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طنجة

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Epidemiological and clinical characteristics of severe burn patients: Experience of the plastic and reconstructive surgery and burns department in the Mohamed VI University Hospital of Tangier

Thesis
Presented & publicly defended on: 17/04/2024

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To obtain the diploma of
Doctor of Medicine

Key words: Severe burns - Prognosis – burn management - Skin grafts

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At the time of being admitted as a member of the medical profession:

I SOLEMNLY PLEDGE to dedicate my life to the service of humanity; THE HEALTH AND WELL BEING OF MY PATIENT will be my first consideration

I WILL RESPECT the autonomy and dignity of my patient

I WILL MAINTAIN the utmost respect for human life

I WILL NOT PERMIT considerations of age, disease or disability, creed, ethnic origin, gender, nationality, political affiliation, race, sexual orientation, social standing or any other factor to intervene between my duty and my patient;

I WILL RESPECT the secrets that are confided in me, even after the patient has died;

I WILL PRACTICE my profession with conscience and dignity and in accordance with good medical practice;

I WILL FOSTER the honour and noble traditions of the medical profession;

I WILL GIVE to my teachers, colleagues, and students the respect and gratitude that is their due;

I WILL SHARE my medical knowledge for the benefit of the patient and the advancement of healthcare;

I WILL ATTEND TO my own health, well-being, and abilities in order to provide care of the highest standard;

I WILL NOT USE my medical knowledge to violate human rights and civil liberties, even under threat;

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Declaration of Geneva, 1948.

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Dedication

Dedications:

This thesis goes to:

My warrior father: Bellafkih Abdelbaset

I am immensely grateful to you for being my hero and inspiration throughout my life. Your love for modesty, generosity, and kindness have taught so much. Your unwavering support and encouragement have propelled me forward, especially in my academic journey of becoming a doctor. Your sacrifices for me and my brother have not gone unnoticed, and I deeply appreciate all that you've done. Thank you for being my guiding light and believing in me every step of the way.

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High Education Professor of Dermatology

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Associate Professor of Plastic and Reconstructive Surgery

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High Education Professor of Paediatric Surgery

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Abbreviations

Abbreviation's list:

WHO: World Health Organisation

Y.O: Year old

i.e.: id est

IV: Intravenous

PPI: Proton-Pump inhibitors

IL6: Interleukin 6

TNF: Tumoral necrosis factor

NO: Nitric monoxide

CO: Carbon monoxide

CN: Cyanide

ACS: Abdominal compartment syndrome

CS: Compartment syndrome

UBS: Unit burn score

SAMU: Service d'aide médicale urgente

IVS: Institut de veille sanitaire

mL: Milliliter

Kg: Kilogram

V: Volt

Kcal: Kilocalories

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Introduction

A burn is defined as partial or total destruction of the skin, mucous membranes and/ or underlying soft tissue, caused by a variety of agents such as heat, electricity, radiation, and corrosive substances.

Most burns are caused by thermal energy including scalding and fires, with the minority caused by exposure to chemicals, electricity, ultraviolet radiation, and ionizing radiation.

Burns can be intentional (violence, aggression, suicide, etc.) or accidental (road accidents, accidents at work, accidents in everyday life).

As it continues to constitute a medical, psychological and economical problem, severe burns remain among the most devastating of injuries leading to long-term profound alterations even after the wounds have healed, which affects not only the physical health but also the mental health and quality of life of the patient, placing a high burden on them, their families and on national healthcare systems.

Globally, burns are considered a public health problem, with non-fatal burns acting as leading cause of morbidity, including prolonged hospitalization, disfigurement and disability, and accounting for an estimated 180 000 deaths annually [1]. This number is still highly underestimated, as most accidents occur in low- and middle-income countries where there are no accurate statistics or epidemiological surveillance systems.

In Morocco, the situation regarding the number of burns at national level is not precise, as there are no reliable epidemiological studies on the subject, apart from a few fragmentary studies. However, it is still considered a real public health problem and the risk of burn injuries is very high given the frequent use of gas resources and fire in cooking and other daily activities.

The aim of the present study is to describe the epidemiological, clinical and evolutionary profile of burn patients treated in the plastic surgery and burns department at the Mohammed VI University Hospital Centre of Tangier, in order to propose preventive attitudes and recommendations adapted to our context.

Patients & Methods

I. Patients:

This a retrospective study of all burn patients hospitalized between October 2021 and December 2023 in the plastic and reconstructive surgery, and burns department at the Mohammed VI University Hospital Centre of Tangier.

1. Inclusion criteria:

The subjects included in the study were patients hospitalized directly or transferred from another facility following a burn injury.

- Regardless of gender
- Regardless of age
- Regardless of origin
- Regardless of their general condition or other associated injuries
- Regardless of their medical history

2. Exclusion criteria:

- First degree burns
- Patients who died within minutes of admission, or who died on arrival.
- Patients with incomplete records of initial treatment.

II. Methods:

1. Data collection:

Data collection was carried out using a data processing form designed to provide information on 3 aspects:

- the first part covers patient demographics (age, gender and date of admission)

- the second concerns the patient's pathological and/or toxic history, and the clinical characteristics of the burn (type of burn, causal agent, degree of burn, burned body surface, area of burn, prognostic indexes);

- the third part concerns the patient's outcome, in this case, the patient's evolution (death or survival) and sequelae.

2. Statistical analysis:

Data entry, data analysis, results, tables and graphs were prepared in Excel and then in Word for the final document.

Results

I. Characteristics of the study population:

1. Overview:

In our study, 73 cases of burns of all types were recorded from October 2021 to December 2023, and hospitalized in the plastic and reconstructive surgery and burns department at the Mohammed VI University Hospital Centre of Tangier.

2. Gender:

In our case series, 59,8% of the 73 cases of burns studied were male and 40,2% were female (Figure 1), with a male/female sex ratio of 1.5.

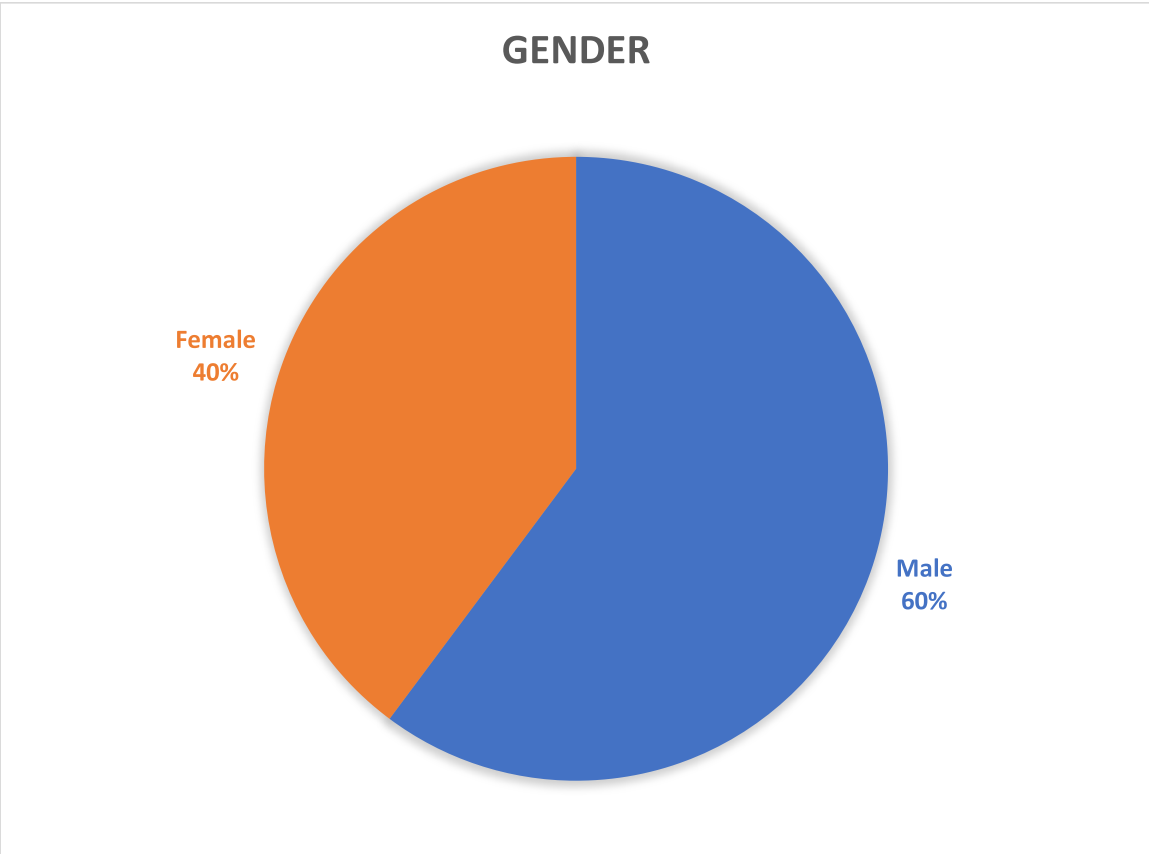


Figure 1: Distribution of the sample by gender

3. Age:

Patients ranged in age from 10 months to 83 years, with an average age of 27 years. In our series, children aged less than 12 years accounted for the biggest percentage of hospital admissions with 36%, while adolescents aged between 13 and 19 years only accounted for 8%, which is the lowest percentage. Young adults aged between 20 and 34 accounted for 27%, while adults aged between 35 and 50 represented 18%. Patients aged over 50 accounted for 11% of cases (figure 2).

For our paediatric patients the majority were less than 4 years old accounting for 46% of children with an average age of 3,6 years.

For our adults patients the majority were in the range of 20-34 years accounting for 43% with an average age of 33,8 years.

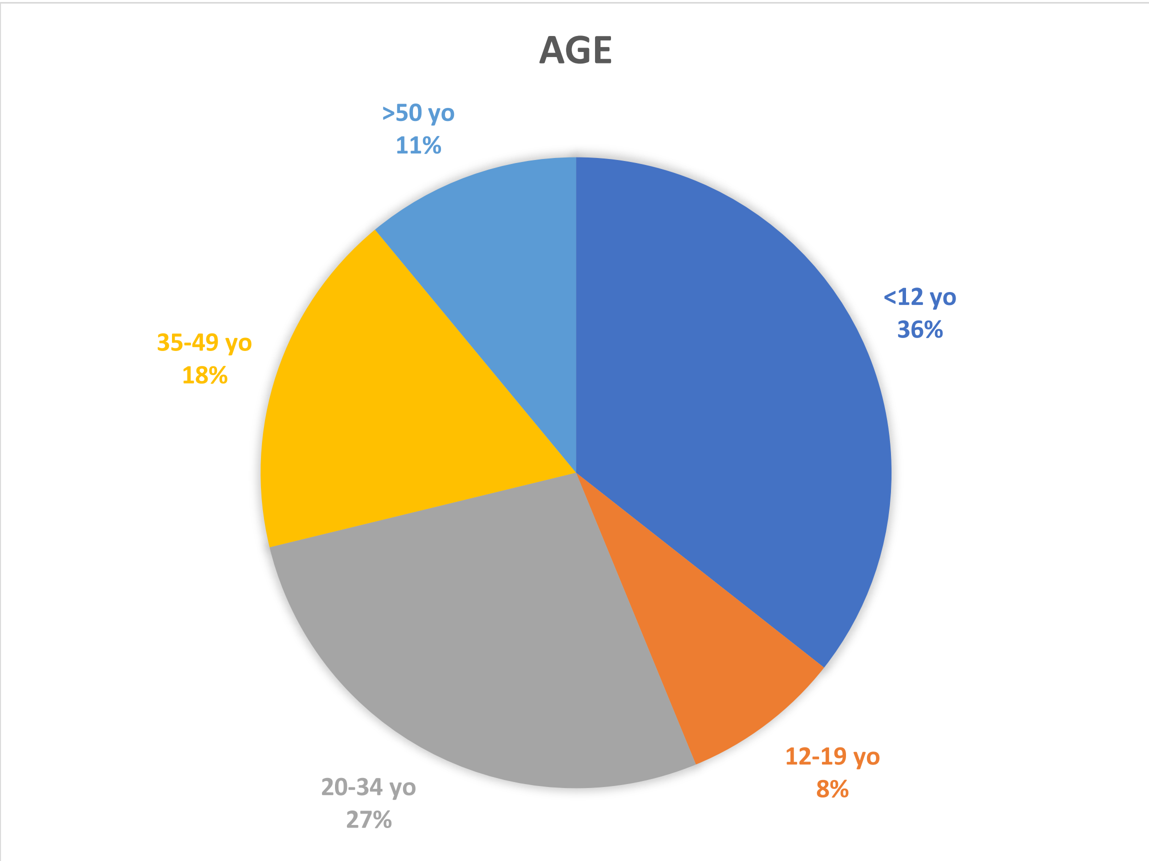


Figure 2: Distribution of the sample by Age

In our case series, males predominated in all age groups (figure 3).

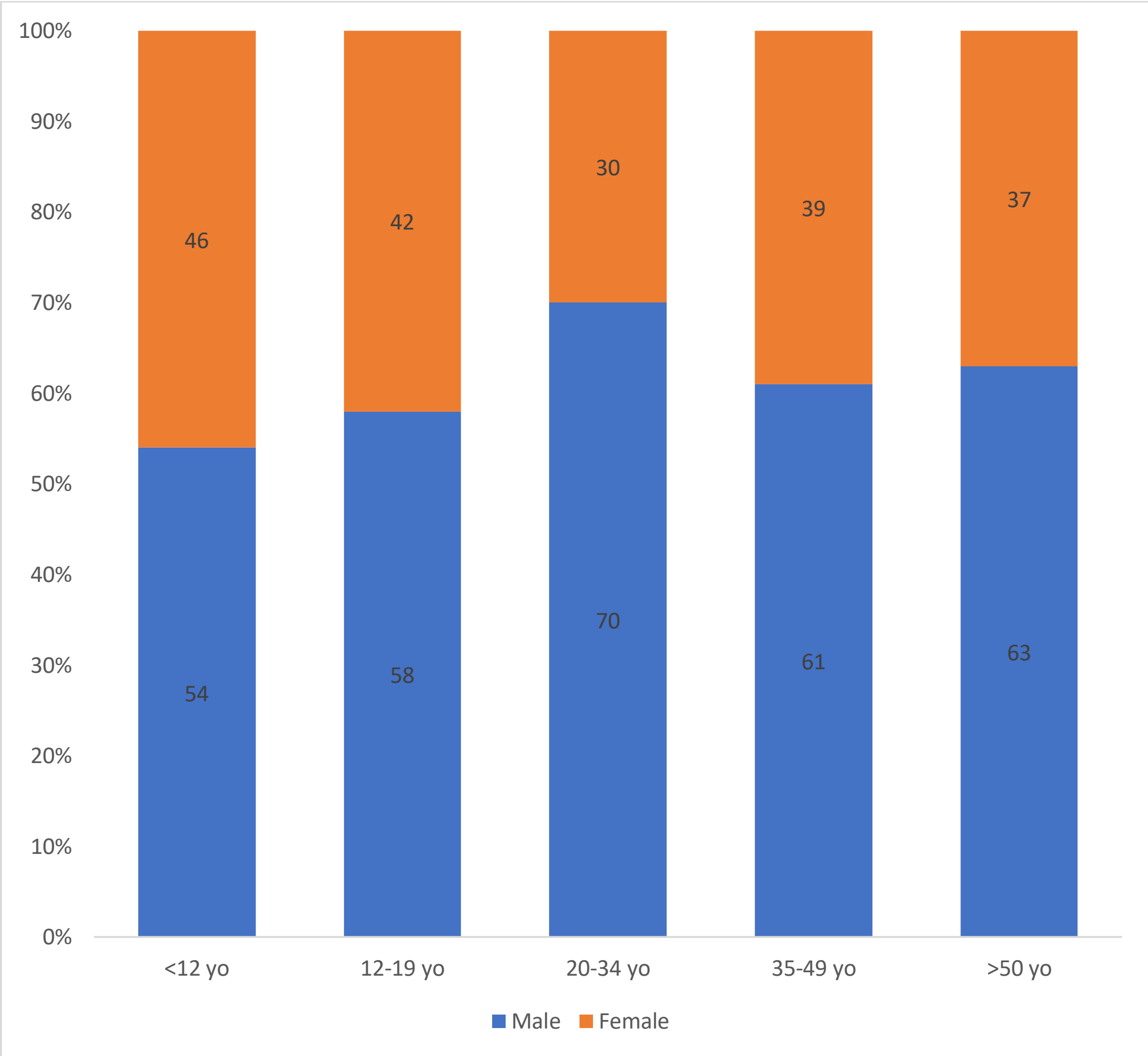


Figure 3: Distribution of the sample by Gender and Age

4. Geographical distribution:

In our case series, 36% of adults with burns were from rural areas compared with 64% from urban areas (Figure 4).

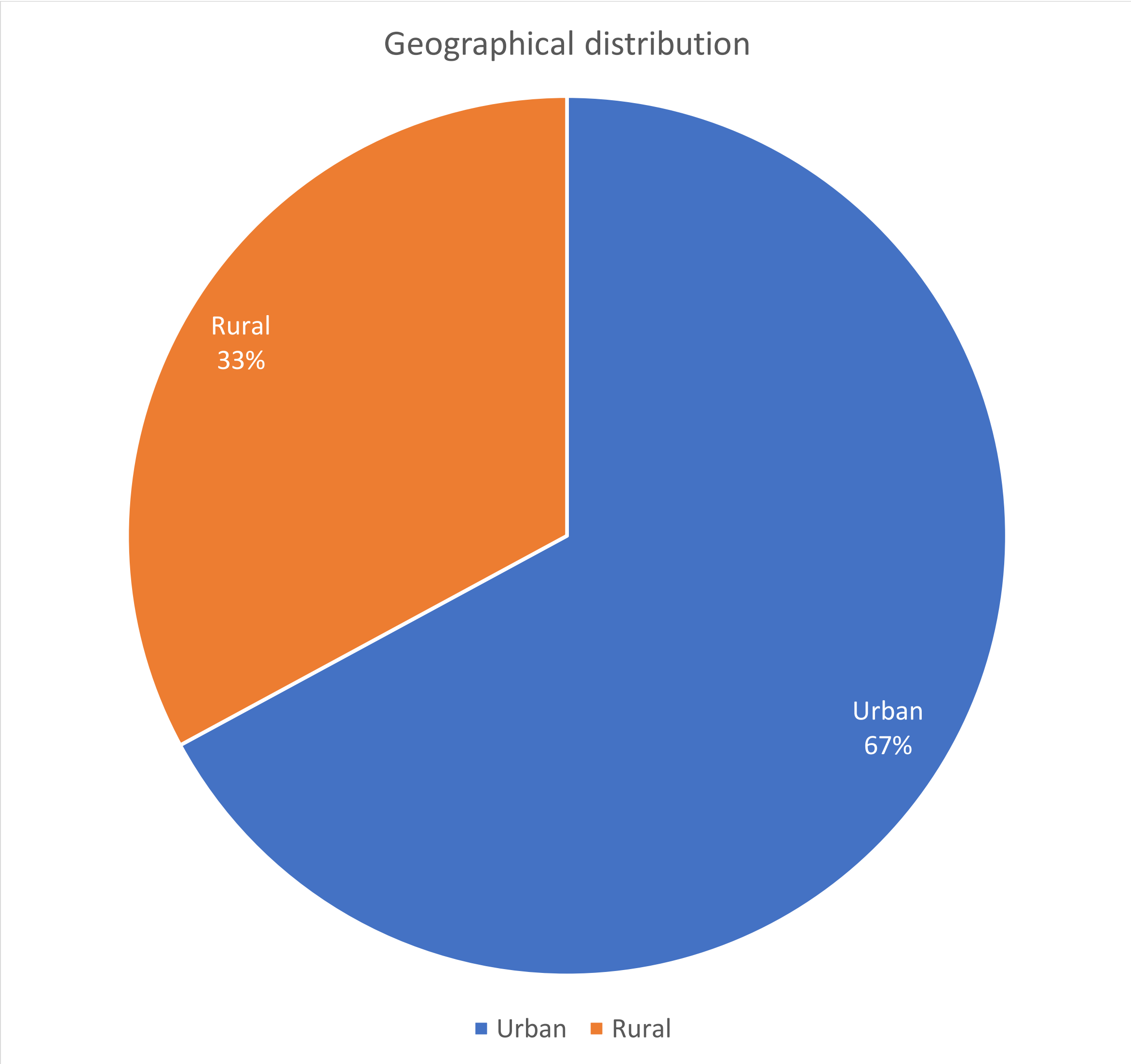


Figure 4: Distribution of the sample by Geographical origin

5. Seasonal distribution:

The seasonal distribution shows a clear increase in cases of burns during the spring (April-Mai) which coincided with the month of Ramadan, and during summer (June-July) months, when 22.8% and 23.7% respectively of hospital admissions were recorded (figure 5).

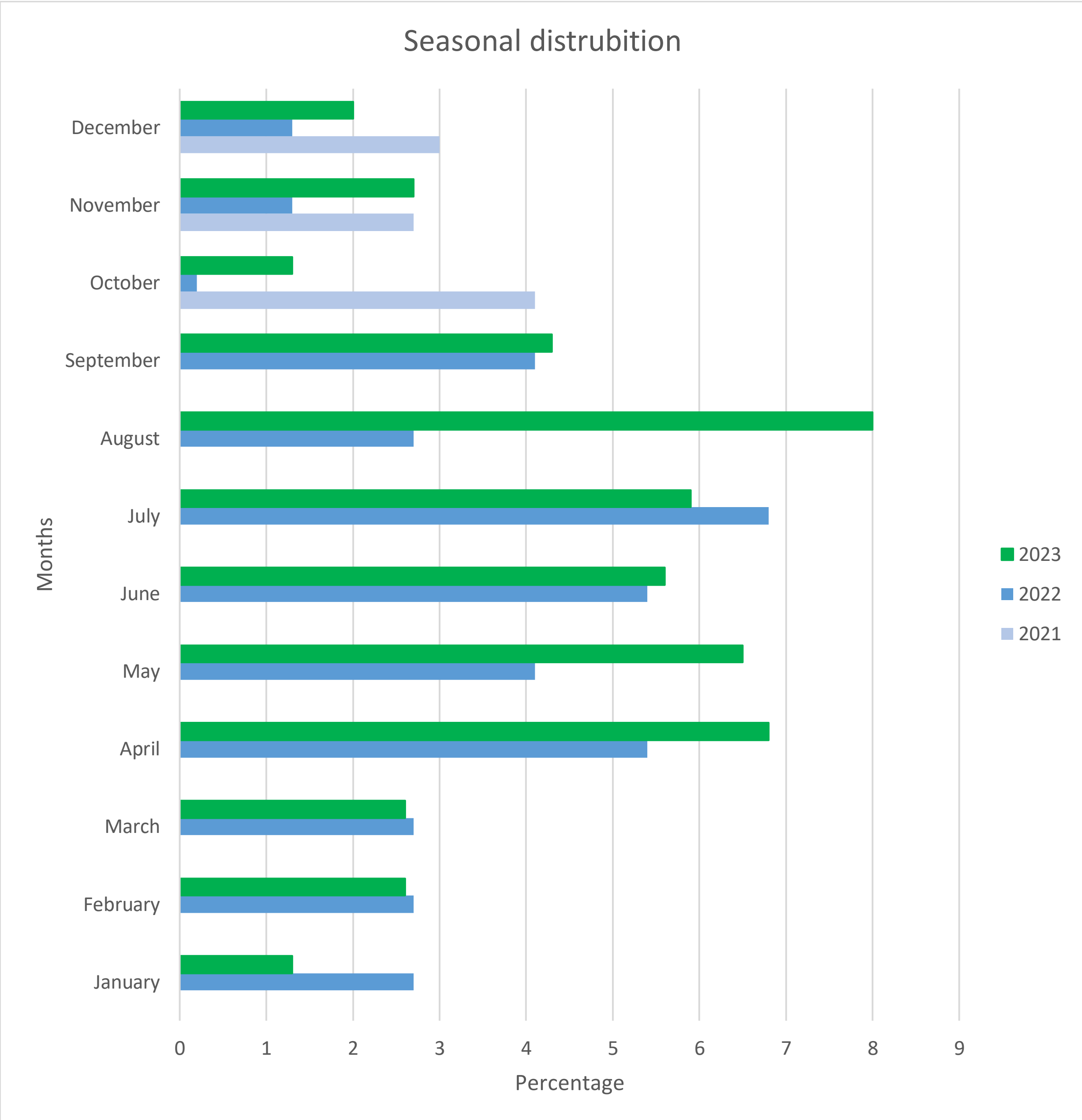


Figure 5: Monthly distribution (%) of burns admissions

II. Assessment of the severity of burns:

1. Mechanism of burns:

Our study showed that thermal burns were the most common, with 69 cases (95% of all burns), followed by electrical burns with 4 cases (5%), while no chemical burns case has been reported (0%) (Figure 6).

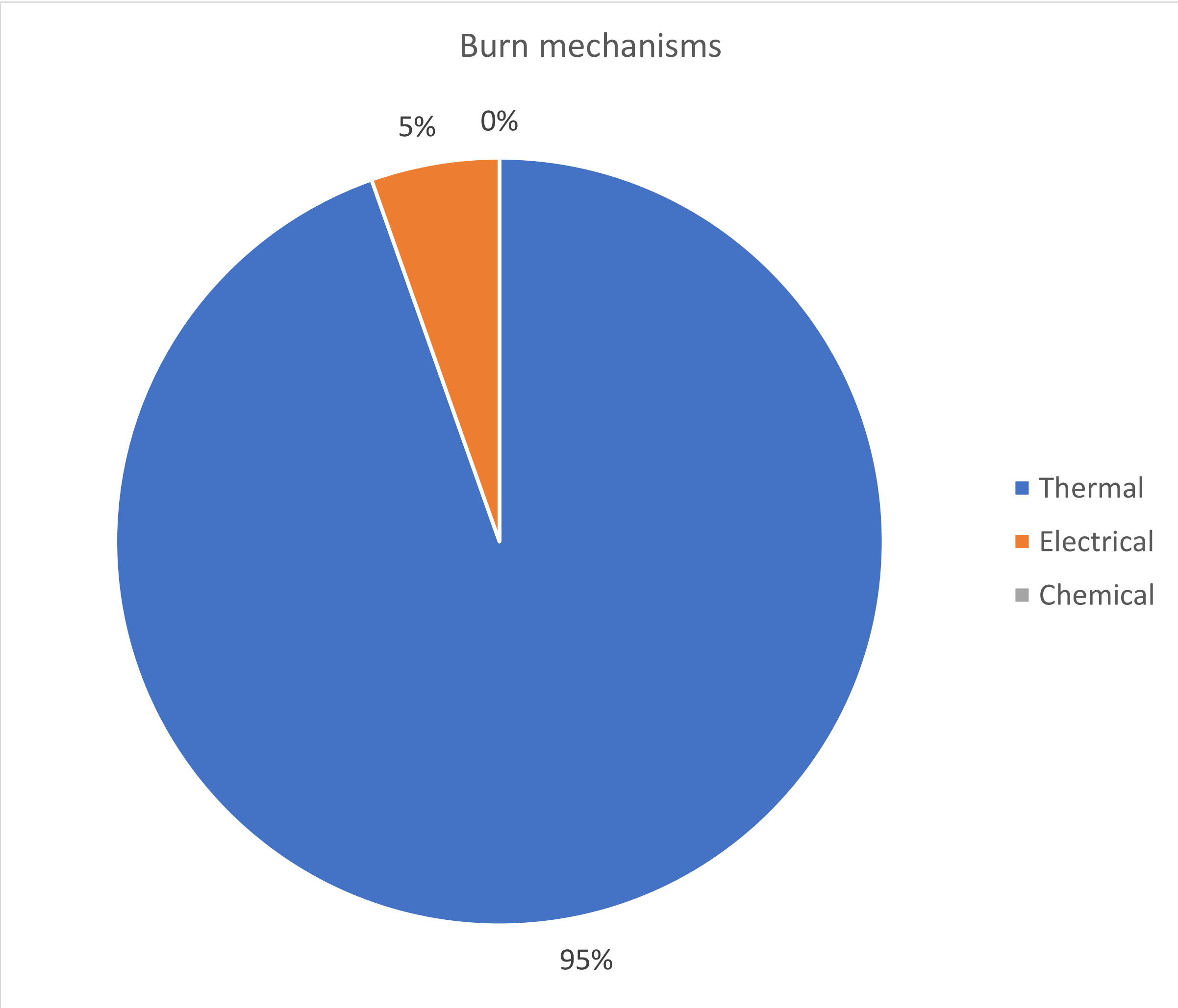


Figure 6: Distribution of burns by mechanisms

2. Responsible agent:

Figure 7 demonstrates that:

- In 46.2% of cases, burns are caused by a liquid (scalding), namely: boiling water, hot tea, hot oil, boiling soup.
- In 38.4% of cases, the burns were caused by flame, with or without a gas leak.
- In 6.8% of cases, burns were caused by exploding gas containers.
- In 4.2% of cases, burns were caused by an electrical shock from a cable.
- In 1.3% of cases, burns were caused by an electrical flash.
- In 3.1% of cases, burns were caused by gasoline whether it was as suicidal attempt or assault.

