed, stamped and particulate. The advantages of the sheet graft include its good cosmetic appearance and better grafting effect; however, it causes greater damage to the skin donor area and has poor drainage, and haematoma and fluid accumulation under the skin graft affect its survival. An RCT about third-degree burns demonstrated that 1:1 meshed grafts could reduce graft failure due to haematoma compared with sheet grafts, but no significant difference was observed in long-term scar quality [191]. Meshed grafts have several regular mesh holes caused by using a rolling machine. The common mesh ratios are 1.5 : 1, 2 : 1, 3 : 1 and 4 : 1. The advantages of meshed grafts include their ability to increase the coverage area of autologous skin, reduce damage to the donor area, and allow blood and body fluids to drain from under the skin grafts. However, it leaves a mesh pattern after wound healing. The larger the expansion ratio is, the larger the pores of the mesh are, accompanying by longer epithelization healing time, the increasing possibility of hypertrophic scars, and the more damage to function and aesthetic effect. For wounds requiring meshed grafts with a large meshed ratio, homograft or xenograft skin is often necessary to cover the meshed graft to minimize the risk of graft failure [192]. Stamped and particulate skin grafts are commonly used to cover large burns with severely insufficient donor skin [193]; however, they have longer healing times and cause more hypertrophic scarring than meshed and sheet grafts.

Therefore, taking into account the size of the injury, adequacy of donor skin, and goal of promoting wound healing and improving scar prognosis, the most recommended graft for second-degree burn wounds is a sheet graft, followed by meshed, stamped and then particulate grafts; it is also important to monitor for haematoma and infection after skin grafting to ensure the adhesion and survival of the graft. Furthermore, with the development of tissue engineering technology, various autologous skin substitutes have been developed, such as epidermal substitutes, dermal substitutes and tissue-engineered full-thickness skin grafts. Nonetheless, there is currently no available product that can achieve complete skin replacement, and further research and development are still warranted.

Recommendation 36 (moderately recommended). Regarding the grafting site, medium-thickness or full-thickness skin grafts are recommended for important cosmetic and functional sites, such as the face, neck, hand and joint, whereas thin split-thickness skin grafts are recommended for other noncosmetic and nonfunctional sites (evidence level: moderate).

Rationale. Skin grafts can be classified as thin split-thickness, medium-thickness, and full-thickness skin grafts based on the thickness of the dermal layer. Thin split-thickness (0.15–0.25 mm) and medium-thickness skin grafts (0.3–0.6 mm) involve the epidermis and part of the dermis whereas full-thickness skin grafts involve the epidermis and dermal layer. Owing to the flexibility and elasticity of the dermis, the thinner the dermis, the stronger the graft contraction, and the greater the impact on the appearance and function of the healed wound. Furthermore, skin graft survival and scar formation in the donor area should be considered. The survival of skin grafts mainly depends on the nourishment from the wound bed plasma and the formation of microvessels. Therefore, the thinner the skin graft, the higher the likelihood of successful grafting [194], and the lower the probability of scarring in the donor area. For burns in cosmetic and functional sites (e.g. face, neck and hand), medium-thickness and full-thickness skin grafts are thus recommended to minimize contractures [195]; these sites have a rich local blood supply, making them conducive to skin survival. Several retrospective clinical studies have found that for deep hand burns, full-thickness skin grafts can better reduce postoperative contractures and deformities, reducing the need for reoperation for scar reconstruction [196–198]. For areas with low functional and aesthetic requirements, a thinner skin graft is preferred if the blood supply is allowed to reduce the risk of scar formation and increase the success rate of skin grafting. The specific thickness of the graft should also be considered based on the thickness of the residual dermal tissue in the grafted area. If the residual dermal tissue is relatively thick, thinner skin grafts are recommended to minimize damage to the donor area and prevent the graft from protruding beyond the wound, which can lead to poor wound healing.

Clinical question 10: Indications for simple surgical debridement of second-degree burns

Recommendation 37 (weakly recommended). Enzymatic debridement is recommended for small shallow deep second-degree burns (≤15%TBSA), with combined surgical debridement for larger shallow deep second-degree burns (>15% TBSA) (evidence level: low).

Rationale. Surgical debridement is quick and effective in the removal of necrotic tissue. However, it will damage more normal tissue and is not conducive to dermal preservation. A large retrospective clinical study found that debridement with collagenase may improve wound healing and reduce wound care costs in outpatients with second-degree burns of ≤15% TBSA [199]. In addition, a European consensus on enzymatic debridement suggests that enzymatic debridement is suitable for superficial-deep-mixed second-degree burns of ≤15% TBSA; however, a single large-area enzymatic debridement may lead to loss of body fluids and affect the patient's circulatory stability. Thus, for large shallow deep second-degree burns, a combination of enzymatic debridement and surgical debridement can be performed to remove necrotic tissue. Furthermore, the choice of debridement should be made by considering the resources of local hospitals; if enzymatic debridement cannot be achieved, surgical debridement is recommended.

Clinical question 11: Specific protocol for surgical debridement of second-degree burn wounds

Recommendation 38 (moderately recommended). Surgical debridement is recommended to be conducted as soon as

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possible when the depth of second-degree burn wounds is stabilized and the surgical conditions allow (evidence level: low).

