Burn Wound Infections: A Review Article

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Abstract

Burn wounds induce metabolic alterations that predispose the patient to various complications. nfection is the most common cause of morbidity and mortality in this population. Bacterial profile of burn wound patients is diverse, depending on timing and location of injury. Early after burning, the predominant microorganisms are gram-positive bacteria such as Staphylococcus aureus. Subsequently, the burn wound colonizes with a variety of microorganisms comprising both susceptible and multi-drug resistant gram-negative bacteria such as Pseudomonas aeruginosa and Acinetobacter species. This review will help in understanding the epidemiology of burn wound infection and the prevalence of highly resistant bacteria in burn wound patients. In addition, it illustrates the role of strict infection control practices in preventing the nosocomial transmission of microorganisms among burn patients, and it provides guidance for empiric antibiotic therapy to avoid unnecessary broad antibiotic usage, which will reduce mortality and morbidity related to infections and decrease incidence of multi-drug resistant organisms in burn units.

Key words: Burn, Bacterial, Infections, Prevalence, multi-drug resistant organisms.

Introduction

Burn wound infection, is a very common problem all over the globe and is caused by pathogenic bacteria whether by gram-negative or gram-positive bacteria. In the last 50 years medicine has been witnessing great progress in the treatment of such complications. Burn wound infection is considered as a thermal injury (1). The treatment of such thermal injuries requires specials units. When they were treated between the 1950s through to mid-1980s as conservative therapy, sadly researchers did not fully comprehend at that time, when the scar, dead tissue on the skin, was removed, there would be a bed of microorganisms that could be mishandled by the caregivers and transmitted by their hands, by fomites i.e. clothing, soap, or any material capable of transmitting infectious diseases, and in some studies, even through the air (2). It is important to know what could be the most prevalent bacteria that is associated with a burn wound, so that it would help healthcare providers to start treating the patient as soon as they walk through the door (3). Such review is also important to know what bacteria is likely to be spreading, and stop it (3). The area where burn infections happen usually have a mix of bacteria, like normal flora, which are harmless to the body, but cannot be recognized in a burn-wounded patient (1). The review will help in a better understanding of what might be the predominant bacteria in burn wound patients; it will also help in identifying the highly resistant bacteria in those patients.

Skin as the major host defence mechanism

The skin is composed of three layers; the epidermis and the dermis layers are disunited by a basement membrane area and the final layer is the subcutaneous tissue (4). The intact human skin surface is considered as the first-line human defence mechanism which is vital for the body's homeostasis through the regulation of fluids, body temperature, and protection against infections(4). When trauma or thermal injury specifically disturbs the defence system many complications can occur(5). Burn wound infections are one of the most common forms of trauma that are likely to happen(1,6). Patients with serious injuries require immediate intervention to reduce the risk of both associated morbidities and mortality. The incidence of thermal injuries in the east Mediterranean region alone was estimated to be between 112 to 518 in every 100,000 per year in a systematic review study conducted in 2010, while hospital mortality reached 20% of the cases(5).