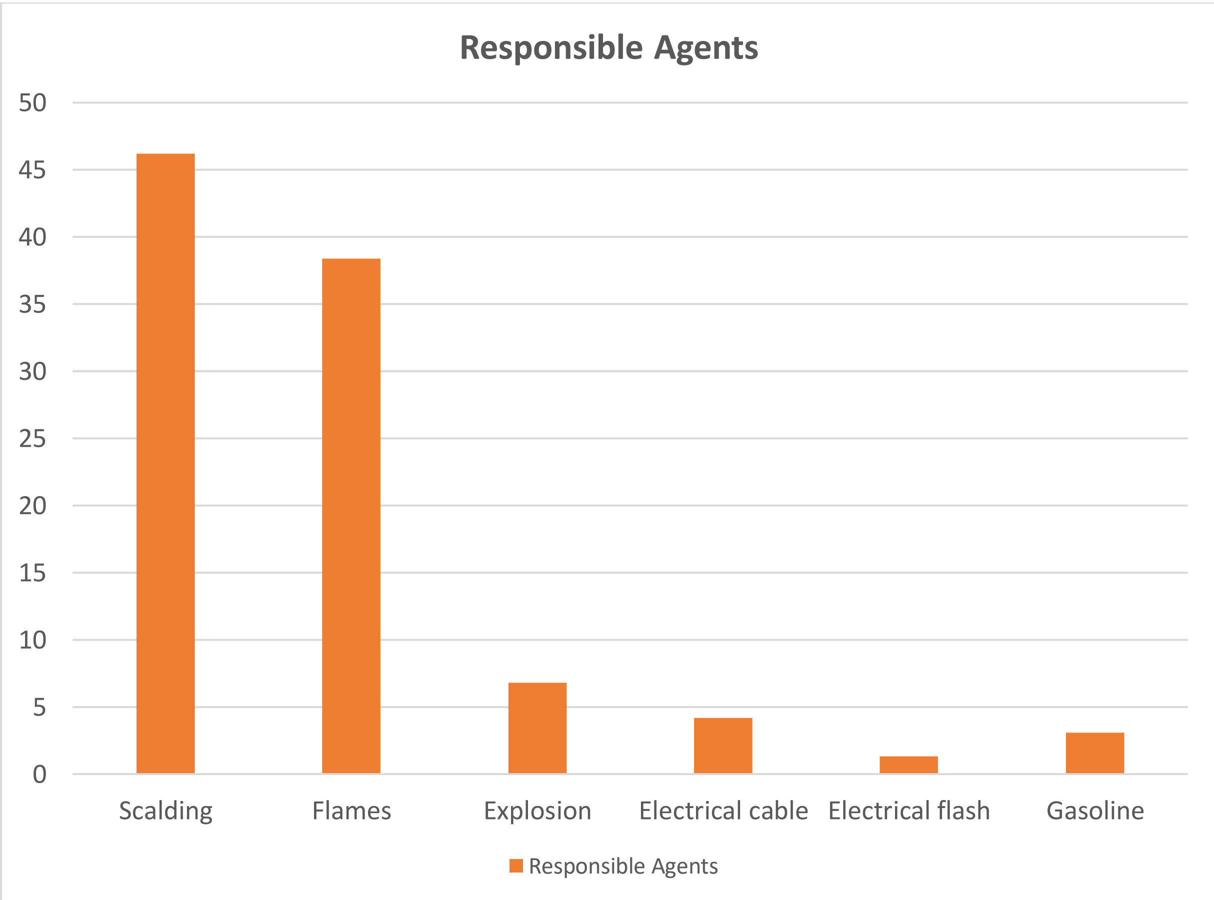


Figure 7: Distribution of burns according to responsible agents

3. Degree of burns:

In Figure 8, we observe that in 38 cases, i.e. 52% of cases, the burn is classified as 2nd degree, and in 35 cases, i.e. 48% of cases, the burn injury was a combination of 2nd and 3rd degree burns.

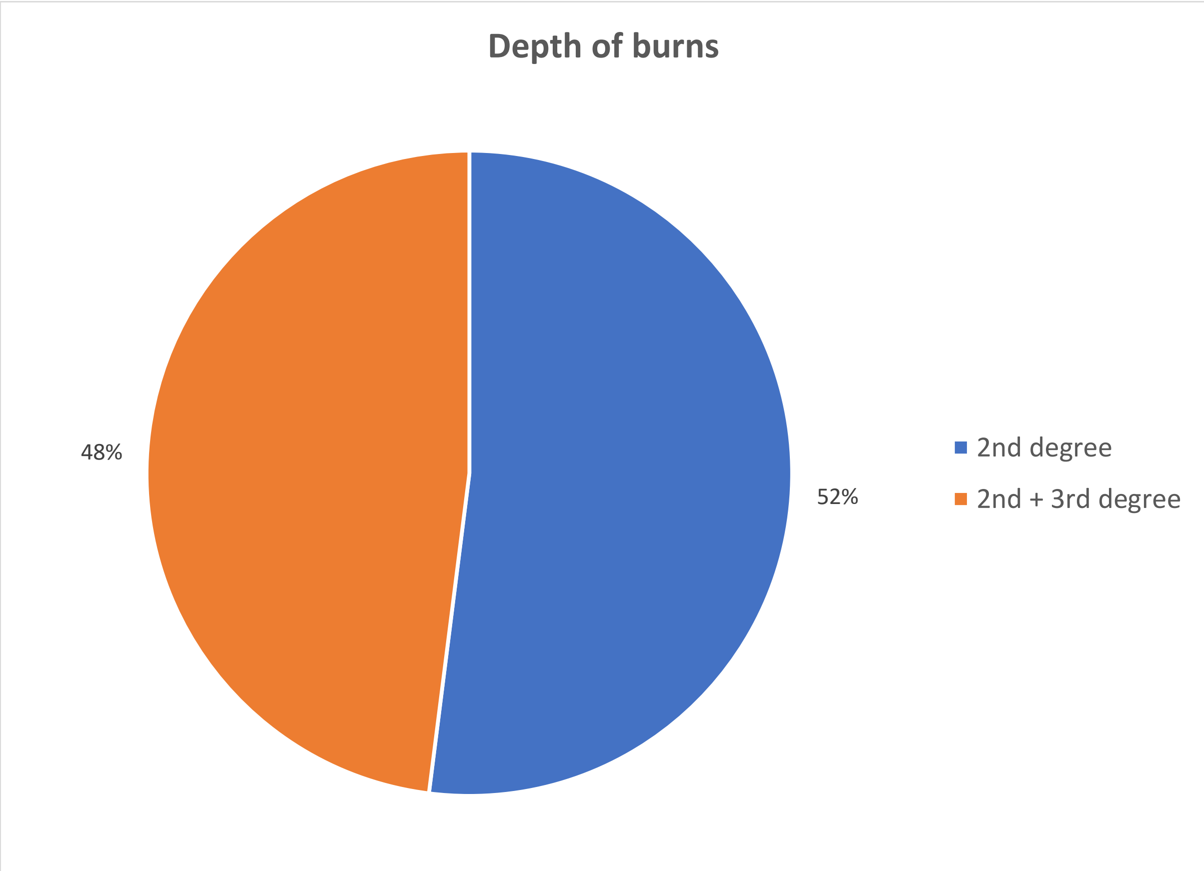


Figure 8: Distribution of burns according to depth of burn

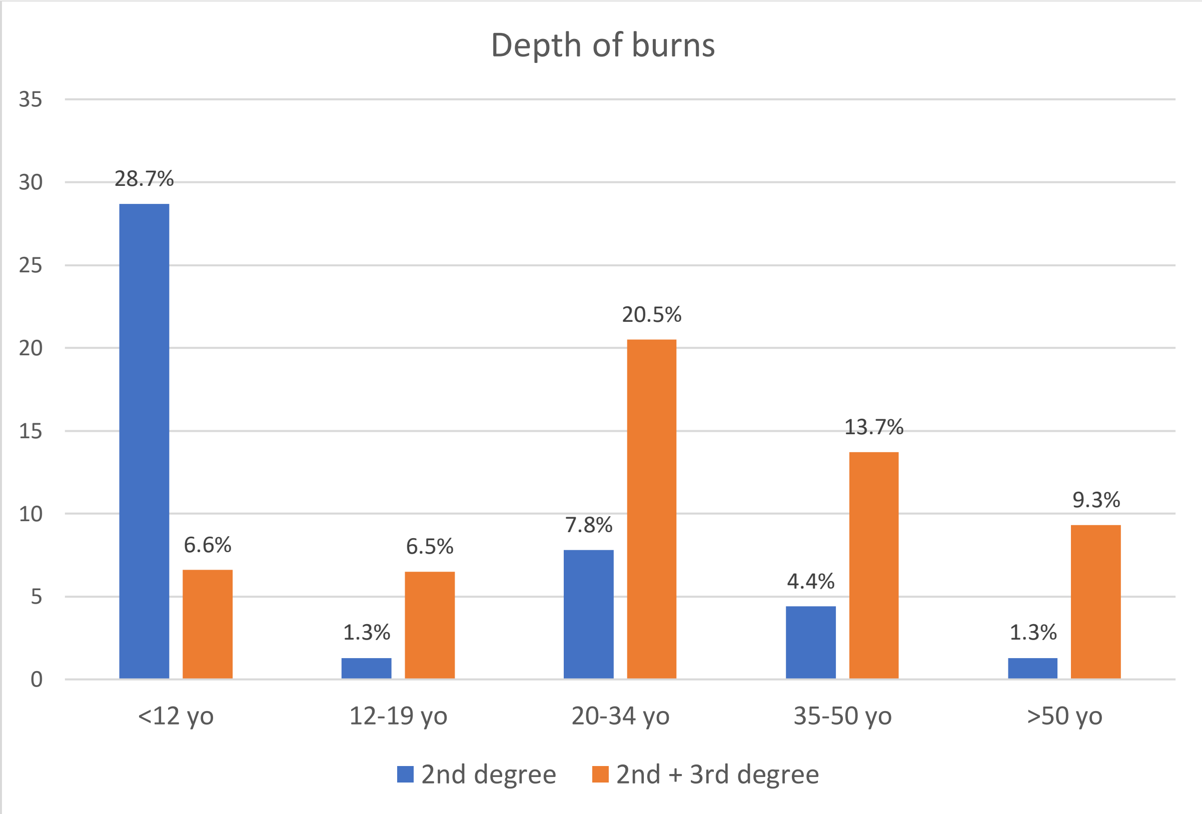


Figure 9: Distribution of burns by age according to responsible agents

4. Burned areas:

Figure 10 shows the topography of burns in patients treated during the period in question. It can be deducted that the upper limbs, the lower limbs and the head were the most affected.

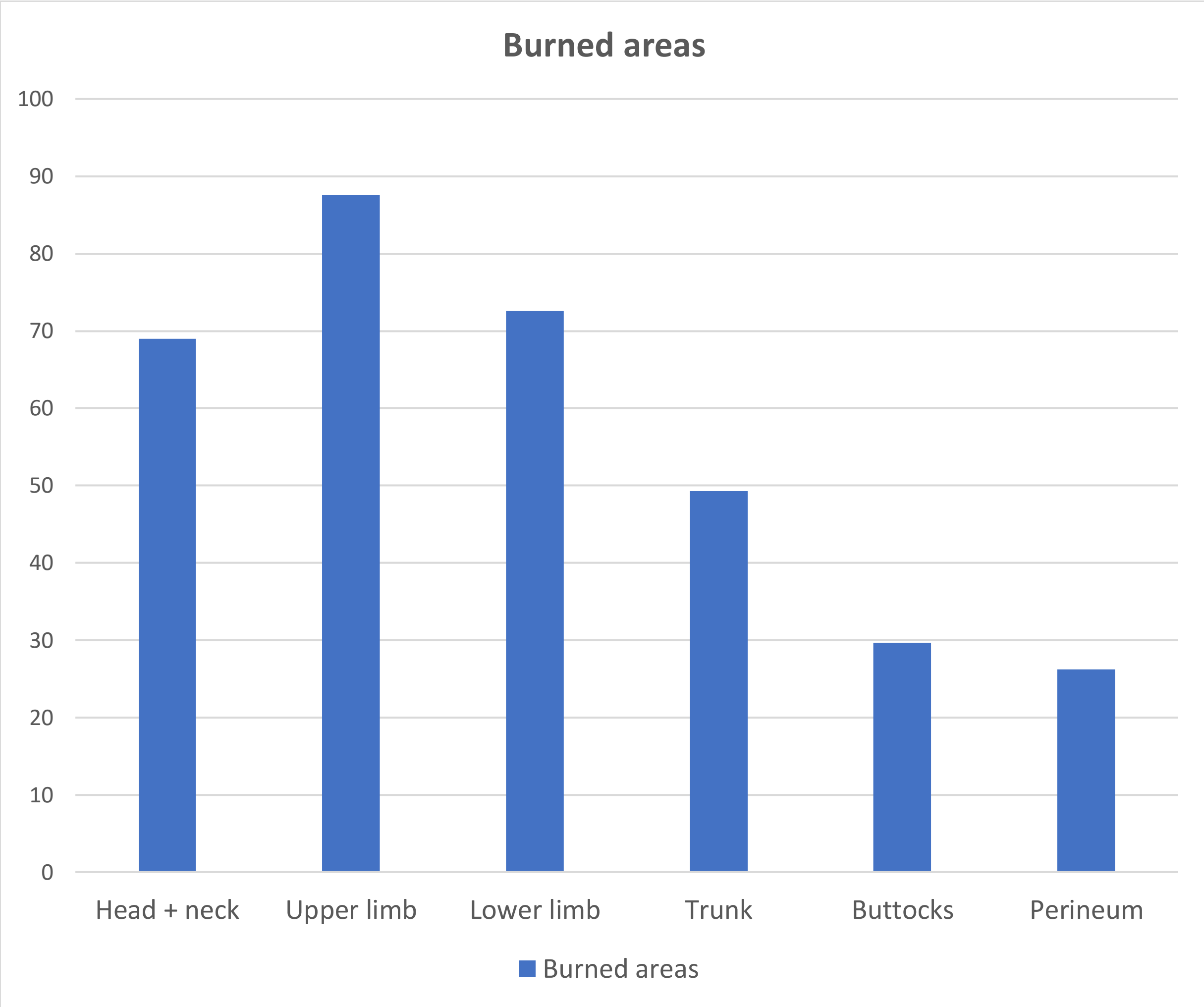


Figure 10: Distribution of burns by burned areas

5. Total burned surface area:

TBSA was less than 20% in 56% of the patients treated in the department (Figure 11), 58% of which were <12 years old (Figure 12). While 44% of patients had a TBSA greater than 20%, 81% of which were >12 years old.

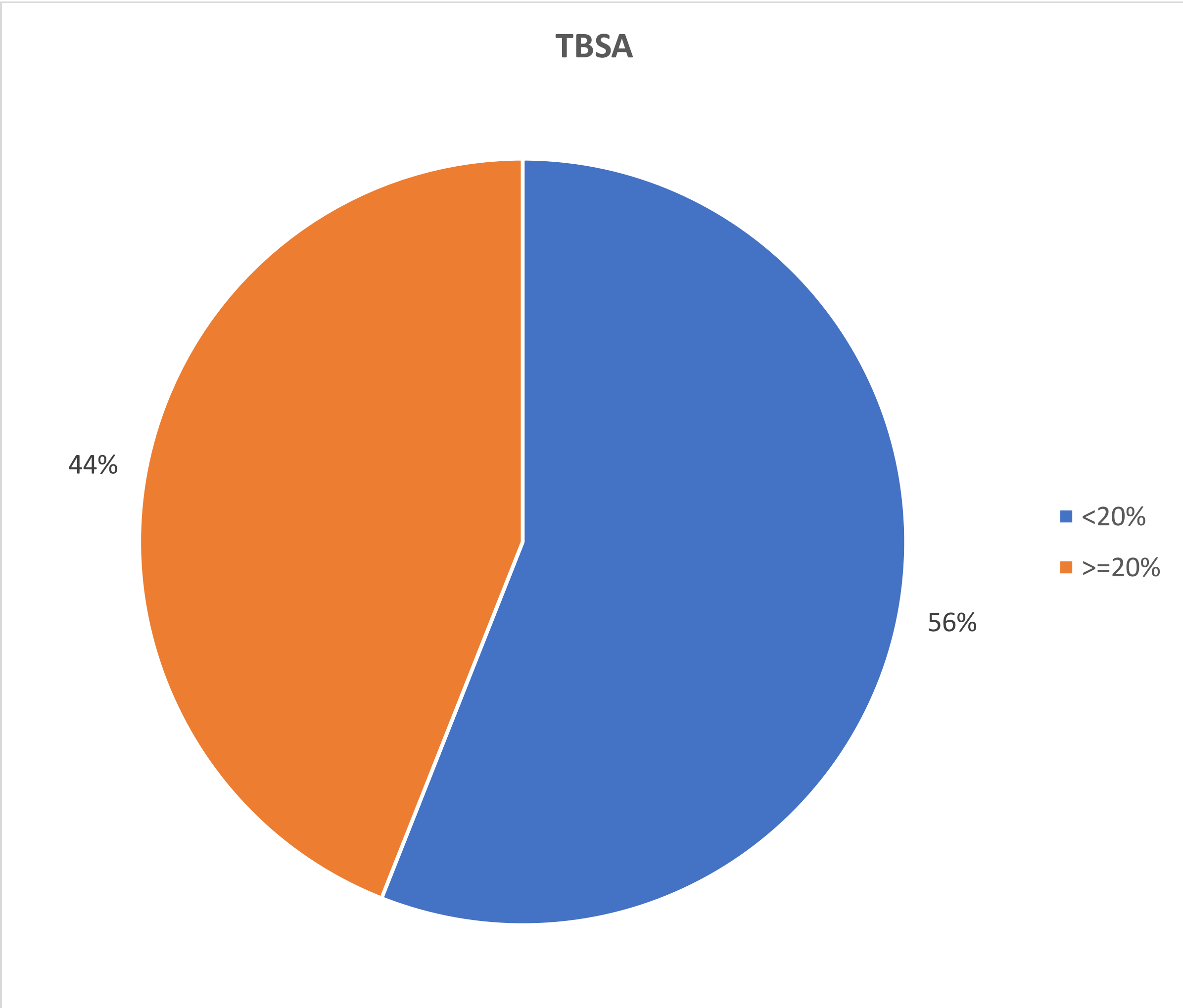


Figure 11: Distribution of burns according to TBSA

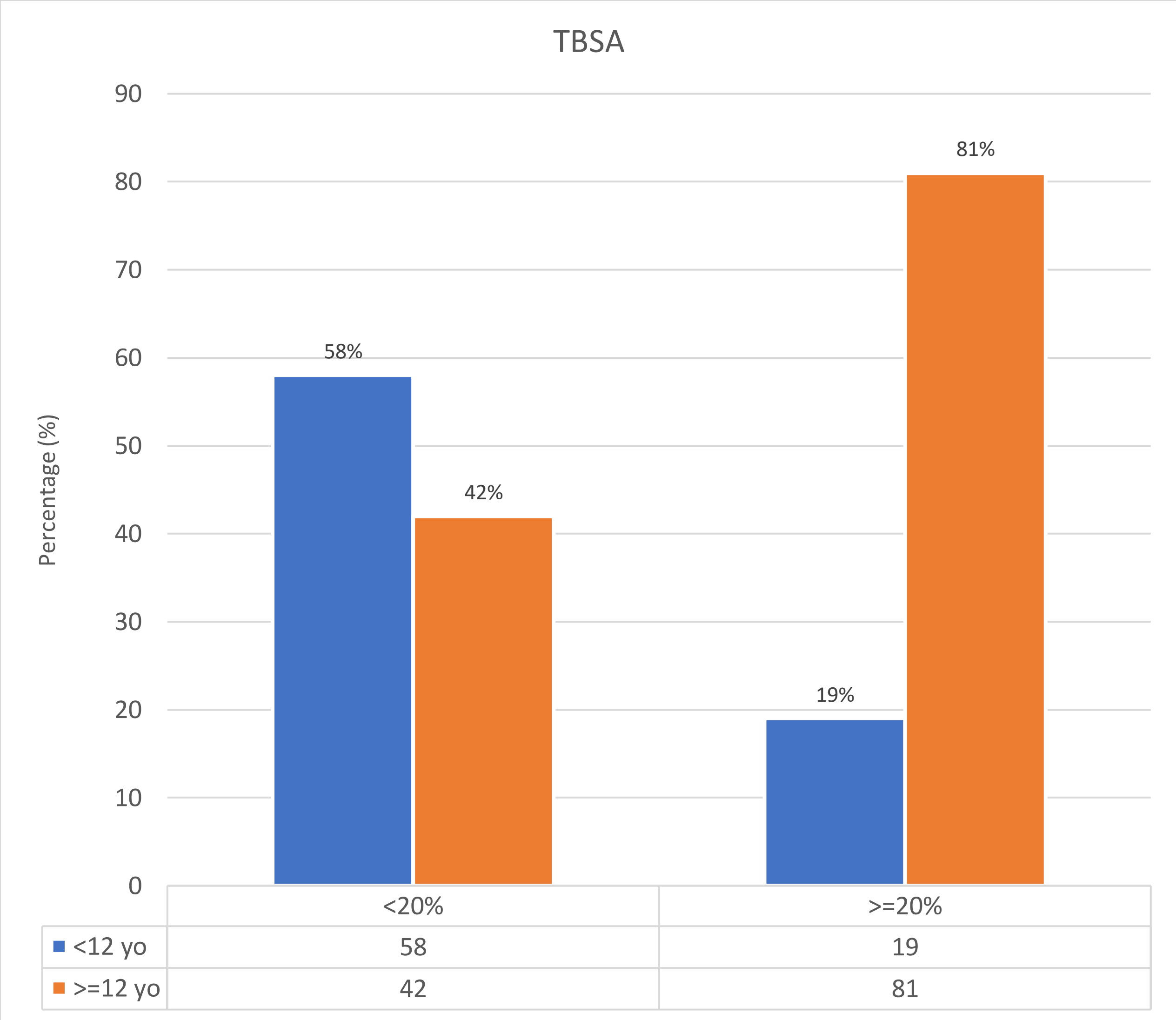


Figure 12: Distribution of burns TBSA by age

6. Pre-existing conditions:

At the time of our study, 12 patients had a pathological history of diabetes, arterial hypertension, cardiopathy or asthma, etc.

On the other hand, 61 burn victims had no associated pre-existing conditions.

7. Associated traumas:

In our case series, only 7 patients that were recorded had associated fumes inhalation.

8. Prognostic indexes:

1. UBS Index:

In our case study, 71% of patients had a UBS<50, 27% of patients had a UBS between 50-100, and only 2% had a UBS>100 (Figure 12).

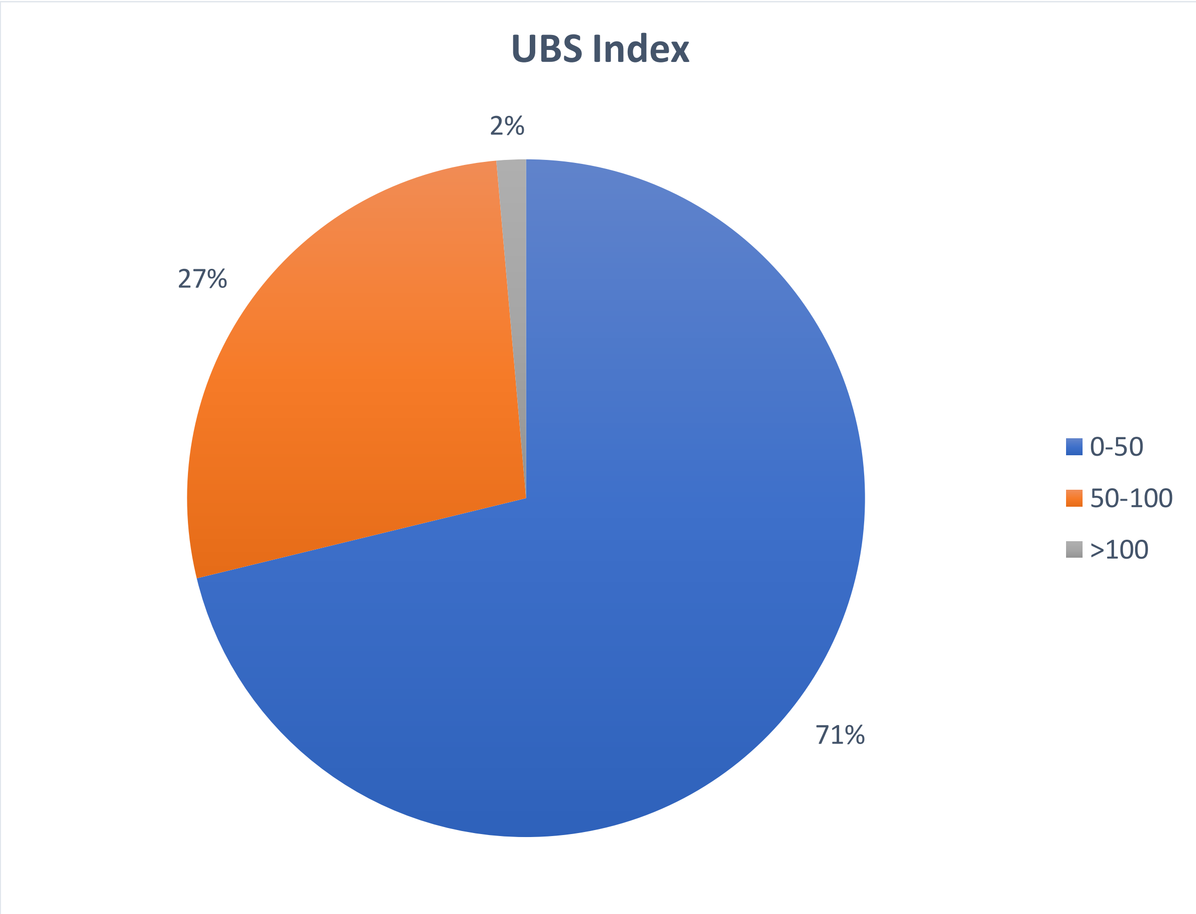


Figure 13: Distribution of burns according to UBS

2. Baux Index:

In our case study, 66% of patients had a Baux Index <75, 30% of patients had a Baux Index between 75-100, and only 4% had a Baux Index>100 (Figure 14).