Rationale. Based on the pathophysiological characteristics of burns, the wound surface will produce obvious exudation of body fluids. In general, the fastest exudation occurs within 6–12 h after the burn and lasts for 24–36 h and can even be more than 48 h in severe burns. For very large burns, the body's failure to sufficiently compensate for the loss of body fluids can lead to haemodynamic changes and even shock. Patients with this type of burn need to be comprehensively evaluated, and surgical debridement can be performed only when the patient is haemodynamically and systemically stable. Due to the interaction among heat stress-induced inadequate local wound perfusion, excessive inflammatory response and autophagy, second-degree burn wounds progressively deepen in the early stages and last until 48–72 h after injury depending on the degree of injury; this may be related to the presence of necrotic tissues, but there is no clear evidence yet. This indicates that the depth of second-degree burn wounds is still unstable during 48–72 h after injury, and early surgical debridement may result in the removal of more surviving tissues or incomplete removal of necrotic tissues. Therefore, when surgical debridement is determined, it is recommended to perform the surgical debridement as soon as possible after the wound depth is stable and when the surgical conditions allow.

Recommendation 39 (moderately recommended). For the depth of simple surgical debridement of second-degree burn wounds, removing necrotic tissue as much as possible and preserving partial-damaged tissue is recommended (evidence level: low).

Rationale. Second-degree burn wounds on which simple surgical debridement is performed generally have strong self-healing ability and can achieve epithelialized healing through the residual dermal tissue in the wound. The quality of wound healing is also closely related to the degree of dermal tissue preservation. Therefore, surgical debridement aims to remove obvious necrotic tissues, preserve partial-damaged tissue and skin appendages as much as possible, and subsequently protect the wound by covering it to promote spontaneous epithelialization and wound healing [190].

Recommendation 40 (moderately recommended). For second-degree burn wounds after simple surgical debridement, it is recommended to use biological dressings such as xenograft skin and amniotic membrane or artificial synthetic temporary skin substitutes (evidence level: moderate).

Rationale. After simple surgical debridement, wound management is carried out to maintain an appropriate microenvironment, avoid wound infection, and promote self-epithelialization and healing. Biological dressings have a naturally similar structure to human skin and are effective in acting as the skin barrier, preventing bacterial contamination, maintaining a moist healing environment, and reducing fluid exudation and protein loss [200–203]. Several clinical studies have demonstrated that when applied to second-degree burns, biological dressings can promote better wound healing and reduce scar hyperplasia compared with traditional dressings [110, 204, 205]. At present, the biological dressings commonly used in clinical practice mainly include allograft skin, xenograft skin and amniotic membrane. However, it should be noted that allograft skin has a much higher biocompatibility than the other dressings. When applied to the wound after surgical debridement, allograft skin is more likely to be vascularized and may produce a degree of occupancy than xenograft skin and amniotic membrane [205]. Besides, allograft skin's restricted source and high economic cost have also limited its clinical use [202, 206, 207]. The amniotic membrane is also an excellent biological dressing that contains many factors related to tissue repair, such as growth factors and immunomodulators, which can promote wound healing and improve healing outcomes [208]; however, it is slightly inferior to allograft skin in terms of reducing water loss [209].

Temporary skin substitutes are materials that simulate natural skin function to achieve temporary skin replacement. They can cover and protect wounds, reduce bacterial colonization, and facilitate wound epithelialization and healing. A systematic review and several clinical studies have confirmed that compared with silver sulfadiazine cream, synthetic temporary skin substitutes can reduce pain, promote healing of second-degree burn wounds, and potentially improve scarring prognosis [116, 135, 210, 211], suggesting that they are suitable dressings for wound covering after surgical debridement.

Clinical question 12: Recommendations for surgical equipment of second-degree burn wounds

There are various tools used in surgical treatment. For eschar dermabrasion, the commonly used tools are metal wire balls, electrocautery cleaning pads, sandpaper etc., which can remove superficial necrotic tissue via mechanical friction. Traditional sharp instruments such as roller skin graft knives and hydrodynamic debridement systems can be used for surgical excision. This consensus provides recommendations for surgical tools based on surgical modality and site. However, the choice of specific surgical instruments should be made according to the condition of the wound, level of hospital resources, experience of the surgeon, and other comprehensive considerations.

Recommendation 41 (moderately recommended). Regarding the surgical modality, for simple surgical debridement, the first recommendation is the use of eschar dermabrasion tools and hydrodynamic debridement systems, followed by skin graft knives. For surgical debridement before skin grafting, the prioritized recommendation is the use of skin graft knives, followed by hydrodynamic debridement systems (evidence level: high).

Rationale. Simple surgical debridement should be targeted at the removal of necrotic tissue while preserving partial-damaged tissue as much as possible, with the goal of promoting epithelialization and wound healing; thus, it is crucial to determine the precise level of debridement. Human dermal thickness ranges from 0.3 to 3 mm depending on anatomical location and age. Traditional skin graft knives

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typically control the minimum thickness of surgical excisions at 0.75 mm. However, they cannot accurately control the range of horizontal inclusions, which may damage the surrounding or intervening normal skin and often result in the loss of normal or partial-damaged dermal tissues. On the other hand, hydrodynamic debridement systems can adjust their energy intensity with a minimum surgical depth control of 50 μm and have the potential to preserve partial-damaged dermal tissues [212–214]. Two RCTs have also demonstrated that hydrodynamic debridement systems enable a more precise and accurate excision than traditional skin graft knives, allowing for the preservation of more normal dermal tissues [215, 216]. Furthermore, eschar dermabrasion has a superficial debridement depth. During the procedure, the surgeon can dynamically and directly observe the level of necrotic tissue and make more accurate judgements about the depth of the wound. Similarly, eschar dermabrasion can also preserve more normal dermal tissues [217]. Therefore, for simple surgical debridement, considering the preservation of more viable dermal tissues and ensuring the wound's healing ability, eschar dermabrasion tools and hydrodynamic debridement systems are first recommended, followed by traditional sharp instruments such as skin graft knives.