The etiology of burn wounds

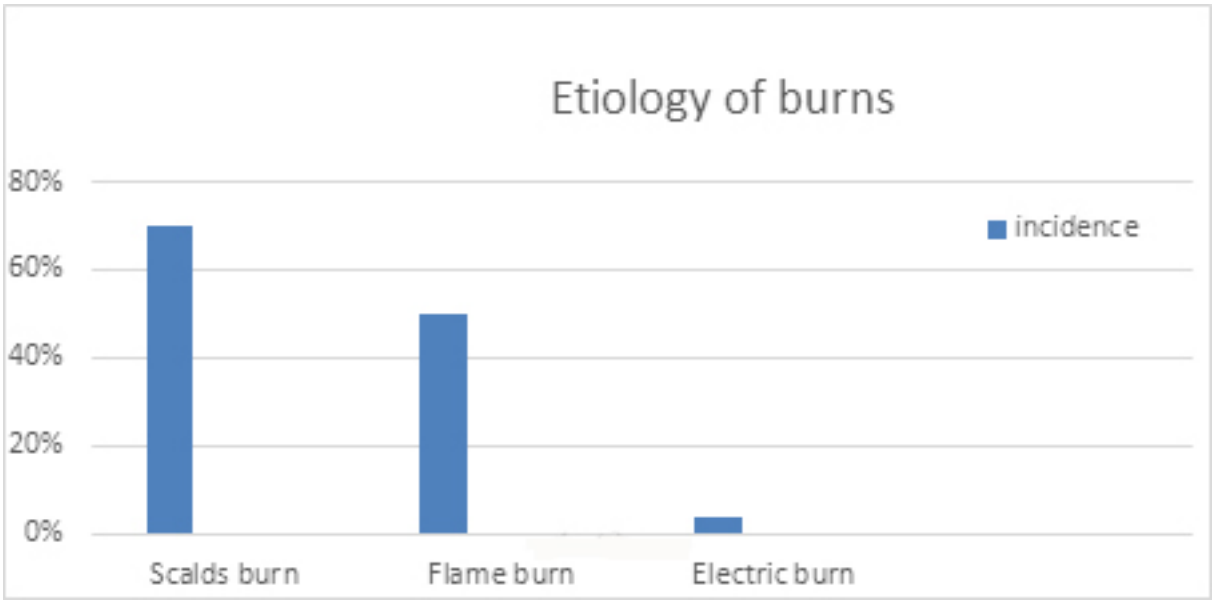
Burn injuries can be caused by a variety of environmental factors, which in addition, could be both minor and life-threatening. The majority of burns are called thermal burns since they are caused by scalds, flame, and contact with extremely hot objects. Other types of burns are electrical and chemical types of burns and they differ from thermal injury in that they tend to cause more drastic damage. Scalds are wounds that affect the skin and are caused by a hot liquid, and this type of incidence most often occurs in children amounting to 70% of burns, but they can also occur with the elderly population(7). Scalds tend to cause superficial dermal burns. On the other hand, flame burns are caused by fire, and amount to 50% of burns in adults, and the injuries tend to be deep dermal or full-thickness(7). Nevertheless, contact with a hot object is the most prevalent and tends to cause deep dermal or full-thickness burns. Electrical burns, on the other hand, are caused by the current of electricity that travels throughout the body creating entry and exit points in all layers of the tissue causing grievous damage; however, the voltage is the main determinant of the degree of tissue damage, and luckily only 3-4% of burns in admissions are caused by the electrical injury(7). Finally, chemical injuries, which are usually caused by industrial accidents, are a type of burn that tends to be deep, alkali, for example, and can penetrate the skin deeper than acid(7).

The pathophysiology of burns

A burn wound is a thermal injury caused by biological, chemical, electrical, and physical agents with local and systemic responses.1,7). Keeping that in mind, the pathophysiology of burn wounds can be characterized as an inflammatory reaction that leads to rapid edema formation (1,7). Nevertheless, understanding the pathophysiology of the burn wound in depth is vital to improving the overall management of patients; however, one must say that it is a complex process as burn wound etiologies lead to various types of injuries which in turn lead to different management processes (7).

Burn wounds result in both local and systemic responses(7). The local change was described by Jackson in 1947 and consists of the formation of three zones (8). The first zone is the coagulation zone in which it forms the maximum damage and is characterized by necrosis and irreversible tissue damage due to coagulation of the constituent Proteins (8). The second zone is the area of stasis which is considered to be peripheral to the zone of coagulation and is characterized by a decrease in tissue perfusion (8). Finally, the zone of hyperemia, which is the outermost zone where the tissue perfusion is increased (8). The systemic response, however, is mediated by the release of cytokines and other inflammatory mediators which have a systemic effect once the burn wound reaches 30% of the total body surface area (7).

Figure 1: Etiology of Burns



At the level of the cardiovascular system, there would be a loss of intravascular proteins due to the increase in capillary permeability which will lead to leakage of proteins into the interstitial compartment, and the myocardial contractility will be decreased due to the release of tumor necrosis factor α (7,8). These changes combined with fluid loss due to the burn wound, result in hypotension and hypo-perfusion at the level of organs (7,8). Also, there would be a respiratory response to the burn wound; due to inflammatory mediators which cause bronchoconstriction, and in severe burn wounds, the patient may develop respiratory distress (8). Additionally once the metabolic state is activated, the metabolic rate will increase up to three times its original rate (8). Lastly, the immune system changes which are characterized by down-regulation of the immune response affect both cell-mediated and humoral pathways (8). These changes generate a greater risk of developing infections, and in several studies, they found that sepsis is the leading cause of death among patients affected by burns.8,9). Burn Infection is defined as the presence of high concentrations (>105 organisms/g of tissue) of bacteria in the burn wound and scab (7).