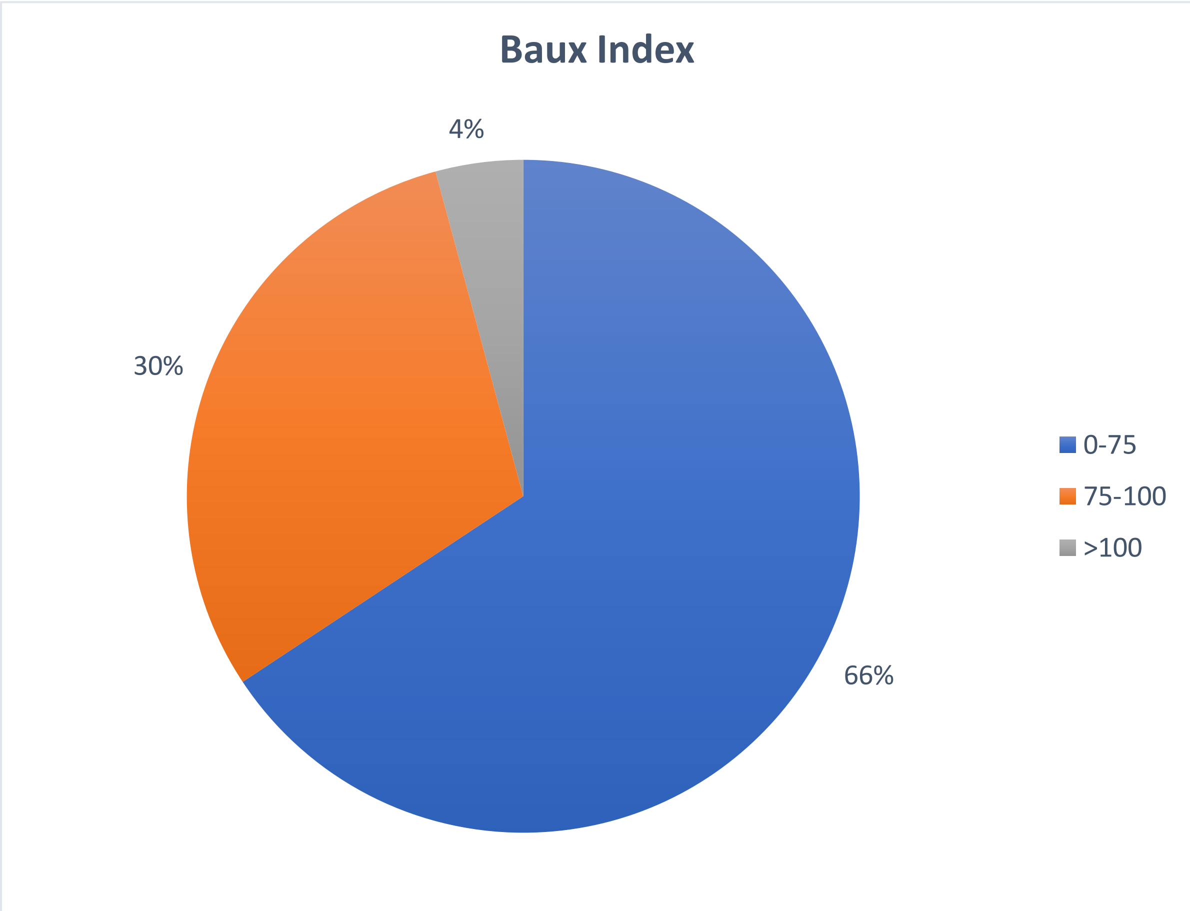


Figure 14: Distribution of burns according to Baux Index

III. Treatment and management:

It should be noted that pre-hospital care was not taken into account.

1. Initial care:

a. Resuscitation:

For all adult patients, hypovolaemic shock was prevented by the administration of IV fluids calculated using the Evans formula based on weight and burned surface area. (Figure 15)

Volume administrated the first 24 hours = (2 mL x % TBSA x Weight) of Ringer's lactate + 2000 mL of maintenance fluid. With half the volume being administrated in the first 8 hours and the remaining half distributed over the subsequent 16 hours.

- Maintenance fluid = 5% glucose serum (with 4g Nacl + 4g Kcl/l if necessary)

For all paediatrics patients, hypovolaemic shock was prevented by the administration of IV fluids calculated using the Carvajal formula based on total body area and burned surface area.

Volume administrated the first 24 hours = (5000 mL x % TBSA) of Ringer's Lactate + (2000 mL x Total body surface area) of maintenance fluid. With half the volume being administrated in the first 8 hours and the remaining half distributed over the subsequent 16 hours.

A central intravenous access was necessary for 15 patients (20.5%), all of them at the femoral level as emergency solutions following the Demling rule.

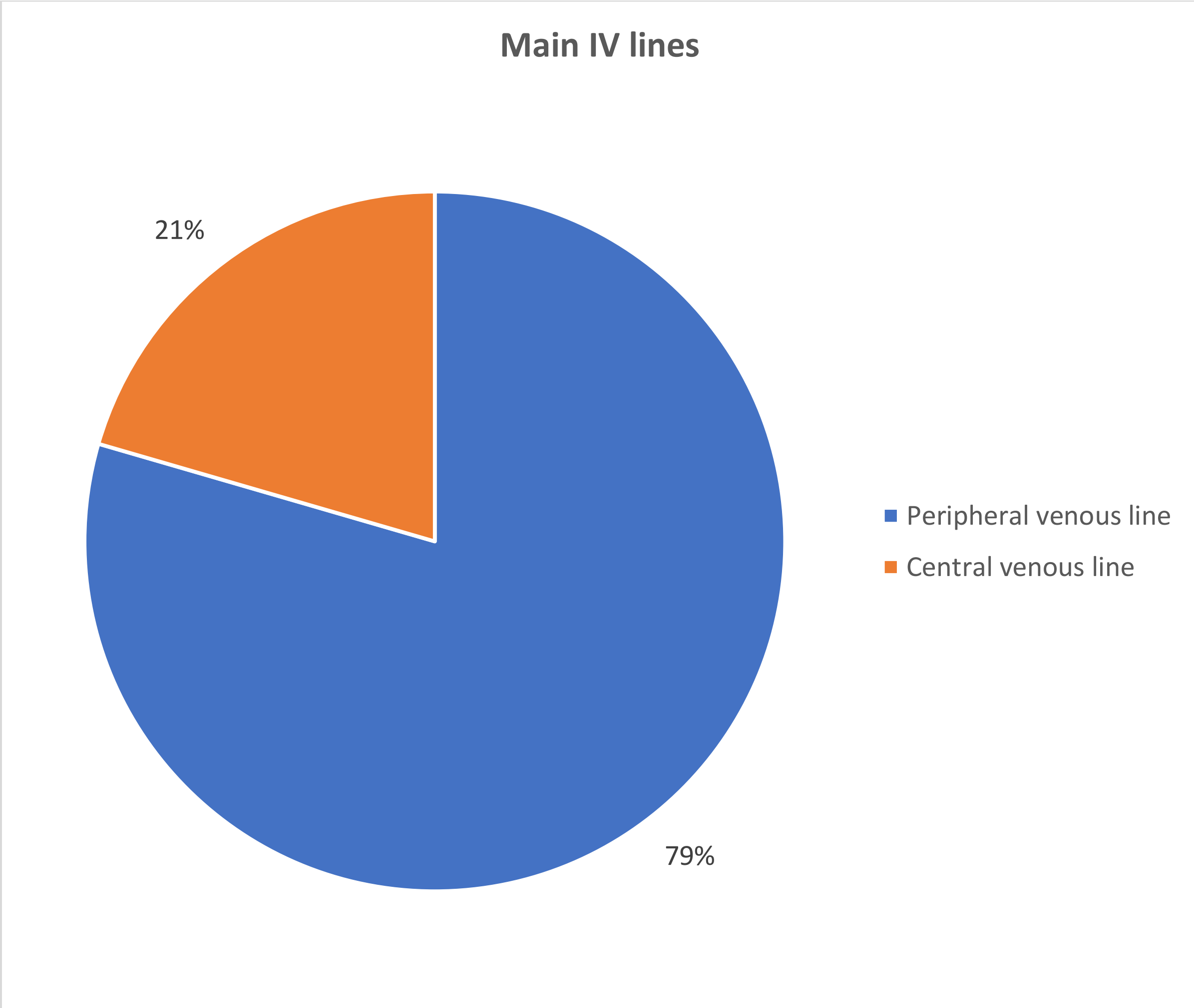


Figure 15: Distribution of main IV lines used initially in patients

b. Respiratory support:

All patients were systematically given oxygen therapy of 3 to 6 L/min by nasal cannula or face mask on admission.

Of the total number of patients, 8 (11%) had required emergency intubation; 5 for respiratory distress caused by face and respiratory burns and 3 for consciousness impairment. (Figure 16)

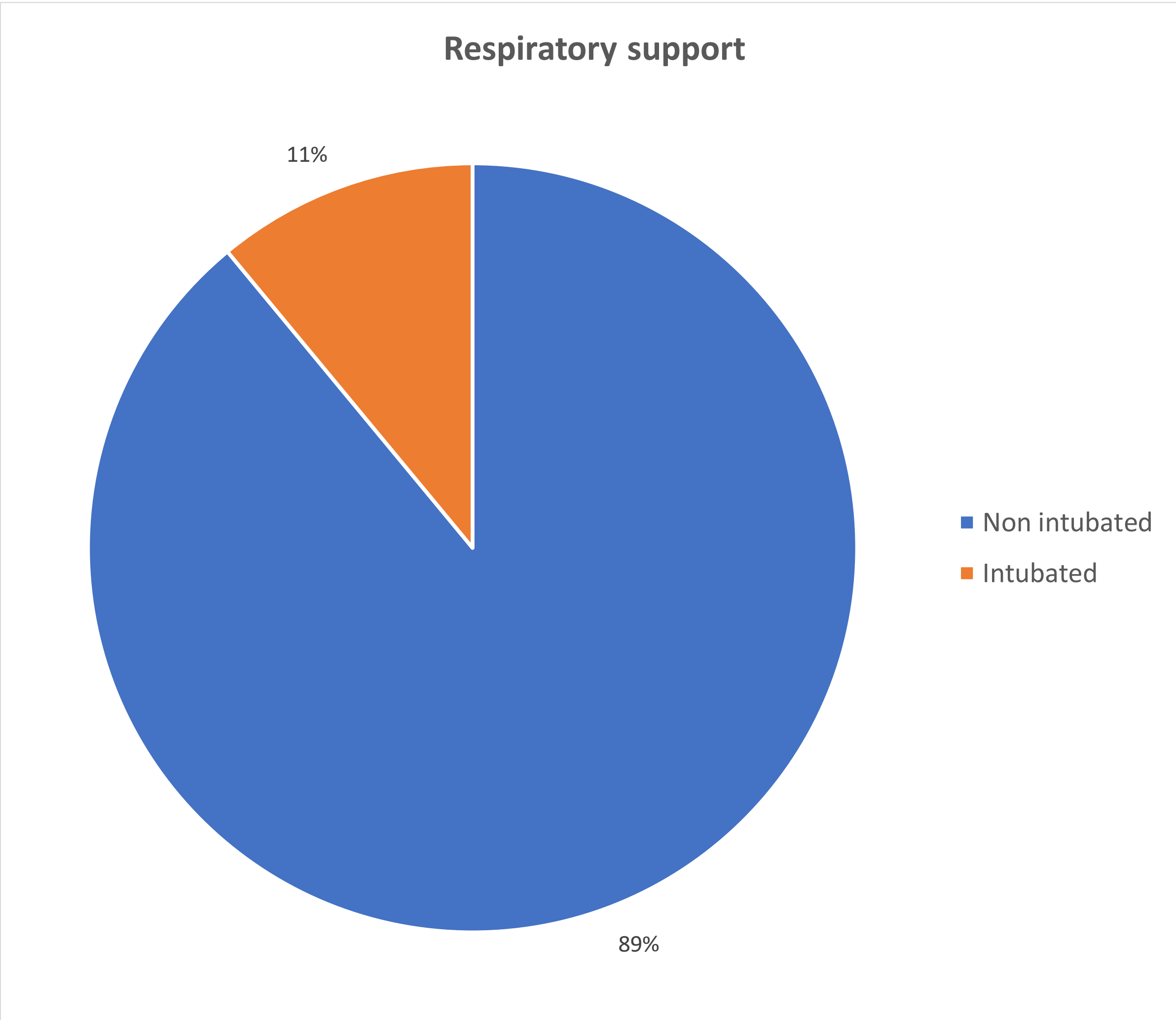


Figure 16: Distribution of respiratory support used in patients

2. General treatment:

As part of the protection against stress ulcers or duodeno-gastritis, all patients have systematically received a PPI or an H2 blocker or alginate.

As part of nutritional support, 65 patients (89%) had benefited initially from early enteral nutrition on a high-protein, high-calorie diet. And all patients benefited from iron, copper, zinc and selenium, additionally to other vitamin supplementation.

38 patients (52%) had received anti-tetanus prophylaxis, while the other 48% were recently vaccinated in the last 10 years. (Figure 17)

Preventive anticoagulants were prescribed for 28 patients, i.e. 38.3% of the total, in the cases of either immobile patients or in the use of a femoral intravenous catheter. (Figure 18)

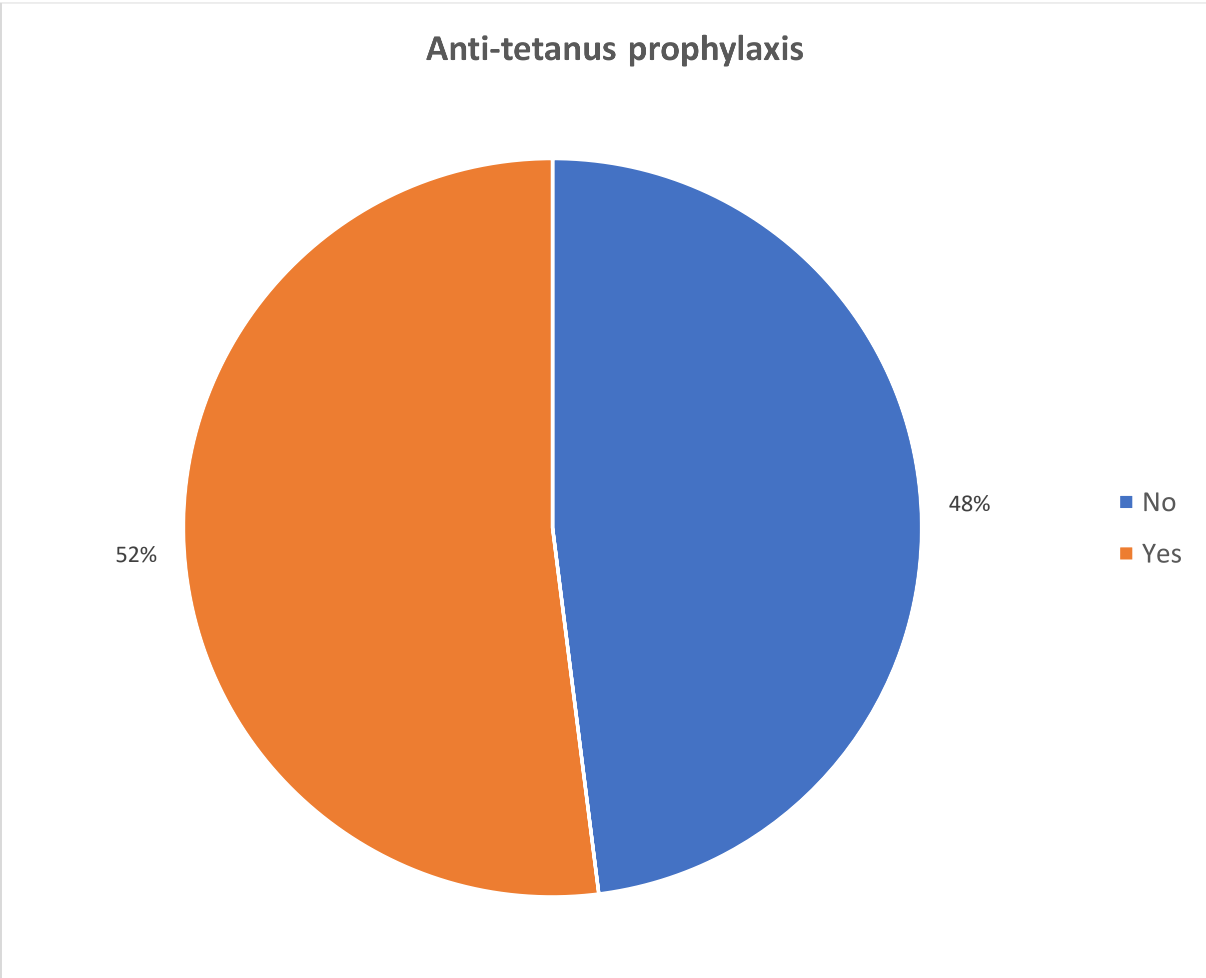


Figure 17: Distribution of anti-tetanus prophylaxis

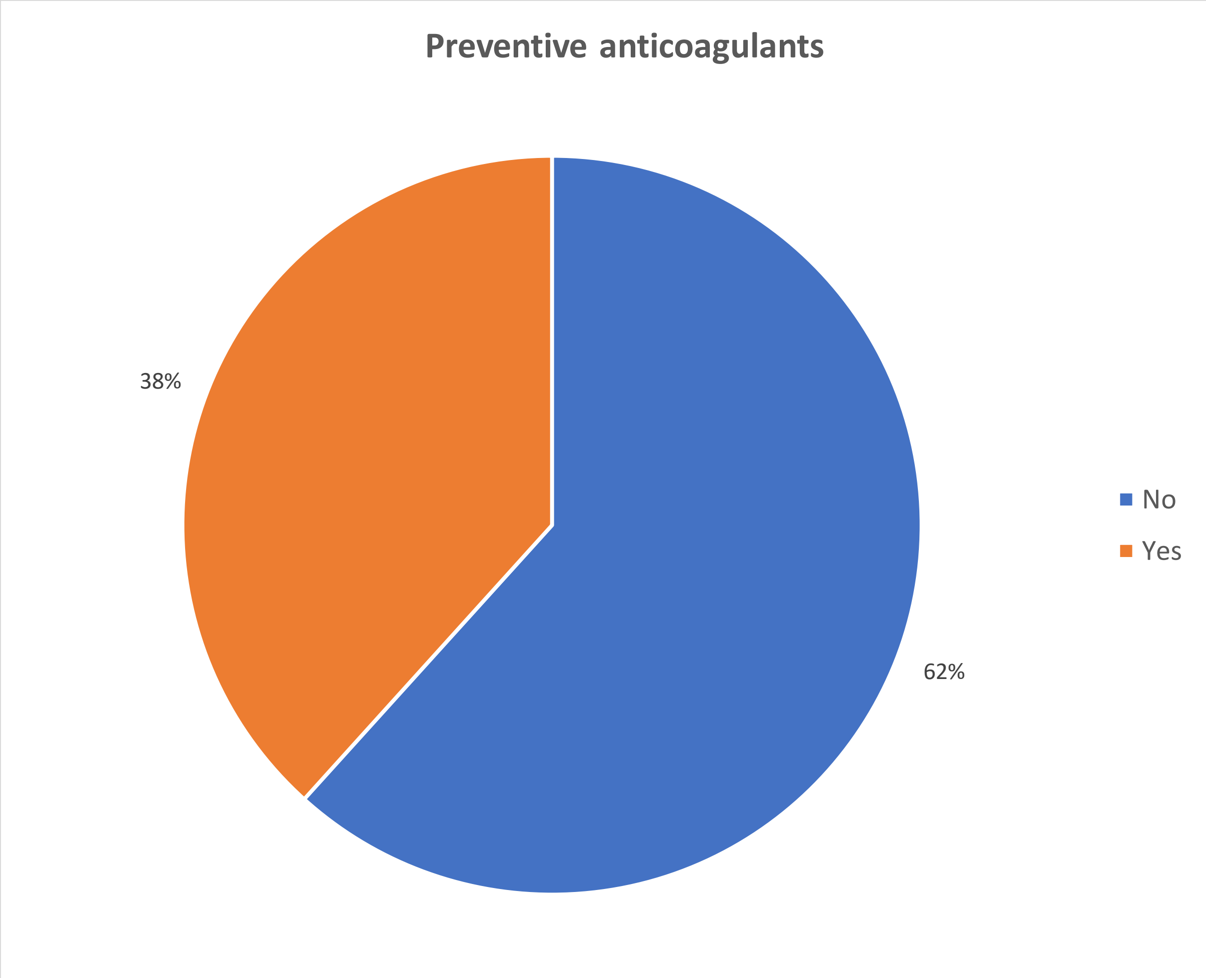


Figure 18: Distribution of preventive anticoagulants

3. Local treatment:

All patients with burns had the injured areas cleaned with saline and the blisters laid flat.

Superficial burns were covered with a layer of moisturising cream. For deep and extensive burns, a silver sulphadiazine-based antiseptic cream (Flammazine®) was applied, together with an occlusive dressing.

The presence of deep circular burns or signs of compression indicates the need for a decompressive incision.

a. Surgery procedures:

16 patients (22%) had undergone decompressive incisions type escharotomy or fasciotomy, most of which were made on the upper limb. (Figure 19)

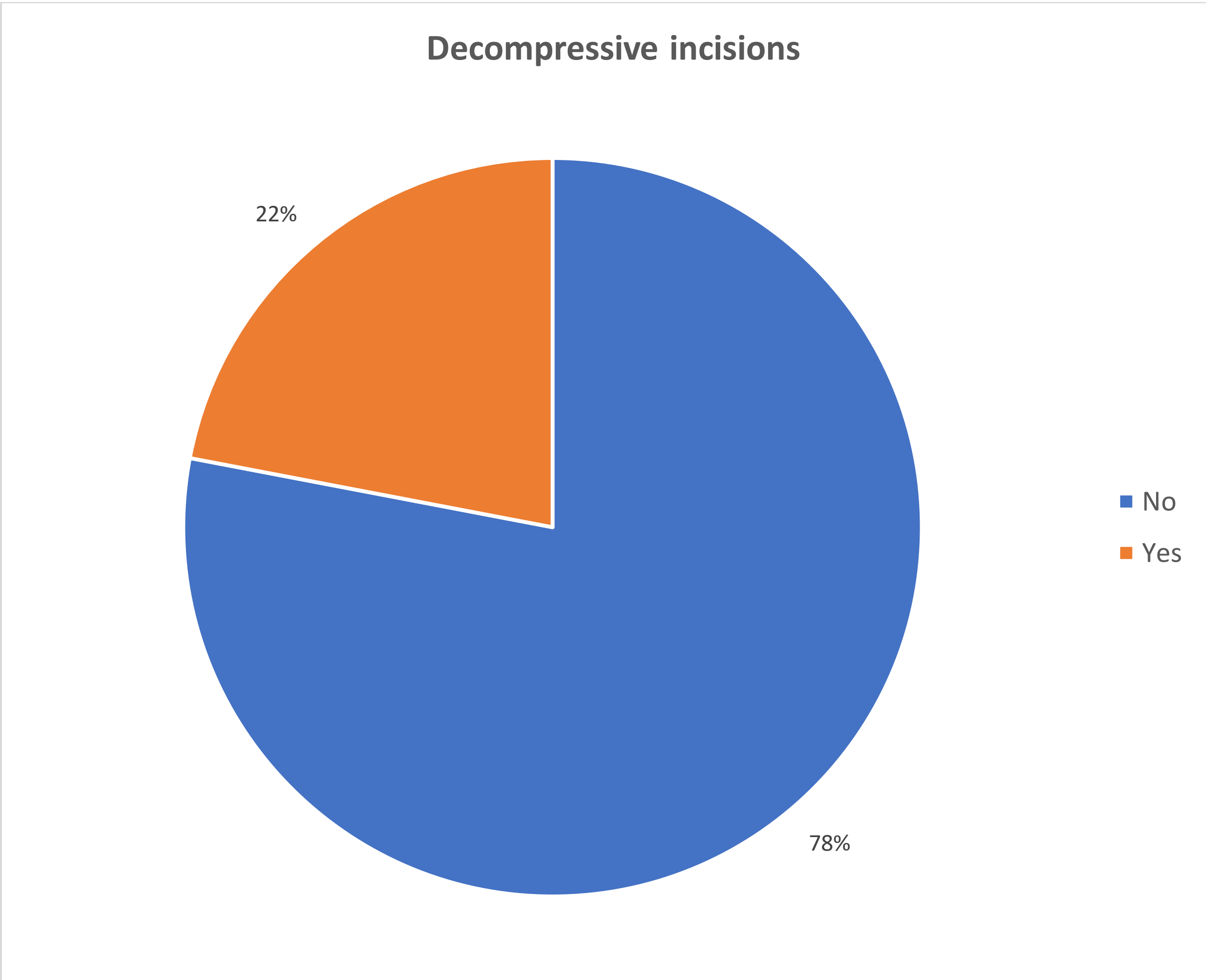


Figure 19: Distribution of decompressive incision

b. Local wound care:

In our case study, 24 patients (33%) benefited from skin grafts after 3 weeks. Either by using full thickness autografts or split thickness autografts. (Figure 20)

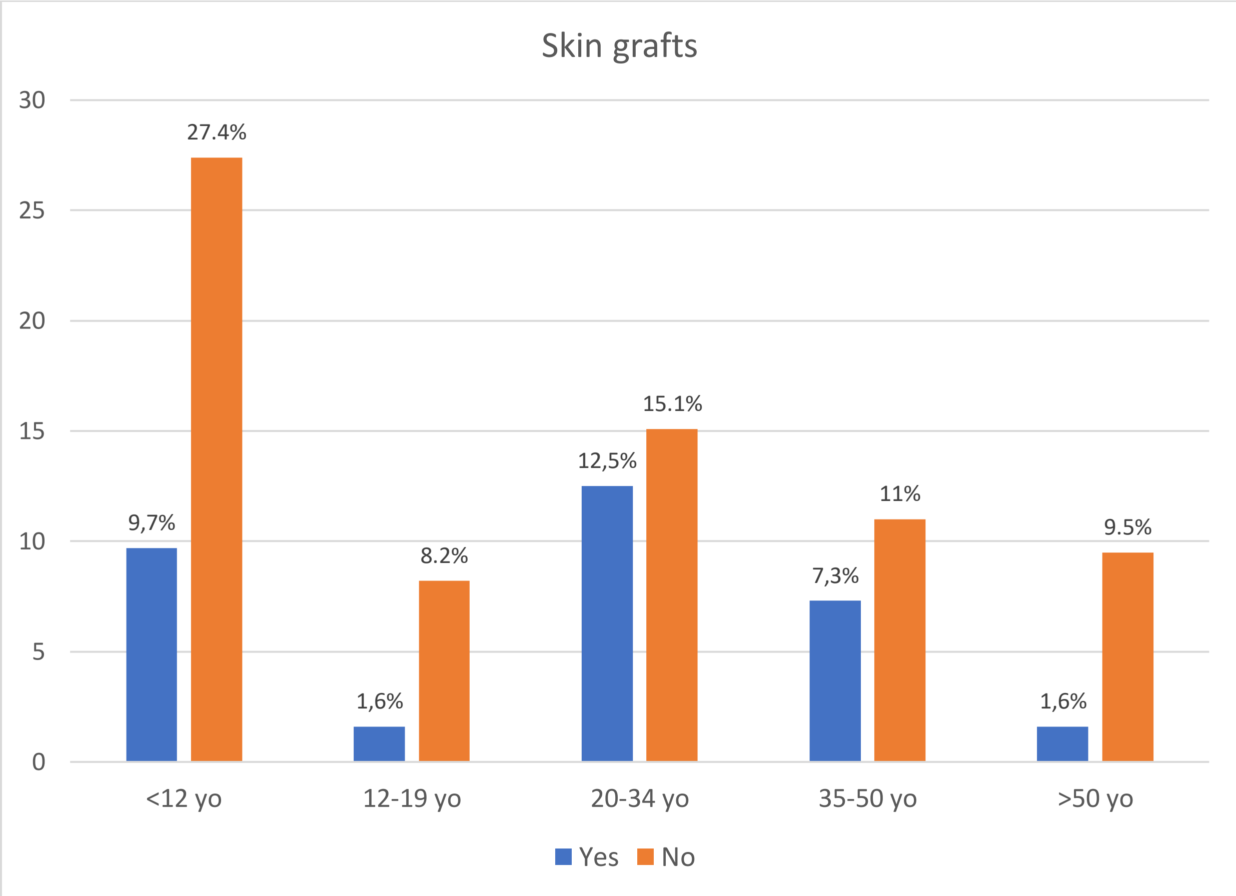


Figure 20: Distribution of the percentage of skin grafts according to age

c. Healing duration:

In our series 70% of patients (51 cases) had their wounds heal in less than 21 days. With an average hospital stay of 9,3 days.