For skin grafting, debridement is performed mainly to completely remove necrotic tissue and ensure a good base for grafting. The debridement layer of eschar dermabrasion is generally superficial in the dermis, and skin grafting is not routinely performed after surgery. Surgical excision can quickly reach the surgical level needed for skin grafting. The commonly used tools include traditional skin graft knives and hydrodynamic debridement systems. The hydrodynamic debridement system performs debridement at a point level, whereas skin graft knives operate at a surface level, suggesting that the latter has a relatively higher debridement efficiency and faster access to levels for skin grafting. However, hydrodynamic debridement systems have poorer penetration ability in thicker eschars and may have higher costs and cause adverse reactions [215, 216]. Therefore, for debridement before skin grafting, considering the extensive clinical experience and surgical operability, traditional skin graft knives are mainly recommended owing to their high efficiency, followed by hydrodynamic debridement systems.

Recommendation 42 (moderately recommended). Regarding the surgical site, for areas requiring delicate operations such as the hands, face and genitals, hydrodynamic debridement systems or eschar dermabrasion tools are recommended as the first choice for debridement surgery, followed by skin graft knives (evidence level: high).

Rationale. The hydrodynamic debridement system is more delicate and controllable, and can retain more viable dermal tissues than traditional dermatomes [218], which could promote wound healing and decrease scar formation. It has also been demonstrated that the hydrodynamic debridement system has a shorter debridement time for areas requiring special attention (such as the hands, face and genitals) compared with traditional debridement; however, both exhibit no significant difference in terms of postoperative pain, healing time or scar contracture complications [215]. Thus, the hydrodynamic debridement system is preferred for sites requiring delicate operations, such as the hands, face and genitals.

Recommendations for the treatment of infection in second-degree burn wounds

Clinical question 13: Diagnosis and classification of second-degree burn wound infection

Recommendation 43 (moderately recommended). Considering the complexity of burn wound infection, it is diagnosed based mainly on a comprehensive assessment of clinical manifestations, including local and systemic inflammatory reactions of the wound. Inflammatory markers and microbiological tests are mainly used as auxiliary diagnostic indicators (evidence level: moderate).

Rationale. At present, there are no unified and definitive diagnostic criteria for burn wound infections due to the relative complexity of their clinical manifestations. A recent systematic review [219] highlighted the need for a comprehensive assessment of clinical manifestations on the wound surface, wound base and surrounding area, including 32 diagnostic items such as local pain, elevated skin temperature, increasing exudation, local oedema, wound deepening, positive bacterial cultures and leukocyte elevations. However, microbial culture results of wound secretion are not completely consistent with the clinical manifestations of the wound infection[220], nor can bacterial contamination, colonization or invasion be clearly distinguished. Thus, wound microbiological test results cannot be used as the standard for determining whether a wound is infected. Clinicians need to make a comprehensive judgement of the local and systemic clinical manifestations of the wound. Furthermore, inflammatory or immunomodulatory markers such as the white blood cell count and C-reactive protein and calcitoninogen levels are affected by various factors, including immunoinflammatory reactions caused by stress from burn, trauma and surgery [221]. Particularly in patients with large severe burn wounds, intense stress can lead to sustained high levels of these indicators for a long time [222]. Therefore, it is difficult to clearly determine whether the wound is infected or to identify the severity of infection by simply using the aforementioned indicators in clinical practice, but its dynamic changes can be used as an important reference. This consensus suggests that burn wound infection be diagnosed based mainly on the comprehensive assessment of clinical manifestations, which requires close observation of the burn wound, the patient's vital sign changes, and the patient's local (local redness, swelling, elevated skin temperature, pain and changes in secretion) [223–225] and systemic inflammatory manifestations. Furthermore, inflammatory markers and microbiological tests can be used as auxiliary diagnostic indicators for wound infection. It should also be noted that the patient's age, presence of malnutrition, obesity, and diabetes mellitus, long-term use of steroids, immunocompromise and

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medication may mask or suppress the signs and symptoms of infection.

Recommendation 44 (moderately recommended). The degree of wound infection is classified as mild, moderate or severe based on its local and systemic clinical manifestations or the level of invaded tissue (evidence level: moderate).

Rationale. At present, there are no definitive and unified diagnostic criteria for burn wound infection. The American Burn Association [226] mainly recommended reliance on tissue biopsy to determine the degree of burn wound infection. They categorized wound infection into noninvasive and invasive depending on the levels of microbial invasion to the skin and subcutaneous tissues. Similarly, the Infectious Diseases Society of America guidelines [227, 228] determined the degree of skin and soft tissue infection according to the level of infection invasion to the skin, subcutaneous tissues, muscles and other structures. In another retrospective study, the degree of wound infection was categorized into five grades based on tissue biopsy results, patient clinical information, survival status of the microorganisms and levels of invaded tissues, as follows: grade 0, clean wound with no microorganisms detected; grade 1, wound with microorganisms confined to its surface; grade 2, wound with microorganisms invading the superficial layers of the dermis; grade 3, wound with microorganisms invading the entire dermal layer; and grade 4, wound with microorganisms invading the subcutaneous tissues [229, 230]. However, some limitations still exist in the classification, such as a lack of consistency in the evaluation of the clinical manifestations of burn wound infection in the judgement criteria and the reliance on tissue biopsy to make judgements, which is not conducive to the promotion of clinical application. Therefore, this consensus classifies wound infection as mild, moderate or severe based on its local and systemic clinical manifestations and levels of microbial invasion (Table 3). This will guide the evaluation, diagnosis and treatment of wound infection.