The Etiology of burn Infections

The Etiology of infection in burn patients may arise due to a variety of factors. These factors can be sub-divided depending on the patient's physical and medical history. The clinical intervention must be provided in hospital settings or a living environment. In regard to the burned patient status, the relation between prevalence of burn infections and the patient immunity is well-established since the skin is considered as a first-line host defence mechanism of the body, therefore when this barrier is disturbed by a burn or any traumatic event, such as a disease or as a part of the natural aging process that will make the body vulnerable to infections (1). It is also clear that very young children, besides the elderly, have an increased risk of being burned and worse clinical outcomes than patients in other age groups(1). Moreover, medical history of underlying diseases such as diabetes mellitus, end-stage chronic kidney diseases, and liver failure might be a risk for weakened immunity and because of that developing infection factors include high body mass index (BMI), or usage of immunosuppressants like corticosteroids for certain medical conditions(1). It is also important to consider the site of the burn wound and percentage of total body surface area involved since this factor can be a major determinant of the type of infection that is possibly going to arise and its complications (1).
Hospital settings are also a core risk factor for patients with burns where different types of infection in association with each clinical intervention can develop. For example, burn wound infections of impetigo, open burn-related surgical wound infections, cellulitis, and invasive infections in unexcised burns in which patients become prone to develop more invasive infections(1). Furthermore, since colonization of the normal flora can be a source of infection, sometimes swabbing and hydrotherapy can lead to infections(1,10). Burn unit outbreaks of infection have been attributed mainly to contaminated Hubbard hydrotherapy tanks or water but in other cases to contaminated surfaces such as the patient's mattress (1). Despite the recognized infection risk of immersion hydrotherapy treatment in burn units, this was standard practice in many specialized burn centers until the 1990s(1). Lastly, health care providers are one of the most common sources of nosocomial infections as they are dealing every day with different medical cases which ease the transition of pathogens between patients unless very strict caution is taken into consideration (10).
Also, lifestyle, living, and work environment are all important risk factors. Those factors are concerned with the prevalence of pathogens in particular areas which could be various and increase the risk of easily being infected by them directly or through delaying the healing process (11,12).

The Prevalence of Bacteria in Burn wound and its importance

The reviewed articles were divided into two sections; the first part explored the prevalence of Bacteria and the second part the importance and reason for such prevalence. For the prevalence and the consideration of the environmental factors and the accuracy of articles the searched studies were conducted according to the closest regional area to Riyadh then to the furthest in a timeline of the last 5 years.

We started with Taif in Saudi Arabia since the capital Riyadh and the surrounding area lacked the required articles. The 2016 paper conducted the following predominance of bacteria in burn patients: Staphylococcus aureus, Klebsiella pneumoniae, and coagulase-negative Staphylococci were the most frequently isolated organisms, each demonstrating (20.2%), next to Pseudomonas aeruginosa (14.6%) and finally E. gram-negative(13). Comparing such results to a nearby geographical area but with a 26 year time difference, the book was titled Diseases and Agents of Klebsiella concerns to Veterans of the Gulf War. The book dates events that happened back to 1990-1991 and stated the following about soldiers who had burn blast bacterial isolates: of the 40 bacteria obtained, 30 were Gram-positive obtained from soldiers before they received antibiotics. Gram-positive commensal skin bacteria such as Staphylococcus spp. and Micrococcus spp. were found in 93% of isolates. Less common were gram-negative bacterial genera, such as Pseudomonas, Chryseobacterium, and Escherichia(14).

Moving to Iraq, Baghdad in particular, a 2016 paper informed that in a total of 182 burn patients the paper showed a prevalence of 14 (7.53%) as gram-positive Staphylococcus aureus. Gram-negative isolates were 172 (92.47%). From those 172 gram-negative bacteria the most frequently isolated bacteria were Pseudomonas aeruginosa 60 (32.26%) isolates followed by Acinetobacter baumannii 40(21.51) (15). According to the Canadian Institute of Health Research, gram-positive bacteria Staphylococcus aureus remains the leading cause of burn wound infection followed by Streptococcus and enterococcus. Gram-negative pseudomonas didn't only show prevalence, it also showed its predominance in burned-linked death by sepsis.(9).