Wound healing <21 days	51 (70%)
Wound healing >21 days	22 (30%)
Maximum length of hospital stays	42 days
Minimum length of hospital stays	1 day
Average length of hospital stays	9,3 days

Table 1: Distribution of healing time and length of stay in burn patients

Noting that all patients whose healing time exceeded 21 days benefited from skin grafting.

IV. Evolution:

Figure 21 shows the evolution of burns patients treated at the burns' treatment centre of Mohamed VI University Hospital of Tangier during the study period. The case fatality rate was 7% of the population studied (5 cases).

For 93% of patients (68 cases), the evolution was favourable with no sequelae in 25 patients, i.e. 34% of cases, whereas for 43 patients, i.e. 59% of cases, the evolution was marred by functional and aesthetic sequelae. (Figure 22)

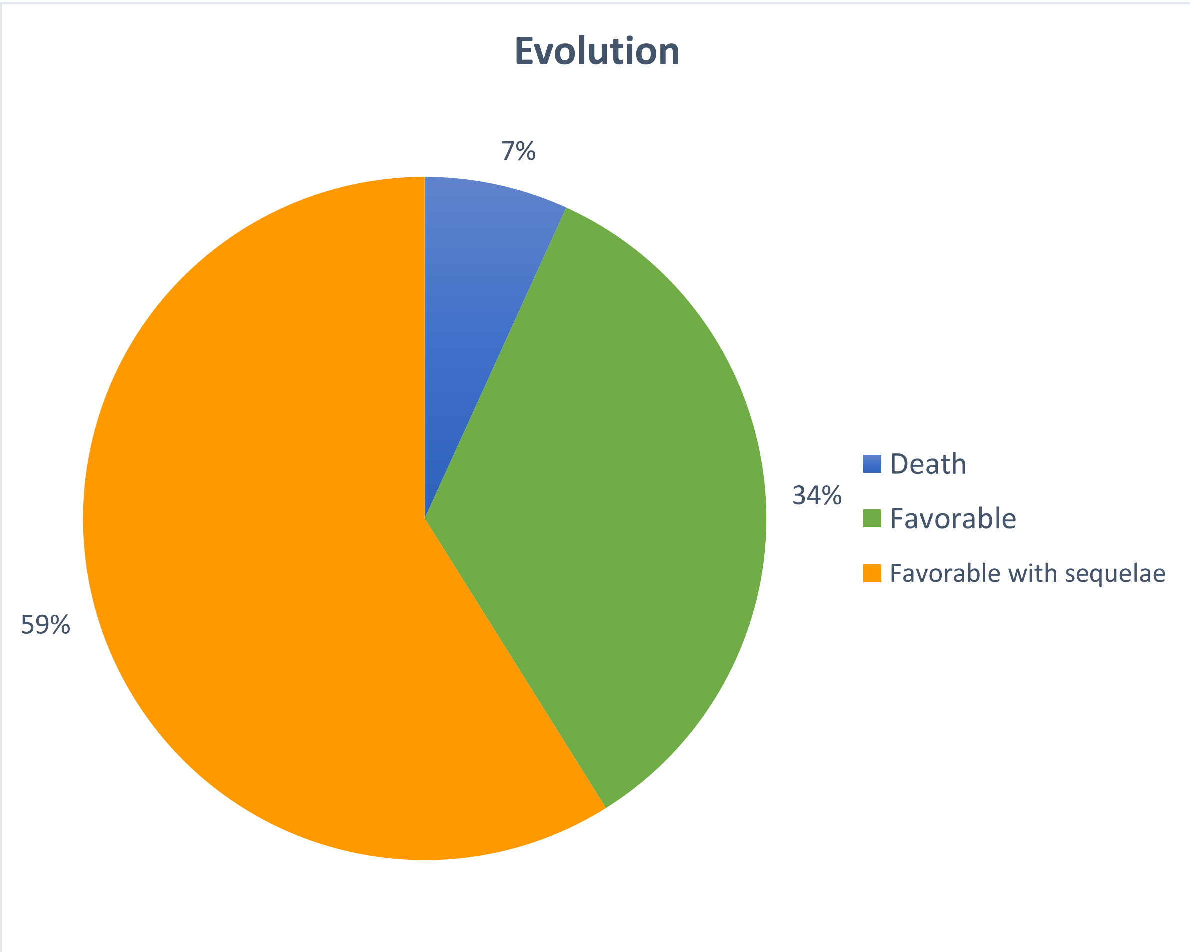


Figure 21: Distribution of burns according to their evolution

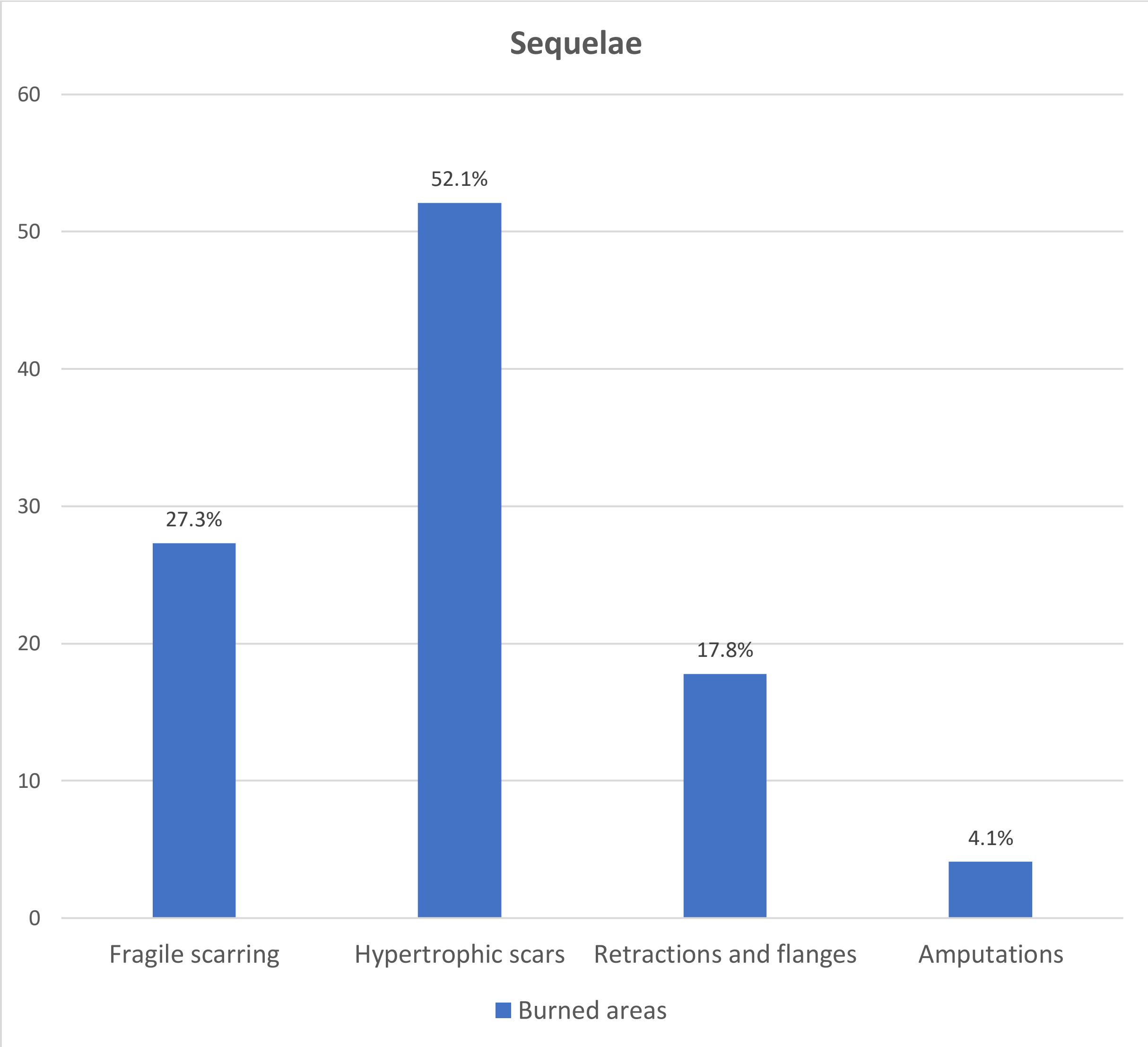


Figure 22: Distribution of different sequelae

Discussion

I. Burns overview:

1. The human skin:

a. Anatomy and functions of the skin:

The skin is the body's largest and primary protective organ. It composes 16% of an adult's body weight with an average of 4Kg, covering its entire external surface with an area of approximately 1.8m^2 [2]. It performs several functions and is made up of three tissues: the epidermis, then the dermis and finally the hypodermis or the subcutaneous tissue.

The functions of the skin include:

- **Protection:** against microorganisms, dehydration, ultraviolet light, and mechanical damage; the skin is the first physical barrier that the human body has against the external environment.
- **Sensation:** of pain, temperature, touch, and deep pressure.
- **Mobility:** The skin allows smooth movement of the body.
- **Endocrine activity:** The skin initiates the biochemical processes involved in Vitamin D production, which is essential for calcium absorption and normal bone metabolism.
- **Exocrine activity**: This occurs by the release of water, urea, and ammonia. Skin secretes products like sebum, sweat, and pheromones and exerts important immunologic functions by secreting bioactive substances such as cytokines.
- **Regulation of temperature:** Skin participates in thermal regulation by conserving or releasing heat and helps maintain the body's water and homeostatic balance.

b. Histological structure of the skin:

Skin is composed of three layers: The epidermis, dermis, and hypodermis or subcutaneous tissue (Figure 23). The skin also contains epidermal adnexa, consisting of important appendages including pilosebaceous units, sweat glands, and sebaceous glands not associated with hair follicles.

Skin is also often classified as: *Thick skin* with an epidermis thickness of 0.8-1.5mm, which is the non-hair-bearing (glabrous) skin, found on palmar and plantar surfaces, and *Thin skin* with an epidermis thickness of 0.07-0.15mm, which is found over the rest of the body, but is especially thin over the eyelids [2].

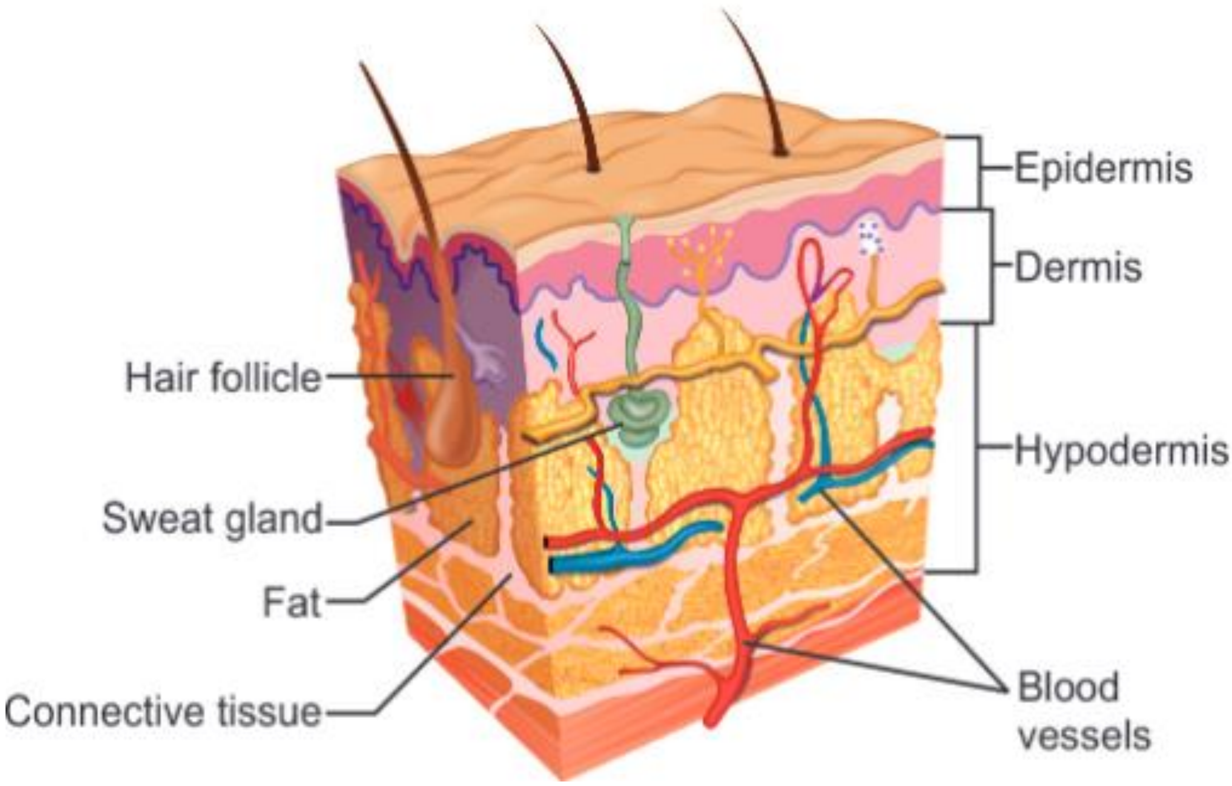


Figure 23: Illustration showing the structural layers of the skin: Epidermis, dermis and hypodermis with the appendages. [3]

1. The epidermis:

The epidermis is the most external layer of the skin. Embryologically, it originates from the surface ectoderm. It is formed by a stratified squamous epithelial layer and is usually divided into four layers, termed stratum, from deep to superficial [3]: (Figures 24)

- **Stratum basal:** also called the basal layer, separated from the dermis by the basement membrane (basal lamina), is the most inner layer of the epidermis and the location of cell division. It contains Melanocytes and Merkel cells.
- **Stratum spinosum:** also called the squamous layer, contains high concentration of keratin filaments and desmosomes that tightly adhere adjacent cells to one another. The stratum spinosum together with the stratum basal is termed the Malpighian layer.
- **Stratum granulosum:** also called the granular layer, is the most superficial layer of the epidermis that has living cells, and is composed of flattened keratinocytes and keratohyalin granules.
- **Stratum lucidum:** is found exclusively in thickened area skin such as the palms of the hands and soles of the feet and is composed of anucleated skin cells.
- **Stratum corneum:** the most superficial layer, formed by corneocytes that are anucleated cells linked together by corneodesmosomes.

Four different cell types reside in these layers of the epidermis [3]:

- **Keratinocytes:** represents 80% of the total cell populations in the epidermis. During the process of keratinization, they migrate up from the basal layer to the stratum corneum differentiating into corneocytes.
- **Melanocytes:** confined predominantly to the basal layer, they produce melanosomes that are transferred to keratinocytes and gives the pigment intensity of the skin.
- **Merkel cells:** found in the basal layer, they play a role in sensation and are found in high concentration in areas associated with cutaneous nerves and touch sensations.
- **Langerhans cells:** found in the squamous and granular layer, they are antigen-presenting dendritic cells involved in several T-cell responses.

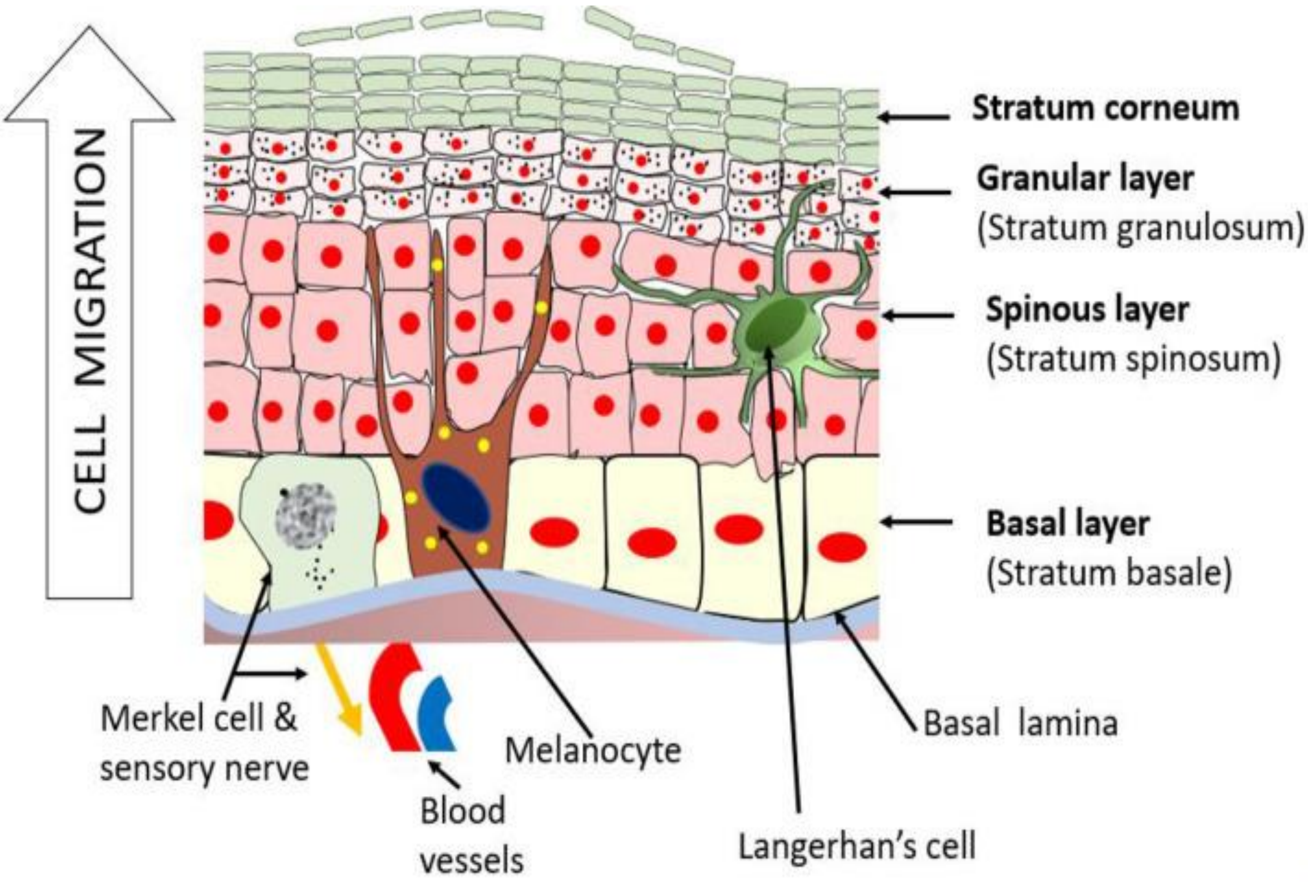


Figure 24: Illustration of the epidermis showing the cell migration and the differentiation of the keratinocytes up from the basal layer to the stratum corneum into corneocytes. [4]

2. The dermis:

Underneath the epidermis, the dermal layer acts as a support network, providing strength and elasticity to the skin. Embryologically, it originates from the mesenchyme.

The dermis is composed of mucopolysaccharides held together by collagen and elastin. Collagen fibres is a key component making up 70% of the dermis, giving it strength and toughness, while elastin maintains normal elasticity and flexibility and proteoglycans provide viscosity and hydration [3]. The dermis is subdivided into two layers: (Figure 25)

- Papillary dermis: thin and superficial, lies below the dermo-epidermal junction and contains loosely arranged collagen fibres.

- Reticular dermis: thicker and deeper, formed by thick bundles of collagen and elastic tissue running parallel to the skin surface.

Within the fibrous tissue of the dermis, we also find blood and lymphatic vessels, nerves, sweat and sebaceous glands, hair roots, mast cells, and small quantities of muscle (Arrector pili).

The dermis also provides nutrition to the epidermis through its capillary network, and innervation of the skin through its sensory nerve endings.

The dermis and epidermis are two very different tissues. When it comes to wound healing, the epidermis undergoes a spontaneous and well-orchestrated healing mechanism known as re-epithelialization based of basal keratinocytes. While the dermis, originating from mesenchymal tissue, exhibits a more anarchic and disorganized healing process, resulting in connective or dermal scarring. Which is responsible for the appearance of sequalae.

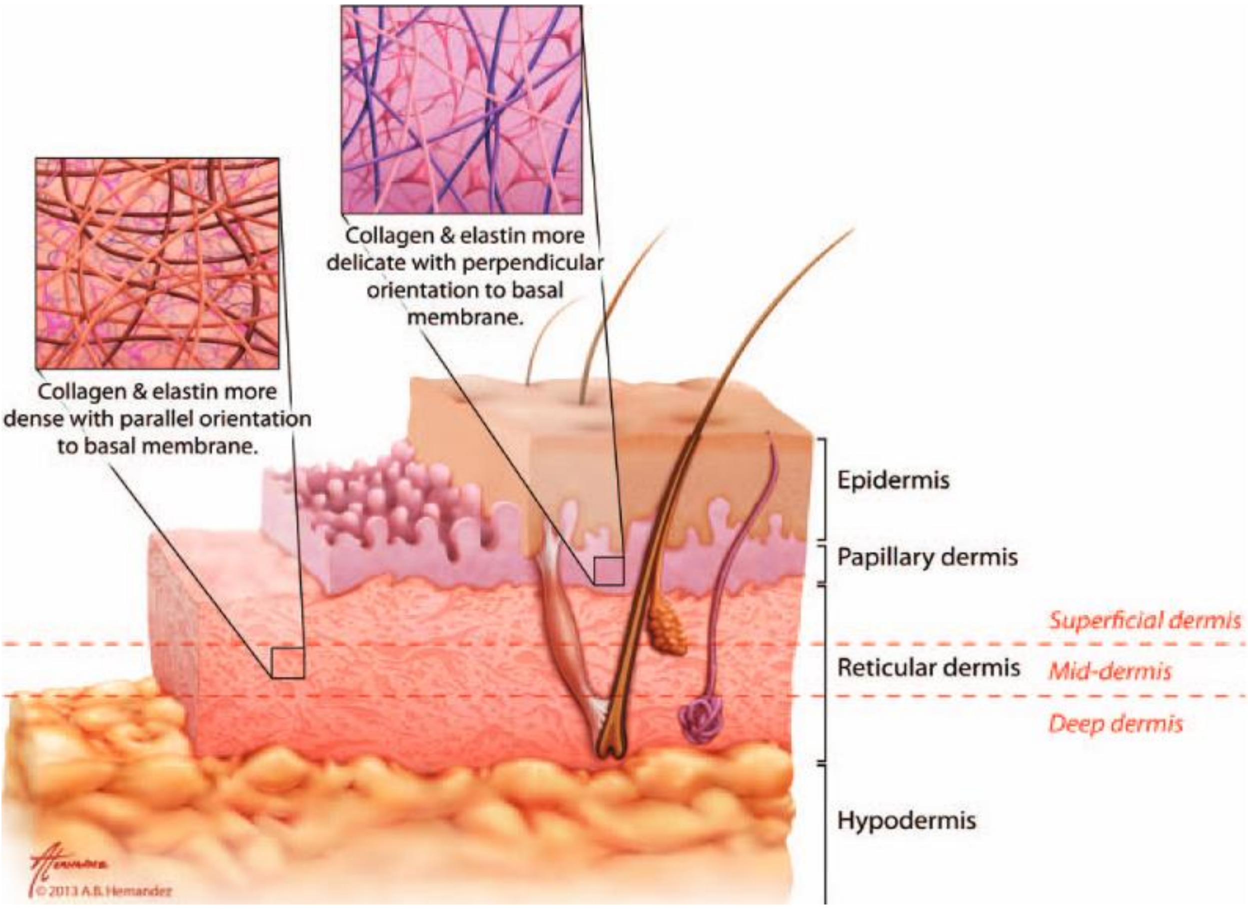


Figure 25: Illustration of structures in the papillary and reticular dermis. [4]

3. The hypodermis:

The hypodermis or the subcutaneous tissue, found beneath the dermis and above the muscles, is the deepest layer of the skin. Embryologically, at the end of the fifth month of gestation, fat cells begin to develop in the subcutaneous foetal tissue [3]. It serves as a reserve energy supply, provides insulation from the cold and allows mobility by sliding over underlying structures.

The hypodermis is primarily formed by adipocytes, which are organized into lobules defined by fibrous connective tissue (septa). Nerves, blood, and lymphatic vessels are located within the septa.

It serves as a clear and identifiable guide during the process of avulsion of third-degree burns.

Medications administered in this layer have rapid uptake because it is abundant with vasculature.

4. Epidermal adnexa:

The adnexa refer to the appendages of the integumentary system. It consists of important appendages including pilosebaceous units, eccrine ducts, apocrine glands, and nails.

The skin appendages promote wound healing by encouraging re-epithelialization after injury through the migration of keratinocytes from the pilosebaceous units to the damaged epidermis [3].

c. Vasculature and innervation of the skin:

1. Skin vasculature:

Skin vasculature depends on the skin's functions. It enables oxygenation and nutrition of skin structures, and maintains blood pressure, thermoregulation and the body's water balance.

The dermis is the essential nourishing structure as it contains blood vessels destined for the skin. The epidermis is totally avascular and rely on diffusion for oxygen and nutriments.

Blood supply to the skin is an arrangement of two plexuses, the first lies between the papillary and reticular layers of the dermis and the second deeper one lies between the dermis and subcutaneous tissues. The deep plexus contains larger blood vessels than the superficial plexus and is supplied by branches of cutaneous and musculocutaneous arteries coursing through the hypodermis [4]. (Figure 26)

In the dermis, collateral vessels extend towards pilosebaceous follicles or sweat glands, generating capillary loops that supply the dermal papillae. The pressure within these superficial dermal networks is consistently low, approximately 1 to 2 mm of mercury. This low pressure explains the susceptibility to cutaneous necrosis through external pressure, as seen in pressure sores. Additionally, the delicate nature of these vessels increases the risk of distress or necrosis in a skin flap following unintentional manipulation [5].