Clinical question 14: Microbiological tests of second degree burn wound infection

There is a wide variety of microbiological tests for burn wound infection and they are categorized into qualitative and quantitative. Qualitative microbiological tests include smear staining, genetic testing, secretion culture, blood culture, etc. However, quantitative tests include histopathological staining and tissue homogenate quantification, both of which require tissue biopsy as a prerequisite.

Recommendation 45 (highly recommended). Both infected and potentially infected burn wounds should routinely have wound specimens retained for microbiological tests (evidence level: moderate).

Rationale. Burn wound infection usually begins with microorganisms invading or colonizing the wound through various pathways. Observational clinical studies have confirmed the association of the species and quantities of local bacteria on the wound surface with wound healing and prognosis [231, 232]. Therefore, the microbiological assessment of burn wounds, particularly when clinical symptoms of infection appear or when the wound condition worsens, provides valuable insights. Collecting specimens and conducting timely and effective testing of wound microbiota before the administration of antibiotics are crucial in the determination of the main pathogens causing the infection and selection of the optimal antimicrobial therapy for wound infection. In clinical practice, infections often progress rapidly. Early collection of specimens for microbiological testing of the wound can shorten the duration of empirical antibiotic therapy and allow for early adjustment of medications based on the microbial flora identified. This can effectively prevent the emergence of multidrug-resistant bacteria and make the treatment more accurate and effective.

Recommendation 46 (moderately recommended). Before obtaining microbiological evidence, it is recommended to initially determine the types of pathogenic microorganisms based on the local manifestations of the wound and systematic condition of the patient, considering the epidemiological characteristics of microorganisms in the ward (evidence level: moderate).

Rationale. Pathogenic microorganisms that colonize burn wounds include bacteria and fungi [233]. The different species of these microorganisms have their own unique mechanisms and varying clinical manifestations. Some of them also have typical manifestations. Therefore, clinicians can initially determine the species of pathogenic microorganisms by observing the local manifestations and systemic conditions of the wound. Bacteria mainly include *Staphylococcus aureus*, *Streptococcus*, *Enterococcus*, *Pseudomonas*, *Acinetobacter* and *Escherichia coli* [234–240]. Some wounds infected with bacteria have special clinical symptoms. For example, wound infection caused by *S. aureus* is often manifested by the appearance of a slightly yellow viscous secretion and yellow film-like scab on the wound surface. Wound infection caused by *Pseudomonas aeruginosa* is usually manifested by yellow- or blue–green (patina-like) viscous secretions and a slightly green wound base, accompanied by a sweet and fishy smell of poisonous fruits. Fungal infections are mainly secondary to long-term systemic use of broad-spectrum antibiotics, including *Candida*, *Aspergillus*, *Penicillium*, *Rhizopus* and *Mucor* [241–245]. Fungal infection are mainly manifested by rapid or gradual wound deepening, bean dregs- or cheese-like necrosis, grey or bright-red granulation tissue, fragility and susceptibility to bleeding, and thick exudate that often covers the wound surface. Among them, *Candida albicans* often presents with a difficult-to-peel white film covering the wound surface, accompanied by pronounced itching and pain. *Aspergillus* or *Mucor* infections are often manifested by a sudden appearance of dark-brown or black spots on the wound surface, rapid expansion leading to ulceration, and even premature detachment of the eschar, often resulting in haematogenous dissemination, thrombus formation, progressive necrosis of muscles or limbs, or extensive skin haemorrhage or necrosis.

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Table 3. Diagnostic criteria for grading the degree of infection of burn wounds

Degree of infection	Local manifestation	Systemic manifestation	Invaded tissue level
No infection	There are no local signs of infection such as redness, swelling, heat and pain.	No obvious signs	Microorganisms only contaminate or colonize the wound surface or necrotic tissue but not normal dermis.
Mild infection	Local redness, swelling, elevated skin temperature and local pain, as well as increased or purulent secretion (viscous, turbid, and opaque or bloody secretion) at the wound surface or around the wound edge are present. Meanwhile, other causes of skin inflammation should be ruled out (such as skin allergy, distal limb fracture and venous thrombosis).	No obvious signs	Microorganisms invade the superficial residual dermis in the wound.
Moderate infection	A marked increase in purulent secretion with odour and foul smell, aggravation of inflammation around the wound surface, obvious expansion of redness and swelling, increase in local pain, possible tissue edema, andthe surrounding tissues swell significantly.	The symptoms may be accompanied by fever, elevated body temperature and other systemic symptoms of infection.	Microorganisms invade the deep dermis or the entire residual dermis in the wound.
Severe infection	Poor wound vitality, dark colour, basal dryness, gradual blackening and necrosis at the centre of the wound, progressive deterioration of blood supply with increased exudation, accompanied by peculiar smell, progressive wound deepening, or expansion to normal tissues around the wound or even to the whole skin.	There are obvious systemic symptoms of infection. Sepsis or septic shock may occur in severe cases.	Microorganisms break through the dermis or invade the surrounding normal tissues.