Table 1: **The etiology of burn wound infection in different studies and their correlation with comorbidities.**

Taif	Iraq, Baghdad	Canadian	Comorbidities
Staphylococcus aureus 20.2%.	Staphylococcus aureus7.03%.	The most common organism is gram positive bacteria (Staphylococcus aureus followed by streptococcus and enterococcus).	- DIABETES MELLITUS. - End-stage chronic kidney disease - Liver failure - High BMI score - Immunosuppressed patients. - Impetigo. - Cellulitis.
Pseudomonas aeruginosa14.6%.	Pseudomonas aeruginosa32.26%.		
E. coli 10.1%.	Acinetobacter baumanii 21.51%.		

The overall reviewed articles state the high rates of mortality and morbidity are caused by burn injuries which represent a massive global health threat. Burn injuries are diverse but are unified in that they all involve necrosis of the largest organ of the body, the skin. The skin is one of the most important immune defence mechanisms(16). Such injuries do not only cause physical deformities but also cause immense psychosocial and emotional damage(17). Sepsis syndrome and bacteraemia are some of the most constant infectious complications in burn patients in the ICU; the two most common isolates from blood cultures are P. aeruginosa and K. Pneumonia (18).

The recent predominance of bacteria that build resistance against antibiotics

The search of the articles was done in consideration of the epigenetic factor according to the geographical area. The chosen reviewed papers population represented the Middle Eastern community starting from the closest region to the capital of Saudi Arabia, Riyadh to the furthest area in Africa, in a timeline of 6 years. Antibacterial resistance has been referred to as the silent tsunami facing modern medicine(3). The reviewed articles showed the shortcomings in the reports and surveillance, which may affect the regular updates regarding the constant developing resistance. Starting from Saudi Arabia the reviewed articles regarding the predominant bacteria that devolved resistance showed a lack in published papers according to Al-Ali who studied 220 admitted patients in the burn unit of AlHada Military Hospital, Taif back in 2015. The predominance of bacterial resistance was reported as the following; gram-negative bacteria resistance: E. coli found to be resistant in 89 out of 220 cases representing 40.4%. Pseudomonas aeruginosa 87 (39.5%). Klebsiella pneumoniae 62 (28.1%), while Proteus mirabilis 33 (12.7%). In contrast, Morganella morganii found to be resistant in 22 out of 220 cases representing 11.3%. Acinetobacter baumannii 43 (19.5%). Gram-positive bacterial resistance: Staphylococcus aureus was found to be resistant in 44 out of 220 cases representing 20%. However, coagulase-negative staphylococci were 50 out of 220 yields representing 22.7%, while Enterococcus facium were recovered from 10 out of 220 cases (4.5%). The result of this study revealed that resistance of Staphylococcus aureus to 15 antibiotics, and was fully susceptible to oxacillin, vancomycin, and apmecillin/sulbactam(13).

A nearby geographical study, which was done in Bahrain recently, showed that Gram-positive bacteria S.aureus was predominant in initial cultures. It was however, succeeded by Gram negative bacteria Pseudomonas(19). Research which dates to 2012 regarding the prevalence of antimicrobial resistance in clinical isolates from the whole Gulf Corporation Council countries stated that the most prevalent microorganism was Escherichia coli (10,073/44%), followed by Klebsiella pneumonia (4,709/20%), Pseudomonas aeruginosa (4,287/18.7%), MRSA (1,216/5.4%), Acinetobacter (1,061/5%), with C. difficile and Enterococcus representing less than 1% (2). A study which was done in a tertiary burn care hospital in Tehran with 3 wards (for men, women, and children separately) indicated that P. aeruginosa is the most prevalent Gram-negative bacterial species isolated from burn patients; A. baumannii and S. aureus were the second and third most prevalent species (20). A cross-sectional case-control study included 220 Iraqi patients who had burns (third-degree) with a total body surface area which ranged from 30-75% and admitted to the burn Department at Al-Kindy teaching Hospital between January – 2013 to June – 2013 indicated that burn is more common in females than males and females with infected burn (28.63%) were more common than males (11.36%). Klebsiella pneumonia is the most frequent bacteria isolated from the burn (44%) and in both sexes, females and males, 41% and 45.56% respectively from burn patients.