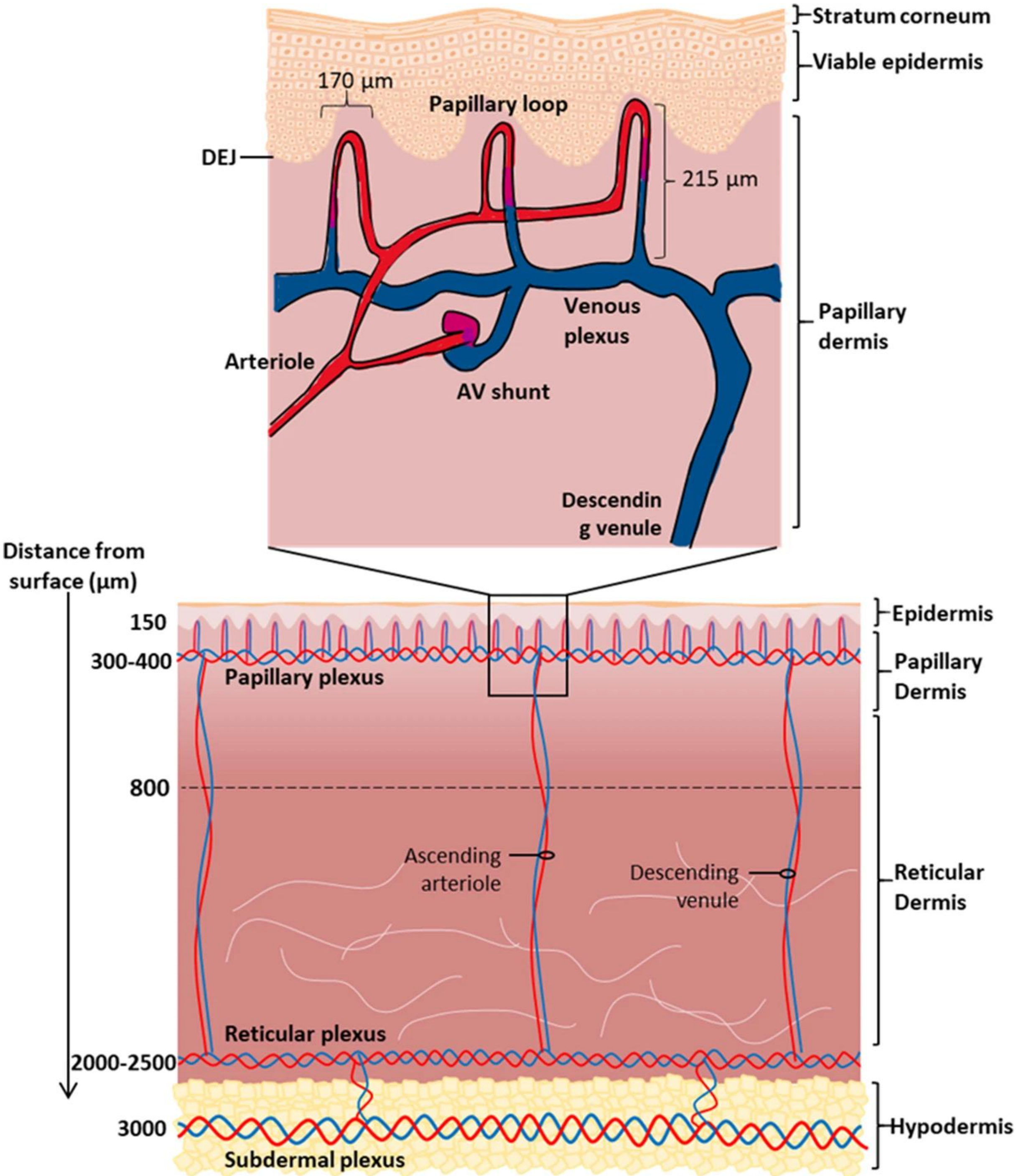


Figure 26: Illustration of skin vasculature. [6]

2. Lymphatic vasculature:

In addition to blood vascularization, the skin also has lymphatic vascularization. Its network is superimposed on the arteriovenous network.

Its importance lies in the fact that, during flap harvesting, its base must be oriented in the direction of lymphatic flow to prevent lymphedema [5].

3. Skin innervation:

Nerves course through the dermis in nerve bundles, along arterioles and venules, and they include both somatic and autonomic nerves (Figure 27).

Several skin receptors play a role in the somatic sensory system:

- Meissner receptors detect light touch
- Pacinian corpuscles perceive deep pressure and stretching and vibrational changes
- Ruffini endings detect deep pressure and stretching of the skin's collagen fibers
- Free nerve endings located in the epidermis respond to pain, light touch, and temperature variations.
- Merkel receptors associated with the Merkel cells respond to sustained light touch induction over the skin.

The autonomic innervation is responsible for the control of the smooth muscles of blood vessels, the pilomotor stimulation at the hair root, and sweating.

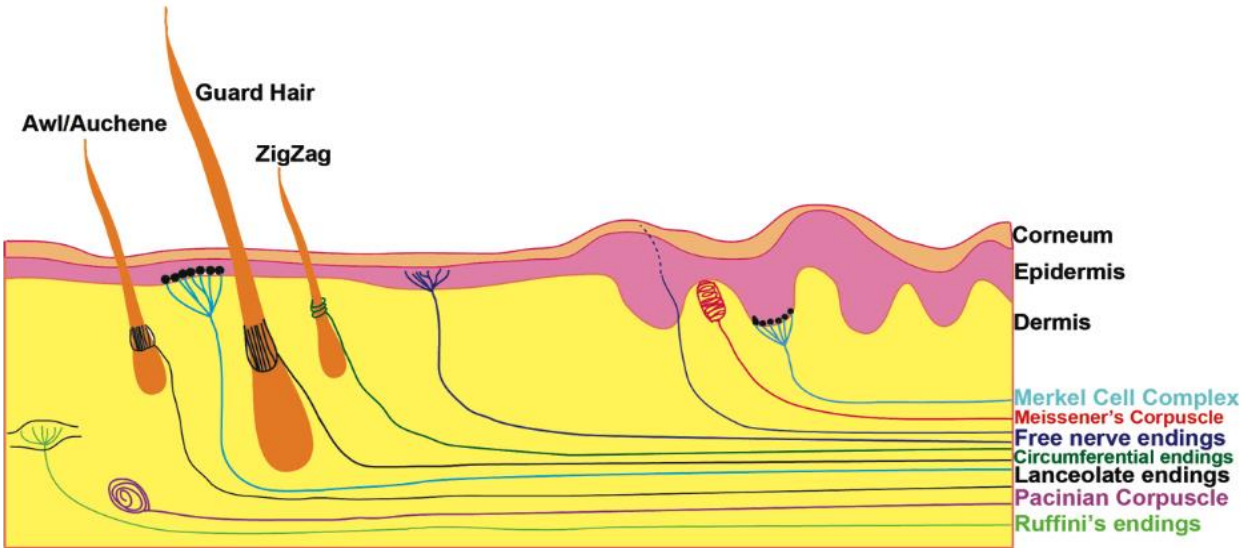


Figure 27: Illustration of the somatic and autonomic nerves of the skin. [7]

2. Pathophysiology of burns:

a. Definition of a burn injury:

A burn is the partial or total destruction of the skin and underlying tissues by a damaging agent. International literature shows a diversity of burn causes: gas, water and boiling fluids (boiling oil at 200°C, coffee, tea, milk and sauces...), flames, explosions, electric current, chemicals such as acid and radiation, all of which can be divided into four main categories: *thermal burns, electric burns, chemical burns and radiation burns* [1].

b. Mechanisms of burn injuries:

1. Thermal burns:

Thermal burns are by far the most common. Approximately 86% of burns are caused by thermal injury [6]. They are characterised by the triad: nature of the burning agent/temperature/contact time. Notably, in order to create a deep burn, the contact must only take 1 minute at 50°C, a few seconds at 60°C and 1 second at 69°C [7].

- **Scalds:** One of the most frequent causes of thermal burns is scalding by hot steam or liquids, usually in the kitchen or bathroom. Steam burn by projection, and hot liquids burn by splashing or immersion. The early appearance of scald burns is often falsely reassuring, with the risk of underestimating their severity (Figure 28).

- **Flames:** Flame-induced burns, such as those caused by direct contact with a flame, often lead to extensive and frequently profound injuries, typically classified as third-degree burns. This risk intensifies, particularly when clothing becomes involved, increasing the severity of the burns. They carry a major risk of damage to the upper airways through inhalation of burning gas or toxic fumes. This risk escalates in enclosed spaces during fires or instances of immolation by fire (Figure 29).

- **Explosions:** Burns caused by explosions are the one of the most common cause of death from burns. They are particularly serious in enclosed spaces, as the shock wave is reflected by walls and bounces back towards the victim. Skin burns are intermediate to deep, and are often associated with screening, crushing or blast injuries.

- **Contact with a hot solid:** Burns caused by hot metal mainly affect manual workers. They are always very deep, but remain localized at the point of contact. Palm burns are characteristic of young children at the age of tactile exploration of the environment: oven door, iron, etc.

Figure 28: Thermal burn affecting the trunk and the lower right limb by scalding (Photo’s taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

Figure 29: Thermal burn affecting the face, neck, trunk and the upper right limb by flame (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

2. Electrical burns:

Electrical burns account for less than 5% of admissions to burn centres [6]. They occur mainly in the context of domestic and work-related accidents.

It’s essential to distinguish between the various electrical phenomena, because they don’t all have the same severity.

- **Electrification:** corresponds to all the pathological effects induced by the flow of current through the body, treating the body as an electrical conductor. Low-voltage currents (below 500V) result in deep yet relatively localized burns at both entry and exit sites. However, high-voltage currents (exceeding 1000V) lead to immediate cardiac arrest and substantial tissue damage at these points. The lesions observed are of two primary categories: some are the consequence of depolarization induced by the passage of the current, others of the heat it gives off in crescents of resistance: nerve < vessels < muscles < skin< tendons < fat < bone). (Figure 30a and 30b)

- **Electrocution:** is the death resulting from cardiac arrest caused almost instantaneously by the sudden depolarization of the myocardium.

- **Lightning strikes injuries:** refer to the effects of lightning on the body, whether death occurs or not.

- **Electric flash:** is a purely luminous and thermal phenomenon, with no current passing through the body. It causes rather superficial burns, except when clothing is inflamed.

Figures 30a – 30b: Electrical burn affecting the hand (Entrance of the electrical current) 30a, and the foot (Exit of the electrical current) 30 b. (Photo’s taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

Figure 30a

Figure 30b

3. Chemical burns:

Chemical burns account for around 3% of all burns [6]. They used to occur mainly in the context of domestic and work-related accidents, but are increasingly being observed in assaults. It is impossible to draw up an exhaustive list of the products involved: acids, bases, organic compounds such as phenols or petroleum derivatives, non-organic agents such as lithium, sodium or phosphorus, and so on. The lesions observed are not only cutaneous, but also respiratory, digestive or ocular. Some agents also have general toxicity: metabolic, renal, hepatic, neurological or haematological, etc.

The appearance of chemical burns varies according to the product involved and the nature of the injured tissue. Lesions are generally deep, but the initial clinical appearance is often difficult to assess. Bases have a stronger and more prolonged penetrating power than acids. (Figure 31)

The mode of contact is a determining factor in lesions: burns caused by caustic sprays are punctiform, linear or "sheet-like", whereas burns caused by massive impregnation of the victim's clothing or immersion affect large areas of skin.

Figure 31: Chemical burn affecting the right hand by black Henna [7]

4. Radiation burns:

Radiation burns or *acute radiodermatitis*, occur after excessive exposure to ionizing radiation. The most common type of radiation burn is sunburn caused by an ultra violet radiation, but it can also be caused by other type of radiation, notably ones delivered to the skin during cancer treatment as well as during nuclear attacks and disasters. (Figure 32)

The specific nature of ionizing radiation makes acute irradiation particularly serious. Factors as the type of radiation, its energy, penetration and ionization power, total amount/dose, fractionation and overall exposure/treatment time, play a role in the severity of the burn [8].

Figure 32: Acute radiation dermatitis (Radiation burn) in breast cancer [9]

c. Local and systemic response to burn injuries:

1. Inflammatory response:

Immediately following a burn injury, an intense and prolonged immunity response occur. This response has both cellular and humoral components.

- **Cellular response:** Following temperature-induced cell destruction, neutrophils migrate to burned tissues triggered by chemokines like IL-8. This migration occurs both in alveoli after respiratory burns and in the dermis after skin burns. The activated monocytes and macrophages following the burn, release cytokines and inflammation mediators, inducing an immunosuppressed state that predisposes patients to sepsis and multiple organ failure [9].

- **Humoral response:** In burned tissues, immune cells release mediators that induce dysfunctions, exhibiting either pro-inflammatory or anti-inflammatory properties. Post-burn, interleukin-6 (IL-6) concentration increases significantly, leading to systemic inflammatory response syndrome (SIRS) by promoting the synthesis of C-reactive protein in the liver [10] [11]. Meanwhile, IL-10 or IL-13 inhibits the production of other mediators and tumour necrosis factor (TNF) [12]. The inflammatory profile in burn patients shifts based on the balance between these opposing pro and anti-inflammatory processes. Dominance of anti-inflammatory mechanisms results in decreased immunity and heightened susceptibility to infections in severely burned individuals [13].

2. Cardiovascular response:

Cardiac stress is the hallmark of the acute phase response and its severity determines postburn outcomes.

- **Hypovolemic chock:** After a burn, two mechanisms set in: capillary hyperpermeability (in burned and unburned areas) and hypoprotidemia. The consequences of these two disturbances are hypovolemia and oedema. Hyperpermeability is due to inflammatory mediators. It is also due to free radicals. Plasma and protein leakage from the intravascular milieu into the interstitium is altered by adrenergic vasoconstriction, but with an increase in hydrostatic pressure. The passage of proteins into the interstitium results in hypoprotidemia and oncotic hyperpressure.

- **Cardiogenic chock:** Burn injuries can adversely affect myocardial function by directly reducing contractility, as demonstrated in isolated heart studies [14] [15]. Severe cases may further experience detrimental desynchronization between the right and left ventricles, exacerbating the compromised state of the myocardium [16].

- **Hyperkinetic chock:** At 72 hours, hypovolemic shock leads to hyperkinetic shock. IL6 and nitric oxide (NO) are involved, causing vasoplegia [17].

3. Respiratory response:

3.1. After fume inhalation:

The direct thermal effect on the respiratory mucosa results in oedema, which is further aggravated by capillary hyperpermeability due to the inflammatory response.

Obstruction of the distal bronchi leads to micro-attenuation and inequalities in the ventilation/perfusion ratio.

After exposure to smoke, the alveolus undergoes an intense local inflammatory reaction. The influx of neutrophils is followed by local cytokine production, pulmonary capillary hyperpermeability and intra-alveolar exudation.

The destruction of surfactant by these inflammatory and toxic mechanisms leads to acute respiratory distress syndrome (ARDS), with alveolar collapse and reduced lung compliance [18].

Finally, smoke contains gases such as carbon monoxide (CO) and cyanides (CN), which have a systemic toxicity responsible for cellular hypoxia secondary to a transport defect (CO binds to haemoglobin) or cellular utilisation (CN blocks mitochondrial metabolism). CN intoxication induces lactic acidosis, with a correlation between plasma lactate levels and plasma CN levels [19].

3.2. Without fume inhalation:

Third-degree burns to the trunk (thorax and/or abdomen) retract, reducing thoracic parietal compliance and creating a restrictive syndrome.

Third-degree circumferential burns to the trunk compress the rib cage, which is immobile and rigid. Spontaneous or mechanical ventilation on a respirator becomes impossible. Thoracic discharge incisions are then used to re-establish normal ventilatory mechanics.

4. Renal response:

Acute renal failure is a well-known complication of severe burn linked to the size and depth of burns and the presence of septicaemia. Predicting renal outcomes is facilitated by monitoring microalbuminuria and urinary malondialdehyde levels, serving as valuable markers in assessing renal function and prognosis [20].

5. Digestive and hepatic response:

Approximately 6% of burn victims develop abdominal complications. These are most often abdominal compartment syndrome (ACS) and acute mesenteric ischemia [21].

6. Haematological response:

The three bloodlines and coagulation undergo major disturbances during the course of severe burns.

- **Erythrocytes:** Haemoconcentration and polycythaemia lead to chronic anaemia. The latter is due to thermal haemolysis, perioperative bleeding and reduced bone marrow production [22].

- **Platelets:** Thrombocytopenia is initially due to haemodilution. Thrombocytosis appears after two weeks [23].

- **Coagulation:** After haemodilution with a reduction in coagulation factors, hypercoagulability occurs, with an increase in factors and a decrease in antithrombotic proteins. This situation can worsen and lead to disseminated intravascular coagulation (DIC) [24].

d. Degree of burn injuries:

The depth of the injury depends on the intensity of the burning agent and the time of exposure. Depending on the depth of skin damage, burns are divided into 3 degrees:

- **First-degree:** Histologically, they are characterized by lesions in the superficial layers of the epidermis. First-degree burns are dry and usually present with erythema, hyperaemia, and pain. Blistering is not observed. Pain due to extracellular release of chemical mediators and prostaglandins disappears in less than 72 hours. Spontaneous healing occurs in 4 to 5 days, with slight desquamation. (Figure 33)

Figure 33: First-degree burn of the back, characterised by the presence of an erythema

- **Second-degree:** affect the entire epidermis and the dermis to a greater or lesser extent. It is the severity of the damage to the dermis that defines superficial and deep second-degree burns:
  - Superficial second-degree: extend to the papillary dermis, manifesting characteristic blister formation. Blistering may not manifest immediately post-injury, leading to potential

misdiagnosis of burns initially perceived as superficial, ultimately necessitating revaluation as dermal burns. The wound surface underlying a blister is pink, wet, and hypersensitive to touch and usually heal within 2 weeks without risk of scarring and therefore do not require intervention [25]. (Figure 34)

Figure 34: Superficial second-degree burn of the face, characterised by the presence of blisters. (Photo’s taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

- Deep second-degree: extend to the reticular dermis. It is characterized by blisters and the wound surface underlying a blister is mottled pink and white, less sensitive and when pressure is applied to the burn, capillaries refill slowly or not at all. It generally takes 3 or more weeks to heal. However, these burns should be excised and grafted once it is clear that they will not heal in 3 weeks [25]. (Figure 35)

Figure 35: Deep second-degree burn (or intermediate stage) of the hand. (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

– **Third-degree:** Histologically, they are characterized by lesions in the entire cutaneous layer and may extend into the superficial subcutaneous tissue. They appear charred, leathery, dry, firm, and depressed compared to surrounding skin. These wounds lack sensitivity to light touch and rarely blanch on pressure and may have a cardboard consistency. Most third-degree burns should undergo early excision and grafting to minimize infection and hypertrophic scarring and to promote fast and effective patient recovery. (Figure 36)

Figure 36: Clinical aspect of a third-degree burn on the leg by scalding. (Photo’s taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

- Deeper burns that involve adipose tissue (fourth-degree burns), muscle (fifth-degree burns), and bone (sixth-degree burns) also require surgical management [25].

3. Severity criteria:

Evaluating the severity of the burn incident on-site is crucial in order to adapt pre-hospital treatment. The prognosis will then be determined on admission, taking into account the main factors of severity:

a. Total burned surface area:

The TBSA is considered to be the main parameter determining the severity of the general repercussions of the burn (hydro-electrolytic losses). It is calculated as a percentage using pre-established rules and diagrams.

In adults, the TBSA is estimated by reference to The Wallace rule of 9 (Figure 37). This tool is only utilized for second-degree and third-degree burns and has been shown to be the most frequently used algorithm for estimating burn surface area in burn injuries in numerous studies for being the least complex and most time efficient assessing the severity during emergency situations compared to other methods [26].

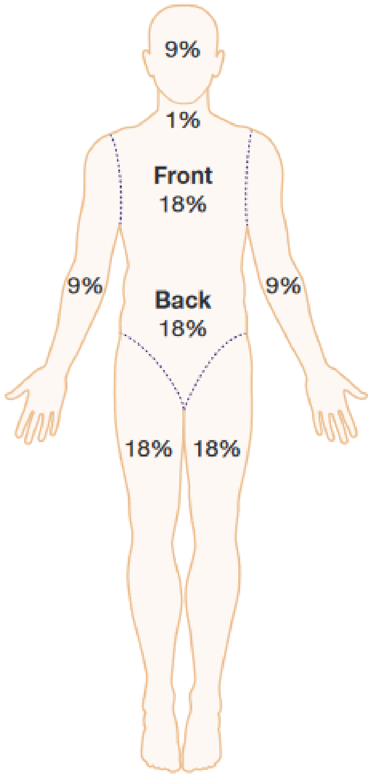
The rule of nines consists of dividing the body surface into several segments, each worth nine percent or a multiple of nine percent of the total body surface, except for the face of the hand, the perineum and the external genitalia, where each represents 1% [26]. Based on the latter, the rule of Palm (1%) is used, representing a simpler unit for easy calculation.

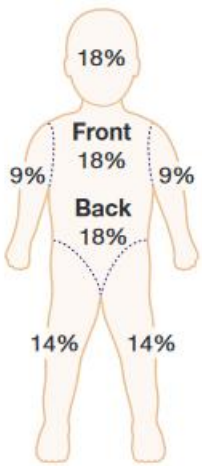
More precise tools that take age into account make it possible to refine this assessment on admission especially for infants, the Lund and Browder (LB) table being one example (Figure 38), the modified Lund and browder (MLB) that has shown to an improved tool with more accurate TBSA measurement and less variability (Figure 39) [27] and computerized methods of burn size estimation that are also available (Figure 40) using three-dimensional photography [28], and smart phone applications [29] which are reported to be very accurate but have not yet found wide acceptance.

It is estimated that, regardless of depth, a burn is considered severe when TBSA > 10% in children and when TBSA >15% in adults.

Special case of electrical burns: the surface area of the skin burnt usually underestimates the real extent of the damaged tissue. This is because the passage of current causes tissue damage that is not taken into account when calculating the burned surface area.

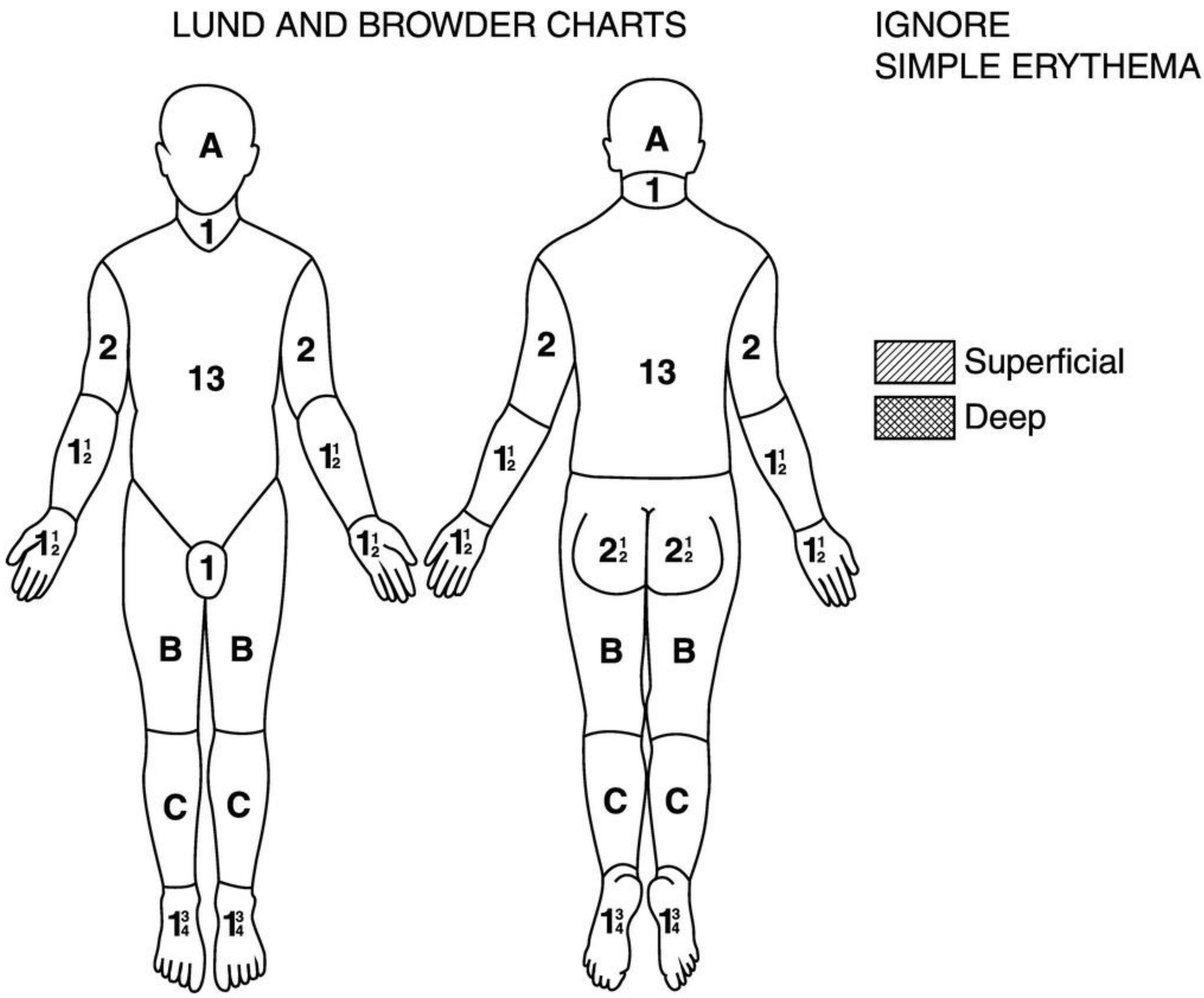
Adult body	% of total
Part	BSA
Arm	9%
Head	9%
Neck	1%
Leg	18%
Anterior trunk	18%
Posterior trunk	18%





Child body	% of total
Part	BSA
Arm	9%
Head and neck	18%
Leg	14%
Anterior trunk	18%
Posterior trunk	18%

Figure 37: Diagram corresponding to Wallace's Rule of 9. [7]



RELATIVE PERCENTAGE OF BODY SURFACE AREA
AFFECTED BY GROWTH

AREA	AGE 0	1	5	10	15	ADULT
A = ½ OF HEAD	9½	8½	6½	5½	4½	3½
B = ½ OF ONE THIGH	2¾	3¼	4	4½	4½	4¾
C = ½ OF ONE LEG	2½	2½	2¾	3	3¼	3½

Figure 38: Diagram corresponding to Lund and browder chart [27]