Burn wounds are often exposed to the hospital environment in the ward or come into contact with surfaces contaminated with microorganisms owing to their open nature, which can lead to colonization and proliferation of a large number of pathogenic microorganisms on the wound, resulting in infection [246–248]. Regular microbial monitoring of the hospital environment and surfaces contaminated with microorganisms (at least weekly, using swabs or quantitative biopsies) enables tracking of the microbial changes in the ward, thereby indicating the potential pathogens that the wound may come into contact with. This can serve as a preliminary basis for identifying the types of microbial infection and provide references for empirical antibiotic treatment.

Recommendation 47 (moderately recommended). Routine use of surface swab culture is recommended to obtain microbiological evidence and, if necessary, tissue biopsy to determine the levels of infection and invasion. Molecular biology testing is an important auxiliary detection method (evidence level: moderate).

Rationale. Microbiological testing, including surface swabs and tissue biopsies, is an important method for determining whether a burn wound is colonized or infected by bacteria. Surface swabs have been widely used in clinical practice owing to their ability to collect a wide range of samples, good representativeness and simplicity of operation [249]. However, they cannot be used to sample deep tissues and distinguish colonization; in addition, they pose a high risk of contamination, which may result in low diagnostic efficacy and a high possibility of false-negatives and false-positives. Therefore, tissue biopsy, including tissue homogenization and histopathology, is still considered the 'gold standard' for the diagnosis of burn wound infection [250]. Histopathology can accurately determine the extent of microbial invasion on deep normal tissues [251], providing the most direct evidence of bacterial infiltration on local normal tissues; it also has high diagnostic value and efficacy. Furthermore, a systematic review and several prospective observational studies have found that quantitative tests such as histopathology and tissue homogenization have higher clinical value and accuracy than qualitative tests such as swabs [252–256]. However, the restricted sample area, high requirements for sampling sites (including completely normal tissues in the deep part of the wound or the shallowest layer below the scab and the tissue at the border where the bacterial content is the highest or the

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subcutaneous fat tissue below the scab), and relatively time-consuming and labour-intensive procedures have limited the widespread implementation of tissue biopsy.

In addition, with the widespread application of modern molecular biology techniques, emerging methods such as genetic testing, serology and immunological testing are increasingly applied to microbiological testing [257]. The advantage of these methods is that they can accurately identify the types of microorganisms in wound specimens, including those that cannot be identified by culture-based techniques [258]. Although several case reports have used genetic testing techniques and molecular marker detection for specific pathogenic microbial subtypes in the diagnosis and treatment of burn wound infections, there is currently a lack of clinical research in this area, and the efficacy of these techniques has not yet been confirmed [259–263]. However, because there is no relevant large-scale clinical research, it is recommended to use these techniques only as a reference and not for routine testing [264].

Therefore, this consensus recommends that surface swabs be routinely performed when wound infection is highly suspected and the wound condition is mild. Tissue biopsies can be performed when infections are severe and have rapid progression or when further clarification of the infection is needed. Emerging molecular biology testing techniques can serve as important auxiliary testing methods, particularly in cases of rare or difficult-to-identify microbial infections.

Recommendation 48 (moderately recommended). It is recommended to collect multiple samples from different areas of the burn wound after cleaning at either regular or irregular intervals (evidence level: moderate).

Rationale. Wound microbiological culture is an important method for determining whether burn wounds are colonized by or infected with bacteria. In clinical practice, surface swabs or tissue biopsies are obtained from burn wounds for qualitative, semiquantitative or quantitative cultures to monitor infection. However, this method has certain disadvantages. It can only assess microbial colonization in the sampling area and cannot differentiate between bacterial infection and colonization. In addition, the relationship between microbial colonization and clinical outcomes cannot be solely determined by bacterial quantity, and it may also be influenced by factors such as bacterial species and patient conditions. Therefore, the collection of samples from different areas of the wound for multiple testing can ensure data reliability [263, 265]. Furthermore, the quality of the collected samples directly affects the testing results. Standardized collection is the first and most important step in obtaining high-quality specimens. Therefore, this consensus recommends that regardless of the sampling technique, microbiological testing specimen collection and submission should be standardized. It is recommended to collect multiple samples from different areas of the burn wound after cleaning and to periodically or irregularly collect samples based on the local dynamics of the wound, particularly when there are slight or significant changes in the local clinical manifestations. Surveillance of the wound microbiology should be improved to immediately clarify changes in microflora on the wound surface.

Clinical question 15: Treatment of second degree burn wound infection

Recommendation 49 (highly recommended). Treatment for mildly infected wounds should mainly focus on local wound management, including cleaning the wound, increasing the frequency of dressing changes, strengthening wound drainage, and, if necessary, removing the necrotic tissue (evidence level: moderate).

Rationale. When clinically determined to be mildly infected, a burn wound typically presents with local redness, swelling and pain, with purulent fluid limited to the surface or superficial layers. Pathogenic microorganisms invade the remaining necrotic tissue and superficial layers of the normal dermis. The preferred treatment options are removal of necrotic tissue and improved local dressing changes, which include increasing the frequency and enhancing the intensity of dressing changes (such as expanding the local cleaning range of the wound, expanding the debridement range, increasing wound drainage, etc). Wound disinfection and necrotic tissue removal are crucial steps in maintaining wound cleanliness. Necrotic tissue on burn wounds is rich in protein, thus providing a favourable environment for microorganism growth. Such tissue also lacks a blood supply, rendering antimicrobial components in the blood ineffective, thereby allowing pathogenic microorganisms to proliferate and invade normal tissues. The removal of necrotic tissue disrupts the favourable growth environment for pathogenic microorganisms and effectively reduces the microbial burden on the wound surface [266, 267]. In addition, topical disinfectants with broad-spectrum antibacterial activities and low toxicity (such as chlorhexidine, sodium hypochlorite solution and povidone-iodine) can be used to clean wounds and reduce contamination and colonization by pathogenic microorganisms. Moreover, excessive exudate from burn wounds can promote the growth of pathogenic microorganisms; therefore, it is recommended to strengthen wound drainage to prevent worsening of the infection.