Klebsiella Prevalence of Bacterial Pathogens Infections in Patients with Burn Wounds (10)

Pneumonia is the most frequent bacterial isolated from the burn (80.9%). Pseudomonas aeruginosa is also resistant to these antibiotics (93.75%). Acinetobacter spp. and Bruckholderia spp. were also resistant to gentamycin, Ceftriaxone, and Cefotaxime (100%). In the case of Gram-positive bacteria, Staphylococcus aureus was resistant to imipenem (90.75%) (21). The most recent study was found in the burn and plastic surgery department, Aljalla Hospital Benghazi dated in October 2018 which stated the predominance as the following:

The most predominant bacterial isolate was Staph. Albus (33.6%), followed by Klebsiella (29.5%), N.L.F (14.7%), Pseudomonas(11.47%). E.coli (5%),N.H.S(4.1%), Staph. aureus (1.6%). Of the 11 nasal swabs obtained from nursing staff in the department,(81.8%) of them were pathogenic; predominant bacterial isolate was Staph. albus (30.7%), N.H.S (30.7%), N.L.F (23%), Klebsiella (15.3%), while11 hand swabs were obtained; (54.5%) were pathogenic, Staph.albus (50%), N.H.S (25%), N.L.F (15%), Klebsiella (10%). Of a total of 31 burned patients, 21 (67.7%) were females and 10 (32.2%) males. 120 burn swabs were collected from them, and the predominant bacterial isolate was Pseudomonas (50.8%), Staph. aureus (16.7), Klebsiella (13.3%) ,Acinetobacter (10%), Enterobacter (2.5%), E.coli (2.5%), N.H.S (2.5%), Proteus (0.8%), Staph. Albus(0.8%). Among these isolates P. aeruginosa was found, and was highly resistant for most of the antibiotics tested (22).

The therapeutic approaches and management of burn wounds

Burn wound patients have a massive psychological and physiological impact more than any other types of injuries. Therefore, if the healthcare provided to them is insufficiently prepared, patients will induce further injuries and won't be healed properly. The initial evaluation of the injured surface and the depth of the wound at the time of admission is essential. After examining the burn wound severity by different methods, fluid replacement during the first 24 hours after the injury is applied. Despite all the improvements in therapy, the infection will remain the major cause of morbidity and mortality in burn-injured patients. In addition, infections do not only slow the healing process within the burn wound but also can lead to systemic infection and block adequate skin grafting. Therefore, including a broad-spectrum antimicrobial activity in topical agents will decrease the wound infection. Even though wound injury is considered a special kind of injury, the healing of these injuries will not differ from other types. Recent studies showed that hydration is the ultimate factor responsible for best wound healing (23). Since the definitive decisions regarding dressings or surgery are made after 48 hours of the burn review, the initial dressing needs to have the ability to remain for 48 hours without any infection. One of the famous initial dressings is Acticoat (Nano-crystalline silver dressings); the silver in its content is toxic to pathogens. As silver dressing could inhibit fibroblasts and keratinocytes, which could prolong the healing process after 48 hours of use we change it to other dressings such as , Hydrocolloids, foams, alginates, and hydrogels. The healing process requires sun protection and moisturizers. Healing time depends on the patient's wound severity, depth, pigmented skin, and genetic history of scar healing. Therefore, further treatment will depend on the individual patient's case (24).

Conclusion

Burn wound is considered a rapid inflammatory reaction that leads to edema formation, hence lack of intact skin surface and skin integrity. Lack of skin surface compromises the first line of defence mechanism resulting in burn wound infection, which is considered as the most common form of trauma. The most common etiology of burn is caused by thermal injuries, and the thermal injures are divided into three sectors; scalds, flame and contact with extremely hot objects. Scalds are considered more severe to flame and to contact with extremely hot object.

Gram positive Staphylococcus aureus is considered the predominant leading cause of burn wound infection in Taif, Saudi Arabia and by the Canadian Institute of Health Research , whereas p. aeruginosa was predominant in Baghdad, Iraq. The predominant bacteria that developed resistance according to the Al Ali Study in Saudi Arabia was gram-negative bacteria E. coli while in the Bahrain study Gram-positive bacteria S. aureus was predominant. To reach the maximum therapeutic management of burn wound a thorough evaluation of burn wound should be reached. The depth of the wound at the time of admission is essential, as well as patients' comorbidities. Early fluid rehydration and broad spectrum antimicrobial topical agents are lifesaving to facilitate wound healing and skin grafting, if needed.

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