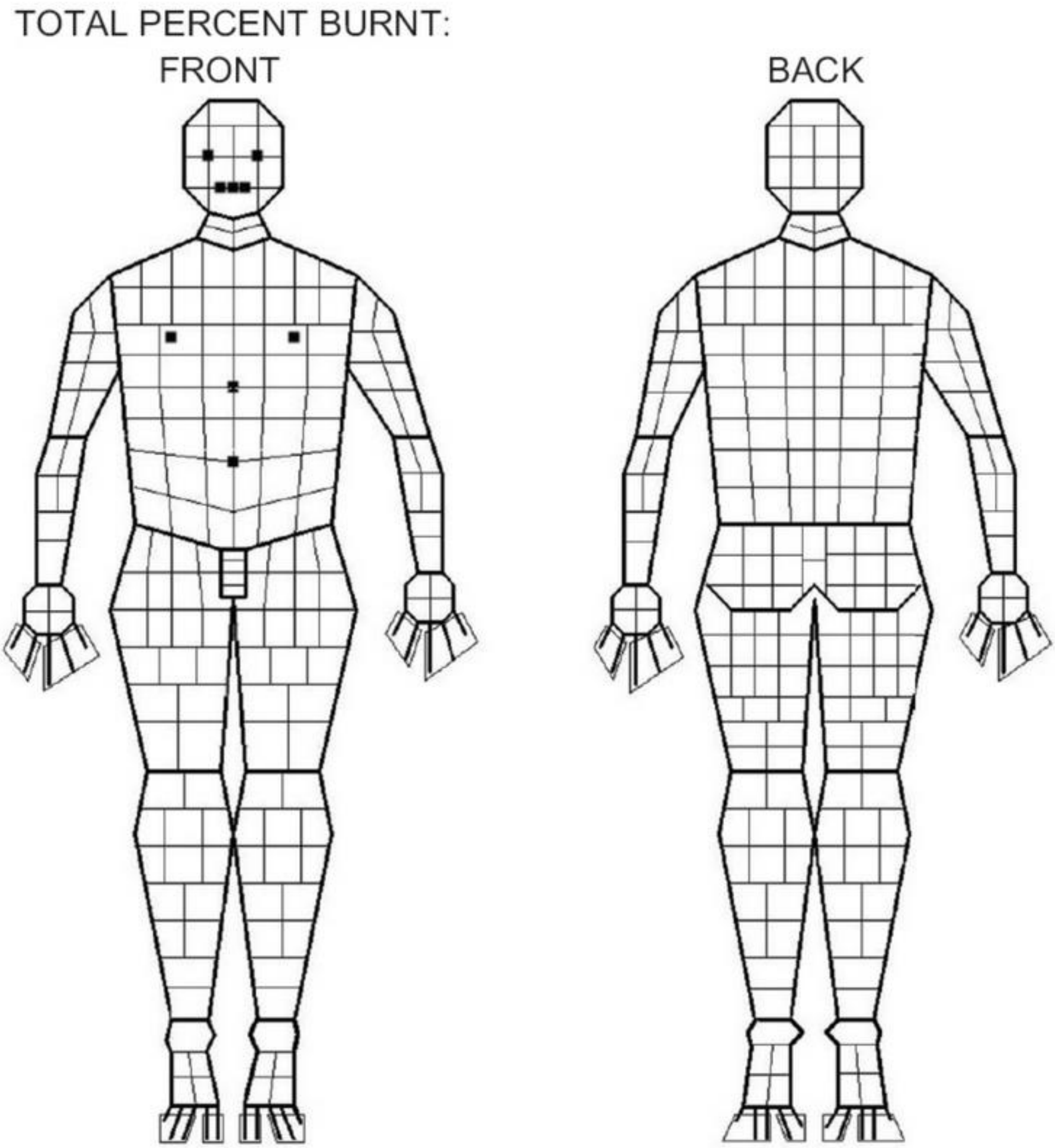


Figure 39: Diagram corresponding to Modified Lund and Browder chart [27]

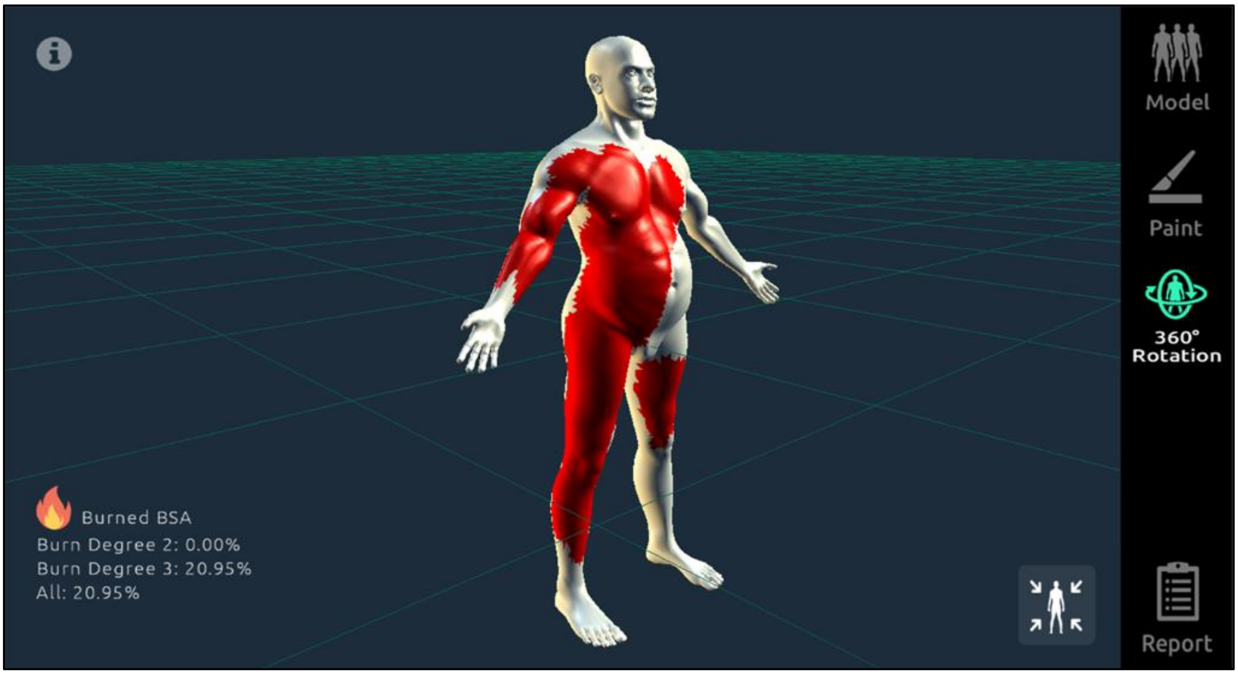


Figure 40: Burned areas are "painted" on the model in the 3D Burn Resuscitation application [29]

b. Depth of burn injury:

When evaluating the severity of burns, another main factor to consider is depth. To accurately determine the depth of a burn, four essential components must be evaluated: appearance, blanching to pressure, pain, and sensation.

Depth of burn	Level of burn	Appearance
First degree (Superficial)	Epidermis	Dry, red, blanches with pressure and painful.
Superficial second degree (Superficial partial thickness)	Papillary dermis	Blisters, moist, wet, blanches with pressure and severe pain to touch
Deep second degree (Deep partial thickness)	Reticular dermis, most skin appendages destroyed	Blisters, wet or waxy, dry, sluggish blanching with pressure and pain to deep pressure
Third degree (Full thickness)	Epidermis and dermis and all skin appendages destroyed	Waxy white to leathery gret to charred black, no blanching, pain only to deep pressure

Table 2: A comparison between the depths of burn

While first-degree burns present no immediate threat, deep second-degree and third-degree burns pose challenging issues due to their prolonged healing process, increasing the risk of infection, and the potential for significant scarring in the future.

c. Age:

The severity of a burn is notably influenced by age. This is evident in vital prognosis indices, like the Baux index, where age is a key factor.

Practically, the prognosis tends to be more critical at the extreme ages (<10 or >50 years old) [6].

d. Burned areas:

The face: Burns to the face present a risk of obstruction of the upper airways due to oedema of the laryngeal tract, and can lead to aesthetic and functional ocular complications (palpebral inocclusion, infections), and scarring after-effects with major psychological and social repercussions.

The hands: Burns to the hands are considered serious because of the functional risks (damage to the extensor tendons of the fingers is common in deep burns) and aesthetic risks.

The feet: Burns to the feet can lead to aesthetic and functional risks.

Circumferential burns to the limbs and neck expose the arteries to the risk of compression, meanwhile circumferential burns to the chest may restrict breathing and chest movement.

The perinium: Perineal burns present an increased risk of infectious complications.

e. Mechanisms of burn injuries:

Thermal burns:

- Boiling water often causes a deep dermal burn, unless the duration of contact is very short. Soups and sauces, due to proteins and oily components, remain in contact longer with the skin and cause deeper dermal burns.

- Grease and hot oils cause deep dermal or 3rd degree burns. Approximately 30%–40% of grease burns require excision and grafting [7].

- Flame burns may sometimes appear shallow with intact epithelium to the inexperienced but is really a deep 2nd or 3rd degree burn due to the prolonged exposure to intense heat.

- Immersion burns are much more extensive than oily liquid splashes, which are often less extensive but deeper. Flame burns are more serious.

Chemical burns:

- Chemical burns cause progressive tissue damage until the chemicals are inactivated by reaction with the tissue or by dilution by copious water.

- They often cause deep dermal or 3rd degree burns

Electrical burns:

All patients exposed to high-voltage electricity are considered severe due to increased deep-tissue injury and subsequent increased amputation rates, organ failure, and mortality as compared to patients with comparable TBSA thermal burns [30].

f. Pre-existing medical conditions:

Apart from age, pathological conditions such as cardiovascular and neurological pathologies, renal failure, immune deficiency or diabetes are important factors in aggravating burns.

g. Associated injuries:

Fumes inhalation:

- Burns resulting from fires often involve significant inhalation of smoke. This not only leads to systemic poisoning, such as *carbon monoxide* or *cyanide poisoning*, but also causes chemical burns in the bronchial mucosa.

- In burn centres, approximately 20% of hospitalized patients experience these injuries, worsening the overall condition, as the mortality rate associated with both pulmonary and skin lesions ranges from 20% to 100% [31].

Other injuries:

- Any patients with burns and concomitant trauma (such as fractures, head trauma ...)

- Blast syndrome

4. Prognostic indexes:

The prognostic scores, which are determined from the combination of the various parameters described above, make it possible to assess the vital risk of a burn injuries.

a. The Baux Index:

The original Baux score was the addition of two factors: the first being the TBSA and the second being the age of the patient.

$$Baux\ score = TBSA + Age$$

- If the score < 50: the chances of survival are close to 100%.
- If the score > 75: the burn is considered serious
- If score > 100: chances of survival are less than 10%.

b. The Revised Baux Index:

The revised Baux score takes into account the effect of inhalation injury.

$$Baux\ score = TBSA + Age + (17xR)$$

With R=1 if there is an inhalation injury and R=0 if there is no inhalation injury.

c. The Abbreviated Burn Severity Index ABSI:

The ABSI score estimates survival expectancy in a burn patient via various negative prognostic factors including: (1) sex, (2) age, (3) presence of inhalation injury, (4) presence of a 3rd degree burns, and (5) percentage of TBSA.

(Figure 41)

Parameter	Finding	Points	Parameter	Finding	Points
Sex	Female	1	TBSA (%)	1–10	1
	Male	0		11–20	2
Age (years)	0–20	1		21–30	3
	21–40	2		31–40	4
	41–60	3		41–50	5
	61–80	4		51–60	6
	81–100	5		61–70	7
Inhalation injury	Yes	1		71–80	8
	No	0		81–90	9
Full thickness burn	Yes	1		91–100	10
	No	0			

ABSI	Threat to life	Probability of survival %
2–3	Very low	≥ 99%
4–5	Moderate	98
6–7	Moderately severe	80–90
8–9	Serious	50–70
10–11	Severe	20–40
≥ 12	Maximum	≤ 10

Figure 41: Diagram corresponding to the ABSI score chart [32]

There is no significant difference between the R-Baux Score and the Abbreviated Burn Severity Index (ABSI) Score as a predictor of mortality in burn patients [32].

d. The Unit Burn score UBS:

The UBS takes into account the depth of the lesions.

$$UBS = \%TBSA + 3x\ \%\ of\ 3rd\ degree\ burn\ area$$

- If UBS score > 50: the burn is considered serious
- If UBS score > 100: the burn is considered very serious

If UBS score > 200: chances of survival are close to 0%

5. Treatment and management:

The management of burn patients depends on the severity of the injuries. Severe burns constitute a medical and surgical emergency, requiring multidisciplinary care. A non-severe burn can be treated on an outpatient basis.

a. Initial care:

1.1. Prehospital management:

At the scene of the accident, the first thing to do is to call the ambulance (SAMU) or the fire brigade (15).

First aid involves a series of actions to be carried out, sometimes even before a medical team arrives:

- ✓ Remove the burn victim from the causal agent or prevent it from continuing to have an effect (switching off the electrical current, washing out chemical burns, putting out a fire).

- ✓ Remove clothing to stop the thermal process and remove watches and rings, as these can compromise the underlying circulation when oedema sets in.

- ✓ Water cooling (8 to 25°C) for up to 20 minutes, to limit pain, swelling and deepening of the burns. This should be done within three hours [33]. Ice or ice water should not be used due to the risk of hypothermia and impaired perfusion. In the case of severe burns (TBSA >15%), due to the risk of hypothermia, the duration of cooling should be limited [33].

- ✓ Protect burn victims from the risk of infection by covering the lesions with clean dry sheets.

- ✓ Avoid hypothermia by covering extremities and head and applying warm blankets.

- ✓ Elevate the burned extremities as far as the patient's clinical condition allows, to limit the progression of oedema, particularly in the head and limbs.

.

- x The application of antiseptic solutions to wounds should be avoided, due to systemic absorption and almost certain toxicity in infants.

- x Avoid putting butter or other greasy substances on the wound as it retains the heat and can increase the severity of the burn.

- x Avoid bursting blisters as it can increase the risk of infection.

1.2. Interhospital management:

The main objective is to assess the severity of the burn as accurately as possible, specifying the existence of any associated severity factors. While at the same time taking the first therapeutic steps.

a. Clinical evaluation:

It is useful to gather all the information you can about the patient (identity, date of birth, weight, medical history) and to ask about the accident: the time, the circumstances and the mechanism.

The examination area must be clean, the patient completely undressed and handled with gloves and by cleanly dressed staff. The admission examination must assess *the severity of the burn* and, more specifically, *the TBSA* using the Rule of 9 or, more precisely, the Lund and Bowder table, and estimating the depth of the burn.

Evaluating the severity criteria: (Recommendations of the French society of burns SFE)

- TBSA>10% or existence of one or more of the parameters below

- Age < 5 or > 60
- Burns in the face, neck, hands, perineum, flexion folds
- Any deep electrical or chemical burn
- Burns in the event of an explosion, public road accident or fire in a closed environment
- Home care impossible (hyperalgesia, unfavourable living conditions)
- Serious pre-existing pathology (polytrauma, heart disease/coronary artery disease, diabetes, chronic respiratory failure)

All severe burns must be treated in a specialist centre. Burn management is started at the pre-hospital stage. It is continued during the initial hospitalization, inter-hospital transport, and then in the specialised intensive care unit.

b. Emergency care:

Assessment of a burn patient begins with the ABCs of a primary survey, including airway, breathing, circulation, cervical spine immobilization, and a brief baseline neurological examination.

During this step any life-threatening emergencies must be identified and addressed.

- All patients should be placed on supplemental oxygen starting with a high concentration mask (6l/min) then adapted to saturation, (15l/min) in the case of CO intoxication.

- Two intravenous (IV) lines should be initiated using a 16-gauge catheter or larger, with one designated for vascular filling and the other for sedation. Ideally, the IV lines should be placed in non-burned areas; however, if no other sites are available, they may be inserted through a burn. In the absence of a peripheral venous line, consider a femoral central venous line as the preferred alternative. The intraosseous route is a last-resort option but proves valuable in cases of extremely extensive burns (> 80% total body surface area).
  Demling's rule: Peripheral IV line in non-burned areas **>** Central IV line in non-burned areas **>** Peripheral IV line in burned areas **>** Central IV line in burned-areas

- Bladder catheterisation should be performed as soon as the burn requires vascular resuscitation, or in case of a burn in the perineal region.

- A nasogastric tube should be inserted in all burn patients in order to decompress the stomach.

- Intubation is required in the event of: cardiorespiratory arrest - signs of respiratory distress - profound impairment of consciousness - deep burns to the cephalic segment (face or neck) - a burnt skin surface area ≥ 40% - smoke inhalation / upper airway burns [34].

- The patient's temperature must be kept between 37.5°C and 39.0°C [7].

- Level 1 and 2 analgesics in the WHO classification are usually insufficient. Morphine drugs for spontaneously ventilated patients and morphinomimetics combined with a benzodiazepine for intubated patients should be prescribed on a titration basis, with assessment of efficacy and monitoring of side-effects.

Apart from the initial stabilization procedures, blood should be collected for initial laboratory studies if not already completed. Initial diagnostic assessments encompass haematocrit, electrolytes, urinalysis, chest X-ray, arterial blood gas, and carboxyhaemoglobin and cyanure levels [7].

c. Resuscitation:

Fluid and electrolyte intake is recognised as essential, and must be adapted early on.

Several formulas have been developed, which are based on the TBSA. The majority of formulas advise using isotonic crystalloid, typically Ringer's lactate (RL) solution, exclusively during the initial 24 hours. This choice helps prevent the development of hyperchloremic acidosis associated with extensive saline infusions [25].

- The Parkland formula is the most widely used calculation to guide fluid resuscitation in burn patients during the first 24 hours after injury. It recommends the administration of crystalloid fluids based on the patient's weight and the extent of burn injury [35].

Total Fluid Volume (mL) = 4 (mL) x Body Weight (Kg) x %TBSA

According to the Parkland formula, half of the calculated volume is administered within the first 8 hours, while the remaining half is given over the subsequent 16 hours. This approach helps to address the immediate needs for fluid replacement and minimize complications associated with both under- and over-resuscitation in burn patients.

- The Shriner's Cincinnati formula, similar to the Parkland formula, designed for children and provides guidance on the administration of crystalloid fluids based on body weight and the extent of burn injury.

Total Fluid Volume (mL) = 4 (mL) x Body Weight (Kg) x %TBSA + 1500mL/m^2 of body surface area

The Cincinnati formula recommends administering half of the calculated volume within the first 8 hours and the remaining half over the subsequent 16 hours.

- The Evans formula, the first *burn* resuscitation *formula* based on body weight and surface area. Requires in the first 24hour the administration of:

1mL/Kg/%TBSA of colloid + 1mL/Kg/%TBSA of Normal Saline + 2000mL of Dextrose 5% in water

In the second day, half of the perfusion intake of the first 24hours should be administered.

- The Carvajal formula, designed for children and provides guidance on the administration of crystalloid fluids based on body surface area and the extent of burn injury.

5000mL/m² of TBSA of normal saline + 2000mL/m² of body surface area of Dextrose 5% in water

The Carvajal formula recommends administering half of the calculated volume within the first 8 hours and the remaining half over the subsequent 16 hours.

- **Monitoring of resuscitation** must be by clinical examination, looking at urine output, extremity perfusion, temperature and hemodynamic monitoring.

Recommended Urine Output is about 30–50 mL/h in adults, 0.5 to 1.0 mL/kg per hour in children of less than 30 kg, and 1.0 to 2.0 mL/kg per hour in infants (Glucose negative) [25].

d. Local treatment:

After the prehospital initial care and addressing life-threatening emergencies, local treatment provides emergency first aid for burn victims. It will promote healing, using various dressings for burns treated externally, and ensure rapid, high-quality skin coverage for deep burns [36].

- ✓ Cleaning burns with 0.9% saline solution, or a diluted antiseptic (Chlorhexidine or Povidone iodine scrub)
- ✓ Shaving of burnt and adjacent areas, flattening of blisters.
- ✓ Pat dry.
- ✓ Wound dressing by using silver sulphadiazine-based occlusive dressings helps prevent infection and accelerate healing and eliminating pressure sores by softening deep burns.

e. Specialised care:

1. Surgical management:

- ***Escharotomy***:

A circumferential third-degree burn on the limbs forms a rigid and inelastic eschar. In the initial 48 hours, significant fluid accumulates within interstitial and intracellular spaces due to increased capillary permeability and fluid resuscitation. The unyielding nature of the circumferential eschar can elevate compartment pressure, potentially leading to tissue ischemia, infection, or contracture. Similar complications can arise in the chest and abdomen areas with large full-thickness burns, restricting adequate expansion and causing respiratory and hemodynamic challenges.

Early surgical intervention by doing escharotomy is critical. The procedure involves incising through burnt skin areas to release constrictive eschar effects, restore distal circulation, and facilitate ventilation in chest areas. Unlike fasciotomy, escharotomy incisions do not breach the deep fascial layer, focusing on relieving immediate constriction and promoting overall tissue recovery. (Figure 42)

Recently, escharotomy has been classified as a part of a wider group of decompressive therapies including fasciotomy, nerve release, and decompressive laparotomy [37].

Figure 42: Escharotomy of the lower limbs (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

➢ *Indications:*

The decision is made based on clinical assessments of the patient and their response to treatment provided before that assessment.

- At the cervical level, strangulation of the cervical part causes inspiratory dyspnoea, followed by asphyxia.

- At the level of the hands, painful paraesthesia are an alarm signal. The onset of Volkmann syndrome is marked by irreducible flexion of the phalangeal joints.

- At the level of the limbs, the swelling of the superficial veins and the bluish appearance of the integuments indicate venous stasis. Arterial ischaemia is diagnosed by the 6 "P"s: pain, pallor, paraesthesia (either tingling or numbness), paresis, poikilothermia (usually the affected limb will feel colder than the unaffected one) and absence of pulse.

- At the level of the thorax, chest wall burns can compromise respiratory function, which can occur even in non-circumferential burns.

- At the level of the abdomen, abdominal wall burns can compromise respiration due to the splinting effect on the diaphragm, especially in infants <12 months due to their predominant abdominal breathing pattern [37].

- At the level of the eye, measurement of intraocular pressure is critical for burns in the region of the eye or in the presence of increased oedema from fluid resuscitation and decompressive therapies including a lateral canthotomy may need to be performed [38].

Escharotomies should be performed as soon as the need for them is identified. This includes indications as described above, but may be done prophylactically in the appropriate patient.

➢ *Technique:*

Escharotomies must be performed in accordance with the rules of surgical asepsis. They require the following equipment: wide-blade scalpel, electrocoagulation, haemostasis forceps and sutures. Haemostatic wicks (Surgicel® or Algostéril®) may be useful. General anaesthesia is recommended, although in theory they can be performed without anaesthetic. Discharge incisions cut the epidermis and dermis in the burned areas, and possibly the fascia superficialis, but not the muscle fascia. Turgid subcutaneous veins must be gradually decompressed by incising from the root of the limb towards its tip, and from the base of the neck towards the chin. If necessary, transverse counter-incisions can be made to free the deep layers. Haemostasis must be meticulous, using electrocoagulation and vessel ligation, followed by the application of haemostatic wicks to protect the entire incision. (Figure 43)

- At cervical level: The incisions follow the vertical axis of the neck along the midline and the anterior edge of the two sternocleidomastoid muscles.

- At the level of the thorax: They follow the right and left anterior axillary lines, starting 1 cm below the clavicle and ending at the costal margin. They go around the nipple.

- At the level of the upper limb: Incisions are made at the inner and outer edges of the upper arm and forearm, in the axis of the limb. Incisions in the hand are dorsal in the intermetacarpal valleys. For the fingers, the incisions are dorsal, slightly above the dorso-palmar junction, to keep away from the vascular and nerve axes.

- At the level of lower limb: The incisions follow the inner and outer edges of the lower limb, in line with the thigh and leg. The main danger is haemorrhage from a branch of the saphenous vein. Incisions on the dorsal side of the foot are radial.

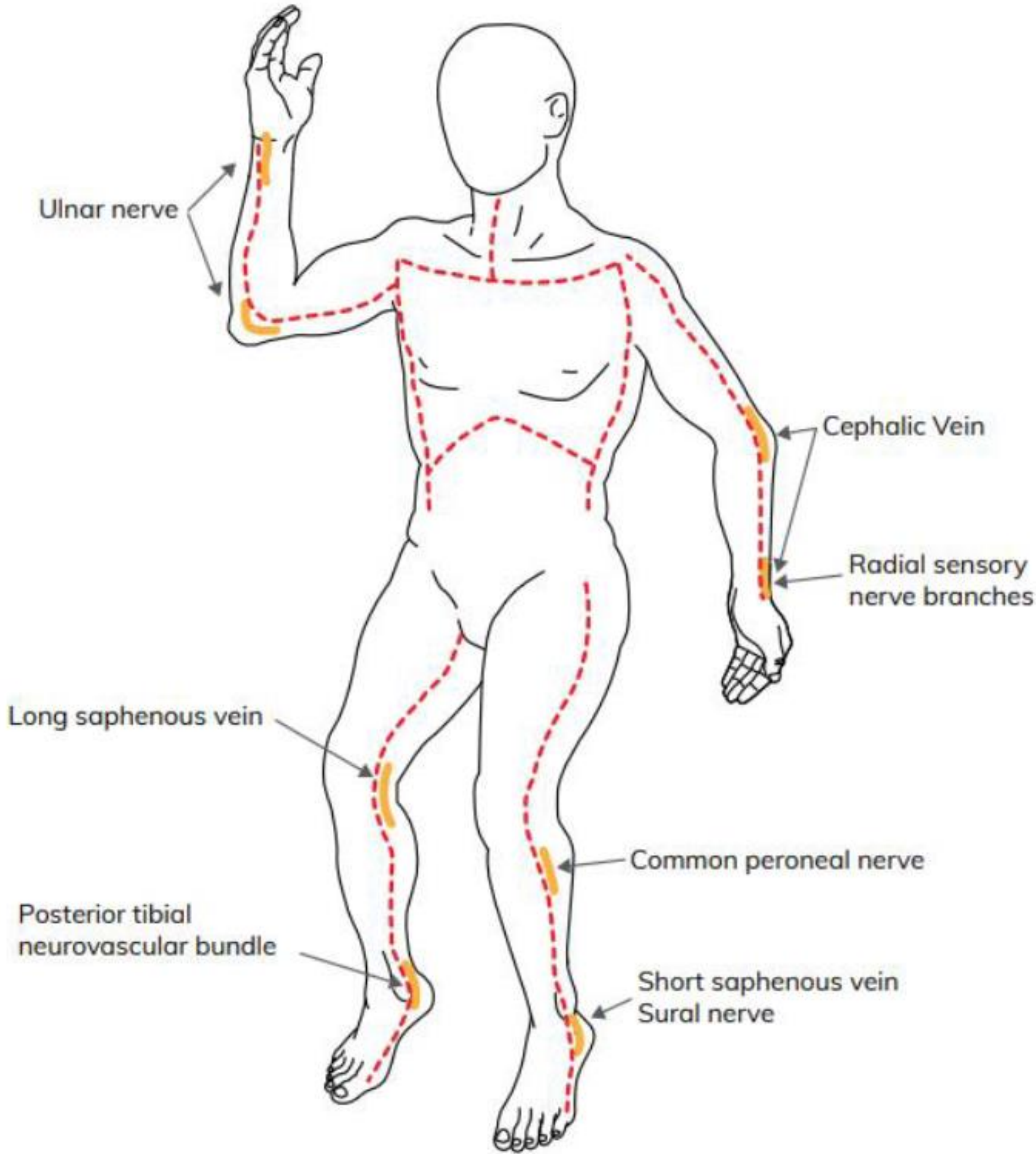


Figure 43: Diagram corresponding to the incision pathways for escharrotomy or decompressive incisions. [39]

➢ ***Complications:***

Escharotomy, like any procedure, carries potential complications related to surgery or anaesthesia.

Possible complications include bleeding (addressed by cauterization), infection, and damage to nearby structures, particularly the ulnar and common peroneal nerves. Inadequate or delayed escharotomy can result in complications such as muscle ischemia, necrosis, and neurovascular compromise leading to gangrene and potential limb amputation.

➢ ***Monitoring:***

Continuous evaluation and monitoring of escharotomy effectiveness are crucial. For limb escharotomy, ongoing assessments of perfusion, compartment pressure, and the potential need for extension or fasciotomy are essential.

Meanwhile chest and abdominal escharotomy require thorough evaluation of respiratory effort, circulatory status, and bladder pressure. Patients may develop intra-abdominal hypertension, necessitating interventions such as paracentesis or decompressive laparotomy when needed.

- ***Fasciotomy:***

The cause of compartment syndrome (CS) is an increase in tissue pressure in an inextensible osteo-fascial compartment, which alters the arterial vascularisation of muscles and nerves. This phenomenon occurs in burn victims in the event of electrification and when escharotomies are not carried out in time in the case of extensive circular burns. If left untreated, nerve and muscle necrosis will result in permanent damage, with a risk of amputation. Aponeurotomy remains the most effective technique for preventing a threatening CS. (Figure 44)

Figure 44: Fasciotomy of the upper right limb (Photo's taken in the plastic surgery and burns department of the military hospital in Rabat)

- *Indications:*

The combination of pain, pallor, paralysis and absence of pulse in a limb is pathognomonic of compartment syndrome according to Griffith. However, each of these signs may be absent at the onset, and the diagnosis must therefore be made systematically in order to rapidly determine the indication for a decompressive fasciotomy. By the time compartment syndrome has set in, serious neuromuscular damage has already occurred.