Recommendation 50 (moderately recommended). The treatment for moderately infected second degree burn wounds should involve prompt local wound management, including aggressive surgical debridement to thoroughly remove necrotic tissue and, if necessary, the removal of infected tissues, along with systemic antimicrobial therapy (evidence level: moderate).

Rationale. Failure to effectively control mild infection of the burn wound can lead to the gradual invasion of pathogenic microorganisms on the deeper layers of the skin. Merely cleaning and changing the dressings of superficial wounds are insufficient to control infection in deeper layers and may worsen it. Therefore, if conditions allow, prompt surgical debridement is needed to completely remove the necrotic tissue and, if necessary, infected tissue, to further reduce

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the microbial burden on the wound. In addition, systemic antimicrobial therapy may be considered an adjunct treatment based on the patient's specific condition, clinical experience and microbial evidence to limit the spread of infection. However, for patients with a high risk of infection, such as those with extensive burns or severe immune dysfunction or immunosuppression, indications for antibiotic use should be appropriately relaxed based on the patient's actual condition.

Recommendation 51 (moderately recommended). The treatment for severely infected second degree burn wounds should involve immediate local wound management, prompt completion of surgical wound excision and systemic antimicrobial therapy (evidence level: moderate).

Rationale. When a burn wound infection penetrates the dermis or involves surrounding normal tissues, immediate strengthening of local wound management is necessary. If conditions allow, early surgical excision should be performed to thoroughly remove necrotic and infected tissues to reduce the microbial burden on the wound and prevent the systemic spread of infection. Simultaneously, immediate systemic antimicrobial therapy should be initiated [268, 269]. In the absence of microbiological and antibiotic sensitivity testing, broad-spectrum antibiotics may be used based on the microbiological characteristics of the ward environment and clinical experience to reduce bacterial burden and inhibit further invasion of pathogenic microorganisms into healthy tissues. Once microbiological test results are obtained, the antimicrobial strategy should be adjusted based on the results, and targeted sensitive antibiotics should be used.

Recommendation 52 (moderately recommended). Recommendation for the application of external disinfectants and antibacterial drugs/dressings for burn wounds.

(1) **Topical disinfectants with broad-spectrum antibacterial and low-toxicity properties, such as chlorhexidine, sodium hypochlorite solution and povidone-iodine, are recommended for cleaning infected wounds.**
(2) **Topical antibiotics/dressings (combining their pharmacological and antibacterial characteristics) for the treatment of burn-infected wounds are recommended, but it is necessary to balance their anti-infection benefits with the risk of delayed wound healing.**
(3) **Topical antibiotics/antibacterial dressings are not recommended for routine use in the prevention of burn wound infection.**
(evidence level: moderate)

Rationale. The disinfection of second degree burn wounds is different from conventional skin disinfection treatment. When selecting disinfectants, colorless and transparent disinfectants with broad-spectrum antibacterial effects and low cytotoxicity should be selected to minimize damage to normal tissues and reduce the risk of delayed wound healing.

In terms of the use of topical antibacterial drugs/dressings, we found that although local antibacterial drugs or dressings commonly used in clinical practice have broad-spectrum antibacterial activity, different types of local antibacterial drugs or dressings still have specificity for specific bacteria or wounds. Silver ions are the most common heavy metal element in local antibacterial drugs or dressings, such as in SSD cream, silver nitrate solution and silver-containing dressings. The silver cations have antibacterial activity against most bacteria and some fungi in a concentration-dependent manner [270] and resistance of microorganisms to silver is quite rare. However, the drawbacks of Ag^+ are also evident, as it is prone to inactivation and cannot penetrate below necrotic tissue, mainly playing a role in superficial infected wounds [271]. Other studies have confirmed that topical antibacterial ointment can effectively reduce the bacterial load in wounds, thereby achieving antibacterial activity and providing a moist healing environment [272]. Therefore, the treatment of targeted bacterial infections should be combined with the specific pharmacological and antibacterial characteristics of antibacterial drugs/dressings.

In addition, although topical antibacterial drugs/dressings can effectively reduce bacterial loads and infection levels, studies have reported that they may have adverse effects on wound healing, including pain and discomfort, sensitivity to itching, and cytotoxicity to cells involved in wound healing (such as keratinocytes, endothelial cells, and fibroblasts), which may lead to the risk of delayed wound healing [273]. Therefore, the selection and formulation of treatment plans for burn wound infection need to balance the benefits of anti-infection and the risks that may lead to delayed wound healing. At the same time, multiple factors, such as the patient's personal situation and economic status, should be considered, such as the economic cost of dressing use, dressing changes, patient compliance and treatment willingness. At the same time, the cost–effectiveness ratio brought by actual medical investment should be considered to strive for maximum benefits. Meanwhile, considering the adverse effects and cytotoxicity of topical antibacterial drugs/dressings on wound healing, and in order to reduce the risk of delayed wound healing that may exist with topical antibacterial drugs/dressings, this consensus does not recommend the routine use of topical antibacterial drugs/dressings to prevent burn wound infection.

Clinical question 16: Special examination and treatment of fungal infection wounds

Recommendation 53 (moderately recommended). For suspected fungal infections in wounds, it is recommended to use routine surface swabs for fungal culture and microscopy (such as smear testing and PAS staining) and perform tissue biopsy, if necessary. When systemic fungal infection is suspected, it is recommended to combine imaging, G test, (1,3)-β-D-glucan assay, and molecular biology techniques, such as PCR and NGS, for joint testing (evidence level: moderate).

Rationale. With the increasingly widespread use of topical antimicrobial agents and systemic broad-spectrum antimicrobials, wound fungal colonization and infection are becoming more common; invasive fungal infection is

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associated with significantly increased morbidity and mortality. In addition to the use of broad-spectrum antibacterial drugs, factors associated with invasive fungal infections in burn wounds include tracheostomy intubation, mechanical ventilation, parenteral nutrition and invasive monitoring [274]. Due to improvements in fungal infection diagnostic technology and increased awareness among health care professionals, the reporting rate of fungal infections has increased [245]. However, the early diagnosis of fungal infections is not reliable, as the clinical symptoms are not obvious and are often confused with those of bacterial infections. Histological evidence of fungal hyphae in wound tissue and evidence of fungal microbiological culture are the gold standard for the diagnosis of fungal infections [275]. However, the results of routine fungal culture may be obtained within 7–14 days, often delaying treatment initiation [275]. On the other hand, molecular biology detection techniques such as PCR and NGS have higher sensitivity and reproducibility in detecting fungal DNA; furthermore, they are rapid and efficient, thus providing better evidence that supports early clinical diagnosis and compensates for the long detection time needed for routine fungal culture [276, 277]. Laboratory evidence from blood tests such as G tests and (1,3)-β-D-glucan (GM) assays also contributes to clinical diagnosis [278, 279]. Two clinical studies have found that the GM assay has comparable sensitivity and specificity for diagnosing fungal infections, and it was found to detect infection more than a week earlier than radiological findings [280, 281]. However, these tests have various interfering factors (e.g. the use of semisynthetic penicillin, haemodialysis, consumption of high-protein foods such as milk) that can cause false-positive results. In addition, because invasive fungi such as *Aspergillus fumigatus* often involve the airways and lungs, chest imaging can quickly detect invasive fungal infections [282]. Early detection of nodules and 'halo signs' on consecutive chest CT scans strongly suggests invasive fungal infections and can facilitate early intervention and improve prognosis [283]. However, the aforementioned testing methods have not been extensively studied in large-scale clinical trials to validate their clinical efficacy and cannot be used as diagnostic criteria alone. They need to be used jointly with multiple methods to verify the authenticity of the results.

Recommendation 54 (moderately recommended). Special treatment of wound fungal infection.

(1) Based on the severity of fungal infections in burn wounds, it is recommended to promptly remove necrotic and infected tissues. For mild infections, it is recommended to use topical antifungal agents to control infections. On the other hand, for moderate-to-severe infections, immediate systemic antifungal treatment and early surgical debridement are recommended.

(2) Based on the invasive characteristics of fungi, it is recommended to start systemic antifungal drug therapy as soon as the wound is found to be infected with more invasive fungi, such as moulds, and to complete surgical debridement as soon as possible.

(evidence level: moderate)

Rationale. Patients with extensive burns, long-term use of broad-spectrum antibiotics and immune dysfunction-related diseases, as well as elderly burn victims are all susceptible to fungal infections. In addition, the larger the burn areas and the longer the exposure time, the higher the risk of fungal infections. At present, the clinical manifestations of fungal infections in burn wounds are relatively typical and easy to recognize, but the infection presentations or invasive characteristics of different fungi vary significantly. This consensus divides fungi into weakly invasive fungi and strongly invasive fungi based on their invasive characteristics. Fungal infections with weaker invasiveness are often characterized by the proliferation and colonization of fungi on the surface of the wound, with less invasion of the entire skin layer. The main representatives of this type of infection are Candida spp. and yeast-like fungi. On the other hand, the clinical manifestations of strongly invasive fungal infection are mainly moderate-to-severe infection and may be accompanied by thrombus formation and ischaemic necrosis in more severe cases. The main representatives of this type of infection are moulds (such as Aspergillus spp. and Mucor spp.). The main treatment approaches for the two types of infection are also different. For confirmed weakly invasive fungal or mild infections, the focus is mainly on local treatment of the wound, removal of necrotic tissue and potentially infected tissue, and use of topical antifungal agents to control the spread of the infection [244, 284]. For highly invasive fungal infections or moderate-to-severe infections, systemic invasion should be avoided, and immediate surgical wound debridement should be performed to remove all potentially infected tissues and ensure that the surgical margins are not contaminated by fungi. Meanwhile, high-dose topical and systemic antifungal drugs should be used to control infections, and early skin grafting should be performed to close the wound [285, 286].

Clinical question 17: Infection control and prevention in the burns ward

Recommendation 55 (highly recommended). Strict implementation of hand hygiene is recommended to prevent cross-infection of burn wounds (evidence level: high).