- *Technique:*

At the level of the lower limb: Leg fasciotomies are performed through two longitudinal incisions:

- The two anterior compartments are decompressed by a long anterolateral skin incision, midway between the fibula and the tibial crest, covering the entire height of the leg from the knee joint line to the lateral malleolus.
- The second skin incision is posteromedial to approach the posterior compartments, 2 cm behind the tibial crest. It extends all the way down the leg, from the knee line to the medial malleolus, bypassing the long saphenous vein and nerve.

At the level of the upper limb: Forearm fasciotomies are the most commonly performed on burn victims. They are performed through two skin incisions, anterior and dorsal:

- The incision in the muscular fascia must cover the entire height of the compartment. The anterior incision begins 1 cm above and 2 cm outside the epitrochlear, and must open the annular ligament of the carpus at the bottom.
- The dorsal incision, if required, starts 2 cm medial to the epicondyle and extends to the junction of the middle and distal thirds of the forearm.

- *Complications:*

Fasciotomy is associated with various complications related to surgery or anaesthesia, including long hospital stay, wound infection and osteomyelitis, need for further surgery for delayed wound closure or skin grafting, scarring, delayed bone healing, pain and nerve injury, permanent muscle weakness, chronic venous insufficiency, cosmetic problems, and an overall increased cost of care.

To reduce the risk of complications, the fasciotomy wound should be closed as quickly as possible.

➢ *Monitoring:*

Continuous evaluation and monitoring of fasciotomy effectiveness are crucial. Fasciotomy wound management begins with an inspection at 48 hours. If the compartments are soft, skin closure is achieved by primary wound closure, secondary wound healing, or split-thickness skin grafting if skin closure is delayed [39].

2. Infections management:

Infection is one of the main causes of mortality in severe burns patients. They become immunosuppressed which make them subject to a number of septic complications.

The three most common types of infection in burn patients are pneumonia, urinary tract infection and cellulitis. Other infections reported as the most common complications in burn patients include burn wound infection, sepsis and bacteraemia. In the first few days of hospitalisation for burns, most of the pathogens responsible for infection are Gram-positive organisms that are fairly sensitive to antibiotics. However, as the length of hospitalisation increases, patients are more likely to be infected by resistant Gram-negative organisms, which can be difficult to treat [40].

The fight against infection is part of an overall global strategy for hospital services, of which antibiotics are only one of the means used, alongside hygiene.

- **Rules of prescription of antibiotics:**

The French Society of Burns recommends the following rules [41]:

- Rule 1: No antibiotics in the absence of confirmed infection.

➢ Reducing antibiotic usage has proven effective in minimizing the emergence of bacterial resistance. Conventional infection criteria based on inflammatory indicators (fever, elevated white blood cell count, increased CRP) are ineffective in burn patients, often leading to unnecessary antibiotic prescriptions, which should be avoided.

- Rule 2: Local infection requires local treatment.

  - Antibiotic therapy prescribed to prevent burn infection does not prevent burn infection and encourages the emergence of multi-resistant bacteria. Local topical preparations are effective in preventing or treating burn infection. When local infection is accompanied by general signs, the infectious process is no longer considered to be purely local, in which case the use of antibiotics may be justified.

- Rule 3: Reduce the bacterial inoculum.

  - Reducing the inoculum not only prevents infection, but also reduces the likelihood of resistant mutants appearing.

- Rule 4: Antibiotic therapy for serious infections is a therapeutic emergency.

  - It is well-established that in the event of a serious (poorly tolerated and/or life-threatening) infection, antibiotic therapy must be started immediately, within 6 hours of the infection being diagnosed.

- Rule 5: Preferably choose bactericidal antibiotics.

  - Experts recommend the use of bactericidal molecules, not only because burn patients have an immune deficiency, but also because the use of a bactericidal antibiotic reduces the inoculum.

- Rule 6: Combining antibiotics.

  - Broader spectrum (useful for probabilistic antibiotic therapy);
  - Increased bactericidal activity (greater and more rapid);
  - Prevention of the emergence of resistant mutants.

- Rule 7: Adapting antibiotic therapy.

  - Any probabilistic antibiotic therapy must be reassessed as soon as the bacteriological results are received, usually in the 48th hour.

- Rule 8: Knowing how to de-escalate or stop antibiotic therapy

  - Replacing a broad-spectrum probabilistic antibiotic therapy with an appropriate narrow-spectrum antibiotic therapy guided by susceptibility testing is known as de-escalation, and should be carried out whenever possible.

- Experts recommend a duration of antibiotic therapy of 7 to 8 days for the majority of infections encountered in burn patients, provided that the initial treatment has been appropriate.
- In the case of an infection by high-risk germs (such as Pseudomonas aeruginosa), a longer period may be necessary, but this should not exceed 15 days.

- Rule 9: Follow the administration instructions: dosage, injection frequency, etc.

- The pharmacokinetics of antibiotics, regardless of their class, are greatly affected in burn patients. It is therefore recommended to increase the dose of each antibiotic administered to burn patients.

- Rule 10: Antibiotic dosage

- Measuring antibiotic concentrations is an excellent way of guaranteeing the effectiveness of the molecules used.

3. Traumas management:

- Diagnosis and Treatment of Inhalation Injury:

Inhalation injury involves three distinct types of damage to respiratory function. Thermal injury to upper throat structures causes swelling and can quickly cause upper airway blockage within the first hours of exposure. Chemical injury occurs within the initial 36 hours, as smoke particles reach the alveoli, triggering inflammatory reactions that result in bronchospasm and compromised gas exchange in the distant airways. Lastly, toxic gases released in most fires, particularly carbon monoxide (CO) and cyanide, impair systemic oxygenation.

There are no pathognomonic signs of smoke inhalation. In the event of a fire in a confined space, the combination of several elements should raise suspicions: face and neck burns, singed nasal hairs, carbonaceous sputum, soot in the upper airways, respiratory symptoms associating dry cough, dysphonia with hoarseness of voice and wheezing, headache and other signs of carbon monoxide poisoning.

Specific therapies for inhalation injury are limited, so treatment continues to focus on supportive care such as intubation. Regardless of the patient's pulse oximetry oxygen saturation, administering 100% supplemental oxygen is crucial due to potential carbon monoxide (CO) exposure. Furthermore, if bronchospasm is evident, inhaled β-agonists can be beneficial [42].

Managing resuscitation in patients with inhalation injury can pose challenges. While severe cutaneous burns combined with inhalation injury elevate fluid needs, aggressive fluid replacement in isolated inhalation injury can worsen airway oedema leading to obstruction in the initial hours and heighten the risk of developing adult respiratory distress syndrome. Optimal rehydration involves frequent reassessment with adjustments based on the patient's evolving condition [42].

4. Initial dressing:

In hospital, after the patient has been warmed up and washed thoroughly, hemodynamically stable and ideally under general anaesthetic, the essential surgical procedures mentioned above can be carried out. Topical antibacterial creams are applied to the initial dressing of burns. They are easy to use and help prevent infection. Silver sulphadiazine (Sicazine®, Flammazine®) and cerium-silver sulphadiazine (Flammacerium®), which also contains cerium ions for a tanning effect, are used as first-line products. Burns should be covered with compresses in sufficient quantity to drain the exudates. The action of silver sulphadiazine is optimal during the first 12 hours, so it should be repeated daily during the first week. It is highly effective against gram-negative germs, particularly pyocyanins and enterobacteria, as well as staphylococcus aureus and Candida albicans.

b. Secondary care:

2.1. Local treatment:

There are two methods for treating deep burns: local wound care and early excision and grafting. Both methods have their advantages, disadvantages and risks. Indications for treatment must be based on reasonable choices, taking into account the depth, surface and location of the burn and the patient's general condition.

1. Conventional therapy: local care

Local treatment of burn wounds includes cleansing and debridement and routine burn wound dressing changes, typically incorporating topical antimicrobial agents. This controlled healing process respond to the physiological phases of wound repair: inflammatory, proliferative and remodelling.

- **Debridement:**

Careful wound debridement promotes effective wound healing, enhancing leukocyte phagocytic activity and oxygen tension in the wound. This ensures optimal conditions for the regeneration of damaged structures. The removal of necrotic debris can be aided by a number of procedures:

- Chemical debridement: The oldest method, by using salicylic acid and benzoic acid.

- Enzymatic debridement: by using proteolytic topical agents which is accompanied by rapid elimination of necrosis (trypsine, papaïne, Élase®, NexoBrid® etc.)

- Hydrotherapy: effective for large surface burns. It combines showers or baths (balneotherapy)

- Surgical debridement

- **Proliferation:**

The formation of granulation tissue progresses as debridement progresses. Its growth is stimulated by oily dressings (Jelonet®, Urgotul®, Tulle gras®, etc.). It is interrupted by infection, the drying out of the wound and the patient's poor nutritional status.

- **Remodeling:**

Healing of the epidermis is centrifugal (from the edges of the wound) and centripetal (from the epidermal annexes). It is accelerated by anti-inflammatory topicals such as strong dermo-corticoids (Betneval®, Diprosone®, Nerisone®, etc.) which flatten the fleshy bud. It is also encouraged by the growth factors present in certain skin grafts such as allografts. When spontaneous epidermal growth is abundant and rapid, healing is complete in three weeks. Beyond this time, grafting becomes the only option for achieving healing.

2. Radical therapy: Excision-grafting

Performing early excision and skin grafting for wound closure has demonstrated effectiveness in decreasing infection rates, shortening hospital stays, and enhancing survival outcomes for burn patients. This proactive surgical approach has proven especially advantageous for paediatric burn patients [43].

Immediate operative intervention is indicated when a burn injury is identified as "deep". Deep burn injuries encompass 3rd degree burns (full-thickness) or deep 2nd degree burns (deep partial-thickness) that are unlikely to heal within a 3-week timeframe and high risk of hypertrophic scarring, often resulting from flame or contact burns.

- **Excisions:**

a. Tangential excision: It is the meticulous removal of burned skin while preserving underlying viable tissue. The surgeon proceeds by excising the burnt skin in successive thin slices, parallel to the skin surface, using blades of calibrated thickness (Watson, Lagrot-Dufourmentel or Gullian razor-dermatome and the Versajet Hydrosurgery System) (Figure 46). Excision is carried out progressively, plane by plane, until the underlying healthy tissue is reached, which can be recognised by the good quality of the bleeding. This technique makes it possible to accurately assess the depth of the burns as the tissue is trimmed.

Tangential excision has the advantage of limiting tissue sacrifices to what is strictly necessary. The main disadvantage is the abundance of surgical bleeding, especially in the dermis. This is why it is recommended to perform tangential excisions in the early phase of burns, before inflammatory phenomena appear, i.e. in practice before the end of the first week of evolution. (Figure 45)

Figure 45: Tangential excision of burn wound of the thigh [44]

Figure 46: A selection of hand-cutting dermatomes available for use for tangential excision [7]

<u>b. Fascial excision:</u> Skin and subcutaneous tissue are excised en-bloc using electrocautery in fascial excision. This involves excision of the full thickness of the integument, including all subcutaneous tissues down to the investing deep fascia. The first stage of the operation involves making an incision around the edge of the eschar with an electric scalpel, then grasping it with strong forceps (Kocher type) to pull it out and separate it from the depth. Dissection is performed above the fascial plane, with the electric scalpel set to fulguration. This technique is virtually bloodless and allows treatment of large areas of skin (up to 30 or 40% of the body surface). (Figure 47)

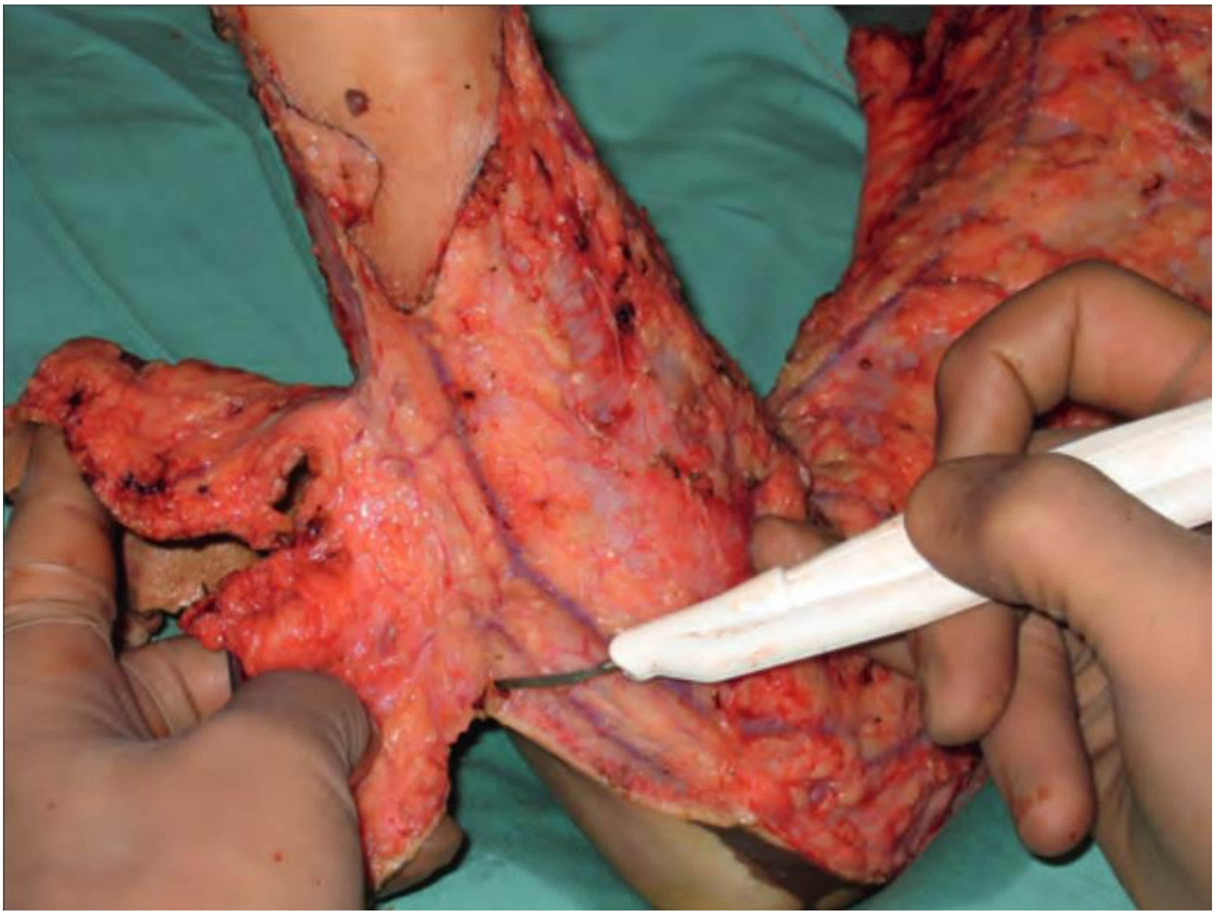


Figure 47: Fascial-level excision using cutting diathermy [7]

- **Grafting:**

Grafting should be carried out at the same time as the excision (if possible), to reduce the number of operations, avoid the risk of infection, and speed up healing.

There are many current methods of covering the skin, as shown in the literature, using autografts, homografts, skin substitutes and biological dressings.

a. Autografts:

Autografts are a skin graft that is harvested from the patient's body. They remain the gold standard cover for all burns. (Figures 48 and 50)

This type of cover can be used whenever the recipient bed (the excision area) is well vascularised, so there is no bone or tendon exposure.

Autografts are categorized as either *full-thickness* (containing epidermis and derma in totality, including annexes) or *split-thickness* (epidermis and a variable thickness from derma). Full-thickness autografts yield superior cosmetic outcomes and reduced scarring in comparison to split-thickness autografts, because the dermis provides flexibility and elasticity.

For split-thickness autografts, the samples are harvested from healthy skin donor sites, and an attempt is made to comply as far as possible with aesthetic standards (easily concealable areas). They vary according to the location of the areas to be covered and the availability of donor areas, and must not involve the hands or face. They can involve the limbs, back, chest, abdomen and even the scalp. The scalp is a valuable donor site; it heals quickly due to the large number of pilosebaceous appendages left in place.

Meanwhile full-thickness autograft's samples are harvested from areas with natural folds (The supra-clavicular fossa, the inside of the upper arm, the suprapubic region and the inguinal fossa) or areas with skin laxity and, if possible, close to the recipient area so that the characteristics of the graft are similar to those of the skin in the area to be grafted (suppleness, thickness, colour).

If the burn is small, skin grafts can be applied without meshing as a "sheet" (Figure 49). The advantage of non-meshed skin is better cosmetic outcomes. In large burns where donor sites are limited, autografts are usually meshed. This allows the autograft skin to be expanded to cover a wider area compared to its original size. The most commonly utilized mesh ratios are 2:1 and 4:1. Much larger areas can be covered when autografts are meshed 4:1 or greater and widely expanded. This widely meshed skin graft requires an overlay coverage of nonexpanded allograft skin to decrease the risk of graft loss, and this is applied over the autograft skin in a sandwich pattern [7].

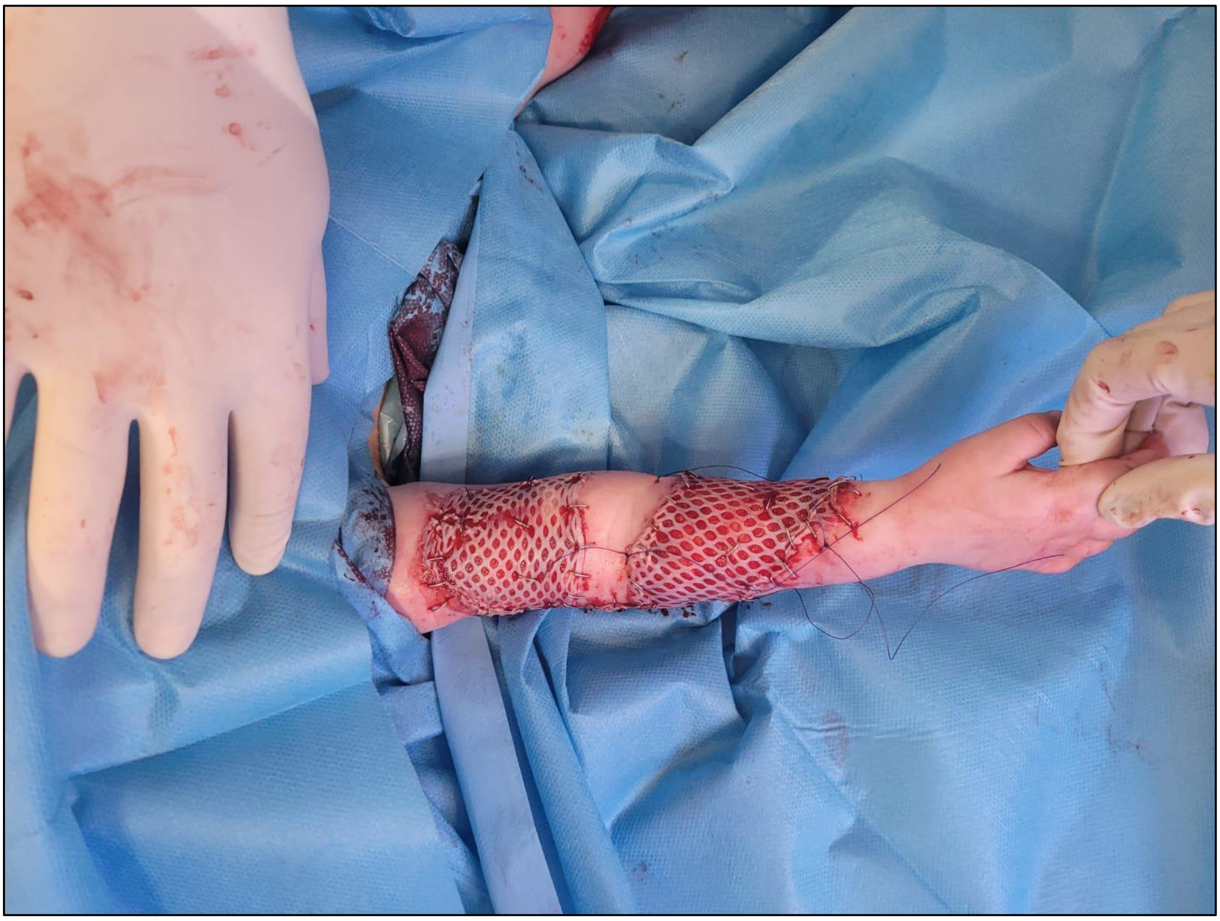


Figure 48: Meshed skin graft of the arm (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

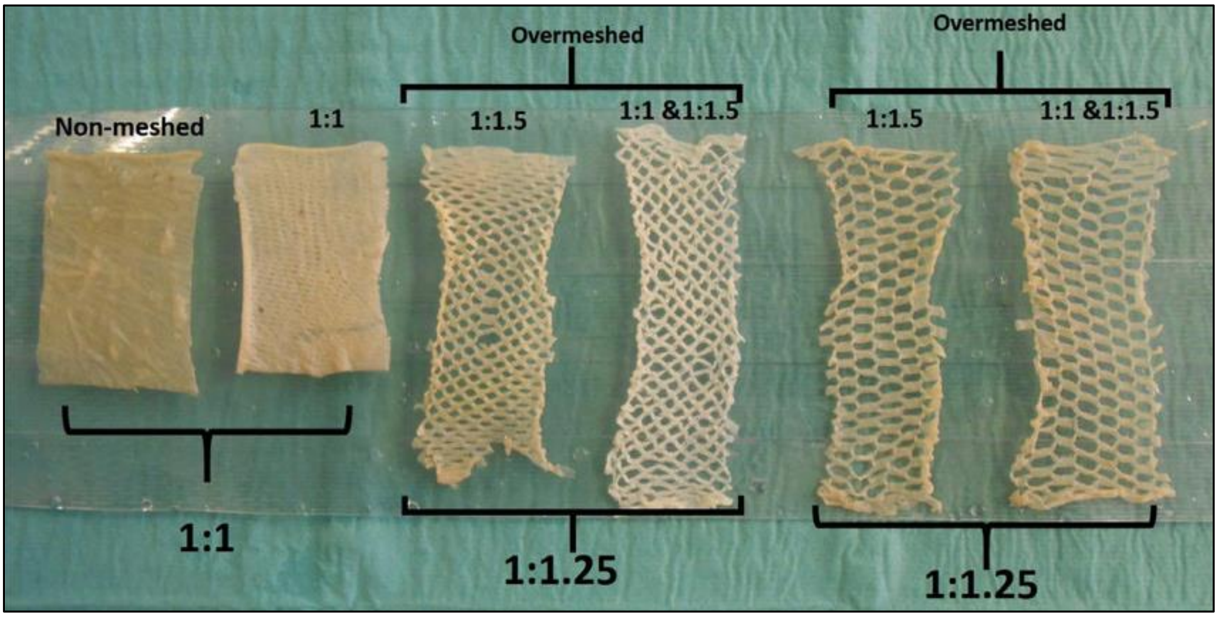


Figure 49: Non-meshed and meshed skin graft [7]

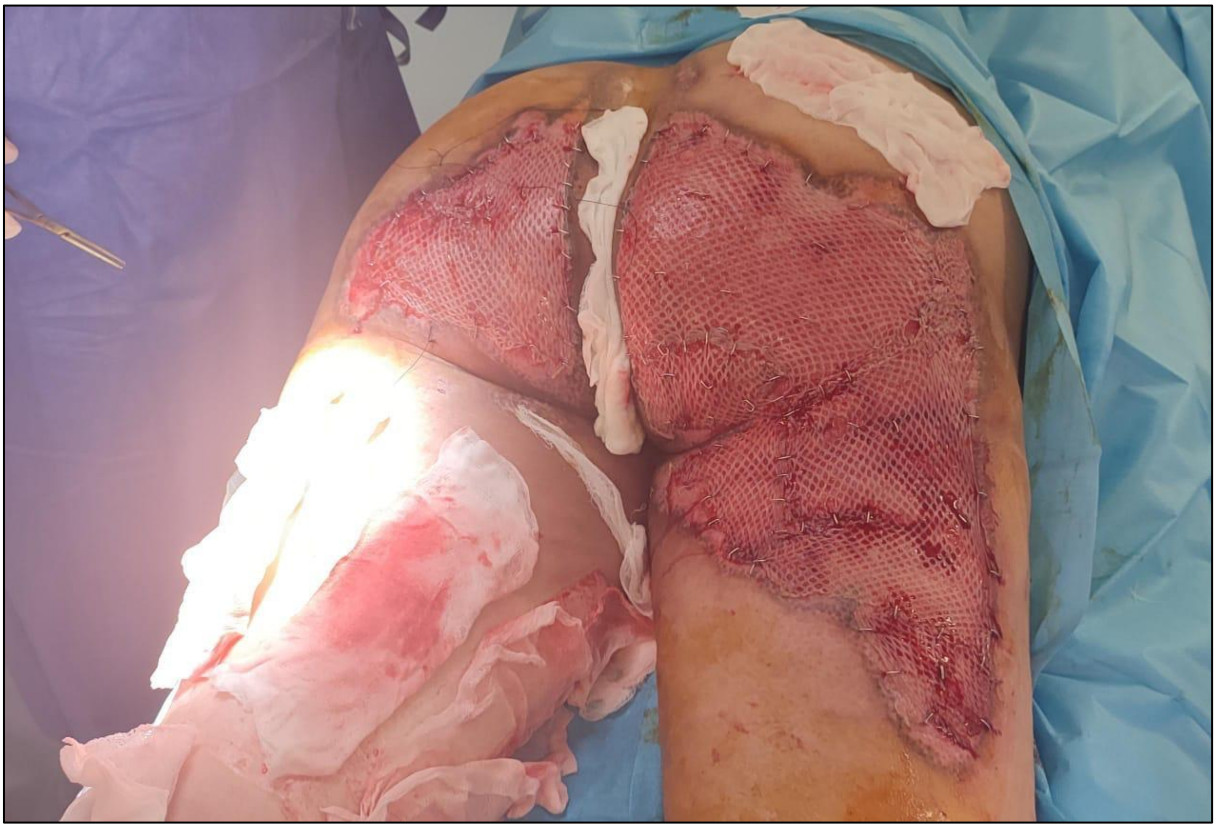


Figure 50: Meshed skin graft of the back thigh and buttocks of an 83-year-old woman (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

b. Allografts:

A skin allograft, or homograft, is a skin graft that comes from another human being and is used as a temporary cover. In fact, only skin autografting provides permanent skin cover. However, they remain an effective temporary burn wound coverage after excision if autograft skin is not available and they have made it possible to transform the vital prognosis of deep and extensive burns.

In most cases, the donor is deceased and, as with all transplants, allograft harvesting is anonymous, free of charge and subject to consent.

c. Xenografts:

Xenografts present an alternative for temporary wound covering, with porcine xenograft skin being the sole option currently utilized in clinical settings. Their primary usage involves partial-thickness burns post-superficial debridement and donor sites. Similar to allografts, xenografts adhere and offer advantages of temporary wound coverage, including pain control, as the underlying wound undergoes re-epithelialization. However, it's important to note that xenografts do not undergo vascularization. (Figure 51)

Figure 51: Porcine xenograft treatment in the trunk and left shoulder. [44]

d. Skin substitutes:

- Temporary substitutes:

The main indication for temporary skin substitutes is 2nd deep burn wounds, in which the main demands to reach pain reduction and high-quality wound healing without scarring is to warrant an undisturbed wound healing. A moist environment and protection against bacterial invasion are the most important qualities that need to be provided.

Temporary skin substitute materials can be categorized based on their tissue origin into two main groups:

- Biological tissues, which include allografts, xenografts, and amnion (keratinocyte sheets and cells).
- Synthetic materials like hydrocolloids and hydrofibers.