Rationale. Hand hygiene is considered an important means to prevent nosocomial infections, particularly cross-infection [287, 288]. Many observational studies have confirmed that physical direct contact, particularly hand hygiene [289], is the most important factor for exogenous burn wound infection [290].Although there is systematic evaluation results indicating that there is not enough evidence to determine which strategies or interventions are more effective than strengthening hand hygiene [291]. Given the importance of hand hygiene in preventing antibiotic resistance and bacterial reinfection in burn units, this consensus recommends strict implementation of hand hygiene

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policies and practices, particularly routine hand disinfection and glove change before and after any patient contact.

Recommendation 56 (highly recommended). Strict implementation of isolation measures between patients and medical staffs as well as between different patients is recommended to prevent cross-infection of burn wounds (evidence level: moderate).

Rationale. Medical personnel items (including gloves, clothing and cell phones) are among the most important factors in exogenous burn wound infections [292–296]. Other causes of cross-infection of burn wounds include the use of immersion bath hydrotherapy systems [297], unsterilized mattresses [290], hand-held shower sprays [298] and shower stretchers [299]. Therefore, this consensus recommends strict implementation of isolation measures including: wearing isolation clothing and sterile gloves before coming into contact with patients; avoiding wearing ties, watches and other accessories that can easily carry germs; reducing visits; setting up independent wards; and not sharing daily necessities, instruments and equipment.

Recommendation 57 (moderately recommended). Ward environmental settings and disinfection requirements should follow uniform hospital-accessibility regulations; additional implementation of more stringent environmental standards is not recommended (evidence level: moderate).

Rationale. A previous systematic review [300] concluded that routine surface disinfection, especially of floors, was not superior to cleaning surfaces using common detergents in controlling cross-contamination and that the effectiveness of environmental disinfectants in controlling infection could not yet be demonstrated. Another systematic review [301] found that more elaborate environmental isolation methods, such as the use of isolators, reduced the quantities of airborne bacteria but did not improve the infection rates of *S. aureus* and *P. aeruginosa*, had a limited impact on the multidrug resistance of the flora, and finally failed to effectively reduce the incidence of infection. Based on the aforementioned negative results, and in combination with the existing requirements for hospital infection control in the existing ward environment in China, this consensus posits that the existing environment has partially met the requirements and that the infection caused by the environment only accounts for a small portion of the overall infection under the existing conditions. Furthermore, the consensus holds that environmental factors are not the leading cause of current hospital-acquired infection. Therefore, this consensus does not recommend the additional implementation of separate and special environmental standards for burn wards.

Recommendation 58 (highly recommended). The microbiological characteristics of the ward environment should be regularly monitored, and ward clinicians should organize a targeted selection of antibiotics to address common bacterial strains in the environment and develop a periodic replacement strategy for antibiotics to reduce multidrug resistance in the environment (evidence level: moderate).

Rationale. Several systematic reviews [302, 303] and retrospective studies [304] have demonstrated that the higher the rate of colonization by drug-resistant bacteria, such as methicillin-resistant *S. aureus*, in burn patients, the higher the level of health care utilization and the rate of complications. Therefore, it is necessary to implement pragmatic prevention strategies. In addition, a previous study [305] found that regular microbial monitoring (at least weekly) can help in the identification of microbial trends and adjustment of the use of topical antimicrobials, thus facilitating better and more effective prevention of iatrogenic infection. Furthermore, some studies have shown that irregular use or abuse of antibiotics not only fails to effectively prevent and treat burn wound infection but also promotes the emergence of multidrug-resistant bacteria [306]. These results indicate that regular microbial monitoring in the ward, systematic summary of the pathogenic microbial characteristics of burn wound infection, and drug sensitivity results of related microorganisms can help elucidate the trend of pathogen transmission in the hospital. This will facilitate the formulation of appropriate response plans, including antibiotic use and regular turnover plans, which can in turn change the microbial characteristics of the environment. The development, implementation and monitoring of local antibiotic stewardship programmes should be part of a broader strategy for hospital infection control.

Conclusions

Second-degree burn wounds are the most common type of burn in clinical practice and the most difficult to manage. Their treatment requires not only a consideration of the different outcomes that may arise from the dressing changes or surgical therapies themselves but also an evaluation of factors such as the burn site, patient age, and burn area. Standardized treatment can effectively prevent deepening of the wound in second-degree burn wounds while improving the quality of wound healing. However, there are no unified standards or specifications for the diagnosis, classification, surgical procedure, and infection diagnosis and grading of second-degree burn wounds, which seriously affects the development of clinical treatment programs. Based on evidence-based medicine and expert recommendations, this consensus gives recommendations for the treatment of second-degree burn wounds, aimed at forming a set of highly operable clinical practice guidelines for second-degree burn wounds. This consensus clarified and standardized the terminology related to second-degree burn wounds, including for the first time further dividing deep second-degree burn wounds into shallow deep second-degree and profound deep second-degree burn wounds, which provided a decision-making basis for standardizing the relevant diagnosis, classification, and treatment of second-degree burn wounds. However, given the current insufficient evidence from large-scale randomized controlled trials, many of the recommendations in this consensus are preliminary and still need to be supported by further evidence. In addition, considering the cultural traditions, economic levels, and patients' educational backgrounds and religious beliefs in different geographic regions, clinical staff

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may adapt the recommendations in this consensus in light of local medical resources and health conditions.

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Conflict of interest

The authors have disclosed that they do not have any potential conflicts of interest.

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Appendix

Consensus on the Treatment of Second-Degree Burn Wounds (2024 edition)

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