- Permanent skin substitutes:

Unlike deep 2nd degree wounds, 3rd degree skin injuries lack a sufficient supply of viable epidermal cells capable of closing the wound within a reasonable timeframe. Therefore, surgical intervention is recommended for deep wounds. The primary objective of the surgery is to introduce a fresh source of epidermal cells to accelerate the process of wound closure. This can be done in various ways, including split-skin graft, cultured epithelial sheets, or skin substitutes.

Permanent skin substitutes offer multiple essential components for skin function, including protection against mechanical trauma, establishment of a physiological vapor barrier, and the creation of a physical barrier against bacteria. These components are specifically designed to be permanently incorporated into grafted wounds.

e. Graft fixation:

The skin sheets must be perfectly maintained at the donor site by peripheral fixation and central padding. The technique most commonly used for burn patients is mechanical stapling, which saves a considerable amount of time. Sutures using separate stitches or surgical thread are not feasible for large surface grafts, but they remain essential for the eyelids and lips, the nasal pyramid and the auricles. Gluing the grafts with fibrin glue improves the graft's coaptation with the recipient site and limits postoperative bleeding.

- **Post-grafting dressing:**

After burn excision and skin grafting, the grafts are covered with nonadherent dressings. The most common method is to use greasy compresses (Jelonet®, Tulle gras®), covered with sterile compresses which drain and absorb exudates. It is important not to hesitate to sew fat pads to hold the grafts in place on irregular or concave surfaces (especially for total skin grafts). Sutures or staples (metallic or absorbable) can be used to support the graft. Splints are often useful for immobilising the cervical region or the flexion folds of the limbs until the grafts are taken.

- **Post-operative care:**

The graft dressings are opened between the first and third post-operative day to check that there are no complications. The most worrying problem remains the risk of infection, which must be prevented by applying antiseptic topical agents. The take-up of a thin graft is assessed around the fifth or sixth day after placement, by testing the adhesion of the deep surface with the recipient site and inspecting the colour, which should remain close to that of normal skin. A whitish or crusty appearance means that the graft is undergoing necrosis. If there are no complications, the dressing is changed only two or three times a week. The topical agents used are fatty or anti-inflammatory, depending on the progress of healing. Complete healing is achieved in eight to ten days for full skin grafts with low amplification (×2 and ×3). It takes several weeks for large amplifications (×4 and ×6) [7].

2.2. General treatment:

1. Nutritional support:

Burns is a severely catabolic illness that requires specific support. Underfeeding causes muscle wasting, increased immunocompromise, interferes with wound healing and other multitude of subsequent secondary and tertiary complications. Overfeeding in the other hand results in fatty infiltration of the liver, leading to hepatic dysfunction, and increased CO_2 production, which can exacerbate respiratory failure.

Early initiation of oral or enteral feeding (within the first 6 to 12 hours) is associated with clinical and biological benefits while limiting the risk of energy and protein deficit, such as attenuation of the neuro-hormonal stress response and hypermetabolic response [45], additionally to an increase in immunoglobulin production and a reduction of the incidence of stress ulcers [46].

Daily energy requirements are determined using predictive formulae specific to burn patients (i.e. Toronto for adults, Schofield for children) [47], [48]. Protein requirements are around 1.5 to 2 g/kg/d in adults, and up to 3 g/kg/d in children [49].

Glutamine (or alpha-ketoglutarate) supplementation should probably be given to severely burned patients from the very first days of treatment, and appears to be associated with a reduction in gram-negative bacteraemia infections, hospital length of stay and in-hospital mortality [50].

Both adults and children with burns require early micronutrient supplementation. The main trace elements concerned are copper, zinc and selenium. The main vitamins to be supplemented are B, C, D and E [51], [52], [53], [54].

The evaluation of metabolic status can be conducted through indirect calorimetry using bedside metabolic carts which measures Resting Energy Expenditure (REE) by analysing expired gas volumes, directly measuring oxygen consumption (VO2), and carbon dioxide production (VCO2). REE is then calculated:

$$REE\ [Kcal/day] = 1.44\ (3.9\ VO_2\ [mL/min] + 1.1\ VCO_2\ [mL/min])$$

2. Other therapies:

a. Thromboprophylaxis:

Thermal injuries are associated with systemic coagulopathy, which is explained by an increase in platelet count, fibrinogen and factors V and VIII, associated with a fall in antithrombin III (AT III) and proteins C and S.

The risk increases with age, the surface area of the burns, the depth of the burns, the presence of central venous access (particularly femoral), the duration of mechanical ventilation, the need for intensive care hospitalisation and multiple transfusions.

A thromboprophylaxis is therefore necessary for burn patients as for other intensive care patients. The doses to be used are sometimes higher than usual a standard dose for all adult acute burn patients is not recommended, due to AT III deficiency, increased volume of distribution and increased clearance [55], [56].

In paediatrics, thromboprophylaxis is indicated from puberty onwards or if a central venous catheter is in place.

b. anti-tetanus vaccination:

Tetanus vaccination is must be checked and updated if necessary.

c. Positioning and splinting:

The risk of deformity following a burn is of real concern, requiring proactive management of burn scar contractures. Orthotics and splinting play a crucial role in burn rehabilitation by facilitating correct body positioning and alleviating the contractile forces of scarring that contribute to deformity. The use of positioning techniques is essential to manipulate soft tissue lengths, minimising the restriction of range of movement caused by scar formation and contraction [57].

c. Rehabilitation:

Burn rehabilitation is a long multidisciplinary process designed to preserve patients' functional abilities and reinstate independence. Immediate initiation of physical and occupational therapy is crucial following the injury.

Key components of rehabilitation include wound healing, scar prevention and correction, casting, splinting, traction, pressure therapy, pharmacologic intervention, exercise, and psychological support.

Adults should be aggressively managed during rehabilitation to avoid further loss of strength and function, which are difficult to recover. As for children, providing support and guidance for parents is essential to ensure the patient's well-being upon discharge [7].

d. Pronostic and prevention

1. Sequelae:

Burned areas are scarred areas. If healing occurs quickly, the after-effects are minimal. If it takes longer than 3 weeks, the development of fibrosis leads to hypertrophy and retraction. The quality and urgency of the initial treatment have a decisive influence on the extent and severity of these sequelae.

a. Minor sequelae:

- Pruritus: This symptom is variable and transient, and will diminish as the scar matures.

- Fragile scarring: Scarred skin after burns loses its suppleness and elasticity, and is often dry. Problems of fragile scarring occur in the joints of the limbs and in areas with superficial bone structures.

- Cutaneous dysesthesia: Problems with cutaneous sensitivity are common in burned areas. Deep and grafted burns are often the site of hyposensitivity, which improves gradually.

- Dyschromia: There are almost always differences in colour and texture between a burn scar and healthy skin. (Figure 52)

Figure 52: Heterogeneous dyschromia with hypertrophic scar of the face [7]

b. Major sequelae:

- Hypertrophic scars and keloids: Hypertrophic scars after burns are characterised by an erythematous, itchy, swollen scar with low elasticity. (Figure 53)

Figure 53: Heterogeneous dyschromia with hypertrophic scar of the lower right limb (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

- Retractions and flanges: Scar remodelling and the contraction of skin grafts cause retractions and scar flanges after burns. Retractions can range from a simple flange with no functional discomfort to a large retractile scar. (Figure 54)

Figure 54: Retraction scars of the axillae [39]

- Scar degeneration: The appearance of a chronic ulceration on an old burn scar should prompt an investigation into the possibility of carcinogenesis. If there is the slightest doubt, a biopsy of the suspected lesion should be taken for anatomopathological analysis.

2. Prevention:

The epidemiology and prevention of burns are inseparable. Prevention, which is defined as any action aimed at reducing a foreseeable health event, presupposes that the causes of this event are perfectly well known and that the efforts made to eliminate them can be evaluated, all of which are impossible without good epidemiology. Epidemiology therefore only makes sense if it is at the root of preventive action: aimed at reducing the incidence and severity of burns (primary and secondary prevention) or improving the care structures needed for treatment (tertiary prevention).

Similar to other injury mechanisms, preventing burns necessitates a thorough understanding of epidemiological characteristics and associated risk factors. However, although significant progress has been made in the areas of primary and secondary prevention of fires and burns in many developed or high-income countries, such as the USA due to sustained research, the same cannot be asserted for many Low- and Middle-Income Countries such as Morocco.

a. Primary prevention: reducing the incidence of burns

There are three main strategies to reduce the incidence of any injury:

- Education: which primarily is an active measure requiring behaviour/lifestyle change,

- Product design/environmental change,

- Legislation and regulation, both of which primarily are passive measures.

Prevention campaigns are of fundamental importance. Educational strategies may be used to reach both children through school education programs and adults through community awareness programs, targeting high risk population groups.

Better regulation and control of the 3 kg butane cylinder, which is a real time bomb in every Moroccan home. These cylinders, like the 11 kg cylinders, should be fitted with safety valves [58].

Other prevention strategies have also been developed and implemented in developed countries. The most common and effective ones can be resumed to:

community implementation of smoke detectors, regulation of hot water heater temperatures, flame-resistant children's sleepwear, and housing codes that assure the safety of electrical wiring.

b. Secondary prevention: reducing the severity of burns

An active approach that can only be achieved by involving different health care specialists (Doctors, pharmacists, nurses, fire-aiders, firefighters...). Forming them for effective and science-based care and support.

Creation of regional burn centres run by plastic surgeons or general practitioners with university degrees in burn medicine.

c. Tertiary prevention: offering the best treatment for burns once they have occurred and limiting the sequelae

The more burns are treated by experienced specialists, the better. It is particularly anomalous that Morocco has only three burn centres and that a large proportion of patients are treated outside specialised centres.

II. Discussion of our results:

1. Incidence:

The incidence of burns in general is difficult to assess in our context, given the limited number of national studies. Additionally to the lack of specialist centres and the difficulty of access to specialised care that play as factors to why many burn patients do not make it to the hospital.

In our series, 73 cases of burns were hospitalised in the plastic surgery department over a period of 26 months, of which 26 cases were paediatric burns.

A study carried out in the burns department of the Rabat military training hospital [59], over a 5-year period from January 2004 to December 2009, recorded 221 cases of severe burns in adults.

A study carried out in the Major burns centre at the Saint-Antoine Hospital in Paris and the Plastic Surgery Department at the Rothschild Hospital, over a period of 6 years between January 2002 and March 2008, included 1002 cases of severe burns in adults.

Another study carried out in the Children’s Hospital of Mohammed VI University Hospital of Marrakech [60], over a 2-year period from September 2008 to September 2010, recorded 394 patients less than 15 years old.

And a recent study carried out in the Plastic and Reconstructive Surgery Department , Ain Shams University Hospital of Cairo, Egypt [61], over a 28 months period, recorded 981 patients less than 15 years old.

2. Patients' characteristics:

a. Age:

The results of our study are in line with those of national and international studies: 43% of adult patients were young adults aged between 20 and 35 years, with the average age being 33.8 years. Meanwhile 46% of our paediatric patients aged less than 4 years, with the average age being 3.6 years. Knowing that our patients ranged in age from 10 months to 83 years.

S. ElKafssaoui [62] reports in his study that the average age of patients with severe burns is 39.4 years, with extremes of 20 and 75 years.

According to the IVS health monitoring institute in Metropolitan France, burns are most common from the age of 20 onwards, with the average age of patients with severe burns at 38.8.

Zahid A. [63] noted, in their study of burns in children in Morocco, a predominance was shown in the 1 to 5 years age range (42.5%) with an average age of 4.25 years.

Authors	Dominant Age range	Percentage	Average age
S. Elkafssaoui [62]	-	-	39.4
Mitiche B. [64]	15-35	59%	30.2
Wasiak J. [65]	20-35	32%	41.1
Song C. [66]	20-50	61.8%	31
Our study	20-35	43%	33.8

Table 3: Comparison of results according to Age in Adults

Authors	Dominant Age range	Percentage	Average age
Zahid A. [63]	1-5	42.5%	4.2
Messaadi A. [67]	1-5	37%	3.6
Géyik M. [68]	0-4	52.1%	3.9
Kristine G. [69]	0-4	60.2%	3.4
Our study	1-4	46%	3.6

Table 4: Comparison of results according to Age in children

The literature as a whole confirms that severe burns occur at two different age peaks in children and adults, with the average age varying according to the demographic structure of each country.

b. Gender:

In our case, the predominance of males was 59,8% compared with 40,2% for females, with a male/female sex ratio of 1.48. This is also the case in several authors' series.

Authors	Male	Female	Sex Ratio
S. Elkafssaoui [62]	67.4%	32.6%	2.06
Mitiche B. [64]	53%	47%	1.12
Géyik M. [68]	66.6%	33.4%	1.99
Kristine G. [69]	50.5%	49.5%	1.02
Our study	59.8%	40.2%	1.48

Table 5: Comparison of results according to gender

And comparing the results of our study with those of other studies, it seems that men are more exposed than women to burns. And that is mostly explained by the tradition in our country and especially in children by the behaviour of boys, who are described as being more fearless, and being able to easily reach for a container of hot liquid higher up and tip it over.

c. Pre-existing conditions:

In our study, 17% of patients with burns who were admitted to the department had associated diseases: Diabetes, arterial hypertension, asthma, cardiopathy etc.

According to D. Wassermann [70], apart from age, the presence of a condition such as heart disease, neuropathy or nephropathy worsens the condition of the burn victim.

Alcohol and tobacco [71] must also be emphasised, because of their frequency and their particularly marked deleterious effects on the general and local evolution of the burn.

d. Seasonal distribution:

In our series, severe burns were reported throughout the year, with two peaks: the first in spring in April (12.2%), and the second in summer in July (12.7%).

The IVS [72] also reports an increase in the frequency of burns in adults aged between 15 and 49 in spring and especially in summer.

This has been reported by several authors, linking these incidents to home and leisure activities during spring and summer. However, many other authors including Albertyn R. [73] recorded an increase of burn injuries in winter season between October and February linking it to the increase of fire usage for heating.

In our context, burns are also frequent during the Holy Month of Ramadan, which can also be explained by the increase in cooking activities during this holy month, and by the carelessness and reduced vigilance in the kitchen and at the time of breaking the fast.

3. Clinical characteristics:

a. Burn mechanism:

Our study showed that the most frequent burns were thermal burns, with 69 cases, or 95% of all burns. Next came electrical burns with 4 cases (5%) and 0 cases for chemical burns (0%).

Authors	Thermal	By flame	By scalding
Wasiak J. [65]	91%	73%	27%
Boccara D. [74]	85%	52%	29%
Zahid A. [63]	87%	19%	69.1%
Géyik M. [68]	83%	20.5%	63%
Our study	95%	46.2%	49.3%

Table 6: Comparison of results according to mechanisms of thermal burn

Therefore, if we compare the results of our study with those of other studies, it is clear that thermal burns are the most common. However, it should be noted that in our study, burn by scalding (49.3%) was more common than burns caused by flame (46.2%).

The relatively high number of flame burns in Morocco can be explained, on the one hand, by the rural population's habit of cooking outdoors and using ovens in the dining room in cold geographical areas, and on the other hand by the use of fire for heating.

Since a significant proportion of Moroccans have no modern means of heating their homes, they often resort to traditional means. This is the traditional barbecue or "majmer", which remains the main method used in the low-temperature season. However, the 3 kg butane cylinder remains the ultimate murder weapon. These cylinders are only sealed by a spring topped by a ball that is never recycled which makes them very susceptible to leaks.

Therefore, like the 11 kg cylinders, these 3 kg cylinders must be fitted with safety valves.

However for children, scalding accounted for most burn mechanisms, which remains the most described mechanism for children throughout the literature.

Electrification, on the other hand, though it only accounted for a small percentage, can easily be avoided by placing large signs on construction or public works sites. This incident is often due to workers being young, illiterate and inexperienced.

b. Burned areas:

In our series, the areas most affected were the upper limb (87% of all cases), the lower limb (72%), the head and neck (69%), the trunk (50%), then the buttocks (30%) and perineum (26%).

The results of our study are consistent with those of national and international studies.

S. ElKafssaoui [62] reports that the areas most frequently affected are the head and neck, then the trunk, the upper limbs and the lower limbs, then the buttocks and finally the perineum.

Ibnouzahir M., Ettalbi S. [58] found that the face and neck were the most affected, followed by the upper limb, then the trunk, the lower limb and finally the perineum.

However for children, the limbs are often the most frequent site of burn injury, followed by the trunk, and finally the face. Involvement of the neck and perineum was rarer. Most authors explain this location by the fact that children mainly use their limbs for the various gestures made throughout their daily lives. In addition, the trunk occupies a large skin surface area, which is more exposed when a teapot is knocked over, for example. These children often have a large area of burnt skin, or even circular damage to the limbs [60], [63], [67], [68]

c. Depth of burn:

In our series, 38 cases had 2nd degree burns, accounting for 52% of patients, of which 55% were children and 45% were adults. While 35 cases had at least some areas classified as 3rd degree, accounting for 48% of patients, of which only 14% were children and 86% were adults.

We can also note that almost 2/3, 64% of adults' patients had a combination of 2nd and 3rd degree burns. While 80% of children had only a burn injury of superficial or deep 2nd degree burn.

However, some studies did not conclude to the same results regarding the depth of burn in adults.

Authors	2nd degree burns	2nd + 3rd degree burns
Boccara D. [74]	64%	35%
Ibnouzahir M. [58]	68%	32%
S. Elkafssaoui [62]	71%	19%
Our study	36%	64%

Table 7: Comparison of results according to burn degree in adults

Regardless, in children the results of our study were almost consistent with those of international and national studies.

Authors	2nd degree burns	2nd + 3rd degree burns
Messaadi A. [67]	83.9%	16.1%
Zahid A. [63]	63.5%	36.5%
Hamdaoui A. [75]	89.1%	10.9%
Our study	80%	20%

Table 8: Comparison of results according to burn degree in children

d. Total burned surface areas:

Our study revealed that a majority of 56%, presented TBSA below 20%. Further breakdown based on age revealed that within this subgroup, 58% of individuals were aged less than 12 years, suggesting a considerable prevalence of minor burns in paediatric patients.

Meanwhile, 44% of the total patient population, presented TBSA exceeding 20%. And within this subgroup 81% were identified as being over 12 years old, which underscores a pronounced prevalence of severe burns among older individuals, highlighting age as a significant determinant in burn severity.

The average TBSA was 27%, with extremes ranging from 1.5% to 62%.

S. ElKafssaoui [62] found an average burnt skin surface of 23%.

In Algeria, Mitiche B, Behioul M [64] reported that TBSA between 21 and 30% accounted for almost half the cases hospitalised.

In Tunisia, Messaadi A. [67] showed that 84% of children patients had a TBSA of less than less than 10%, and 85.3% received outpatient treatment.

4. Treatment and management:

a. Resuscitation:

All adult patients in our study received fluid and electrolyte resuscitation according to the Evans formula, guided by clinical and biological assessment.

All paediatric patients in our study received fluid and electrolyte resuscitation according to Carvajal's formula, guided by clinical and biological assessment.

According to the French society of burns [72], there is no consensus as to the qualitative and quantitative composition of intakes. The superiority of one vascular resuscitation formula over another has not been established. Fluid and electrolyte resuscitation must be initiated early. Delayed or inadequate intakes may lead to increased requirements at a later stage. Therefore the volume of fluids administered must be adapted to the clinical response and haemodynamic parameters, in order to avoid underfilling or overfilling (fluid creep), both of which are responsible for increased morbidity [76].

In children, the risks of overfilling or underfilling are estimated to be the same as in adults [77].

Resuscitation is essentially carried out with isotonic crystalloids (0.9% saline), which enable the physiological sodium capital to be restored. These solutions were the basis for filling our patients. However, the use of isotonic crystalloids has its drawbacks, especially when the rules for prescribing them are not followed. These include pulmonary overload, increased oedema at the burn site and at a distance from it, abdominal compartment syndrome, hypoprotidemia, metabolic acidosis, haemodilution, etc.

In terms of quality, the colloid-crystalloid debate is still ongoing. Colloids are frequently administered, in varying proportions and over varying periods of time (beyond the first 6 hours of treatment), as it has shown in multiple studies a reduction of organ failure (pulmonary oedema, acute renal failure, abdominal compartment syndrome) [21], [78].

In several mainly observational studies involving patients with a TBSA ≥20-30%, administration of 5% albumin was associated with a reduction in crystalloid filling volume, as well as a reduction in the incidence of abdominal compartment syndrome, organ failure and mortality [77], [79], [80].

In children with burns of TBSA greater than 15%, early administration (between H8 and H12) of 5% albumin, compared with late administration (H12), is associated with a reduction in crystalloid intake, a reduction in the incidence of hydrosodium overload and a reduction in length of stay [81].

Noting that the European Medicines Agency (EMA) and the French National Agency for the Safety of Medicines (ANSM) contraindicate the use of Hydroxyethylamides (HEA) in severe burn victims.

b. Respiratory support:

In our study, all patients were systematically started on oxygen therapy on admission. Mechanical ventilation was deemed necessary in 11% of cases.

The French society of burns suggests intubating patients presenting with a combination of a burn involving the face and one of the following situations:

- ✓ a deep, circular burn of the neck and/or

- ✓ new or established symptoms of airway obstruction (i.e. voice changes, stridor, laryngeal dyspnoea) and/or
- ✓ a very extensive burn (i.e. burned skin area ≥ 40%).

Similar results were found in other studies, such as that carried out by Bougassa [82], where 17.4% of patients required intubation (9.3% as an emergency and 8.1% after close monitoring)

c. General treatment:

Enteral nutrition reduces postoperative septic complications, improves digestive immunity and increases IgA production. Introduced early, enteral nutrition limits hyper-metabolism, reduces translocation and infection rates, and prevents the onset of visceral failure.

Cynober L., Bargues L. [49] state that the superiority of enteral nutrition (EN) over parenteral nutrition is recognised.

A study carried out in Iran on 688 paediatric patients, randomised into two groups, clearly demonstrated the advantage of enteral feeding in terms of reducing mortality and length of hospitalisation [83].

For the prevention of tetanus at the time of injury, including burns, local treatment of wounds including the removal of foreign bodies and debridement is considered essential. In addition, *Church et al.* [84] recommends at burn centres, to usually administer human tetanus immunoglobulin (TIG) at 250–500 U and to administer tetanus toxoid (Tt) to patients who have not acquired complete primary immunity or those more than 10 years after the last vaccination.

d. Surgery and Local treatment:

In our study, all burn patients received local treatment including washing, rinsing, flattening of blisters, application of a silver sulphadiazine-based antiseptic (Flammazine®) for deep and extensive burns, and coverage with a protective dressing.

22% of patients with deep circular burns or with signs of compression required emergency decompressive incisions type escharotomy or fasciotomy.

H. Carsin, H. Le Béver [85] report that silver sulphadiazine-based dressings provide good infection prevention and excellent patient comfort, although they must be renewed every 24 hours, or even twice a day.

E. CantaisP., P. GoutorbeY. [86], indicate that decompression surgery remains an emergency surgery and must be performed within the first 12 hours.

In the University Hospital Mohamed IV in Marrakech, Tadili M. [87] report that 30 (26.5%) patients had undergone decompressive incisions most of which was performed on the upper limb.

e. Local wound care:

In our case study, 24 patients (33%) benefited from skin graft. Either by using full thickness autografts or split thickness autografts.

In the Kingdom of Saudi Arabia, Othman S. Et al report that 85 patients between the years of 2010 and 2015 received skin grafts of which 65.8% were split-thickness and 34.1% were full thickness skin graft.

In Zimbabwe, S. Mzezewa, K. Jonsson, M. Aberg [88] found that skin grafting was done on 26% of the patients.

However, Garcia-Espinoza J., Navaro D. [89] found a total of 63% of patients required cutaneous grafting.

Early excision and grafting are recommended with indeterminant burns of less than 20% TBSA over non operative treatment of burns (using silver sulphadiazine-based dreassing), as they lead to shorter hospitalization, lower cost, and minimize infection and hypertrophic scarring.

f.Healing duration:

In our study, 70% of patients had their burn injury heal in less than 21 days. The average length of stay was 9,3 days, which increased significantly with TBSA.

The results of our study are consistent with those of national and international studies.

The study carried out by the IVS health monitoring institute in Metropolitan France [72] reported that the average length of hospital stay for adults was 9.78 days, and also increased with age, rising from 6.5 days for 15-19 year olds to 14.8 days for the over 60s.

Authors	Average length of hospital stay
Larour S. [90]	11,6 days
Messaadi A. [67]	17 days
Géyik [68]	12 days
Our study	9,3 days

Table 9: Comparison of results according to average length of stay in hospital

5. Evolution:

In our study, 93% of patients were discharged with a favourable outcome:

- In 59% of patients the outcome was favourable but with sequelae
- In 34% of patients had a favourable outcome with no sequelae

At the Meknes burns centre [90], 43.2% of cases were discharged on medical advice, with an improvement rate of 93.3%.

Boccara [74] reported that 54% of patients had a favourable evolution with managed healing and 46% required skin grafting, in the Department of Plastic Surgery at the Rothschild Hospital in Paris.

The death rate in our study was 7%.

S. ElKafssaoui [62] reports that the mortality rate at the Mohammed V military hospital is 5.8%.

Mitiche B. and Behioul M. [64] state that at the Clinic of burns and plastic surgery of Algiers, the mortality rate is 5%.

In children, Zahid A. [63] reported a mortality rate of 13.2% in their study.

Authors	Favourable evolution rate	Mortality rate
Wasiak J. [65]	99%	1%
S. Elkafssaoui [62]	94.2%	5.8%
Zahid A. [63]	86.8%	13.2%
Salama S. [61]	97.7%	2.3%
Our study	93%	7%

Table 10: Comparison of results according to patients' evolution

III. Clinical case:

An 83 years old female patient, originated from Tangier, was admitted to the Plastic surgery and Burns Department on December 2023 for burns of the buttocks and part of the posterior right lower limb.

Pre-existing conditions: High blood pressure

The burn happened 10 days prior to the admission, caused by scalding (Boiling water). The patient only applied medicinal plants for the burn, then seeked medical attention after no improvement.

At the admission: Patient was conscious, with normal vitals BP = 12/7 HR = 75 b/min RR = 18 C/min T = 37,5 SpO_2 = 98% and conserved urine output (non measured).

At the examination: Patient had a necrotic plaque in the lower half of her buttocks and posterior half of her right thigh with signs of local infection.

TBSA estimated at 8% *UBS index* = 31 and The *Baux index* = 91

The rest of examination was without abnormalities.

Figure 55: Necrotic plaque around the burn area. (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

Lab results were as follow:

Hb	-
Hémocratite	-
GB	-
PLQ	-
Na+	141
K+	4,03
Urée	0,39
Créat	9,46
CRP	121,5
Protéines totales	77,63
Albumine	40,76

Figure 56: First lab work of the patient after admission

The initial therapeutic plan was:

- Daily resuscitation: 2L (1L normal saline + 1L G5%)
- Paracetamol: 1g/8hours (if pain or fever)
- Lovenox 0.4 UI/day
- PPI: 40mg/day
- Diprezar 50mg/12,5mg 1cp/j
- Iron and multivitamins supplementation
- Change of dressing every 2 days using Flammazine® and Tulle gras dressings
- Surveillance

The patient then benefited from a surgical debridement with the continuation of the initial therapeutic plan.

Figure 57: Aspect of the burn area after surgical debridement. (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

Figure 58: Aspect of the burn in day 4 of surgical debridement and local treatment. (Photo’s taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

After the third week of the burn the patient benefited from an Excision-grafting surgery.

Figure 59: Evolution of the patient after surgical debridement and local treatment pre-excision and grafting. (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

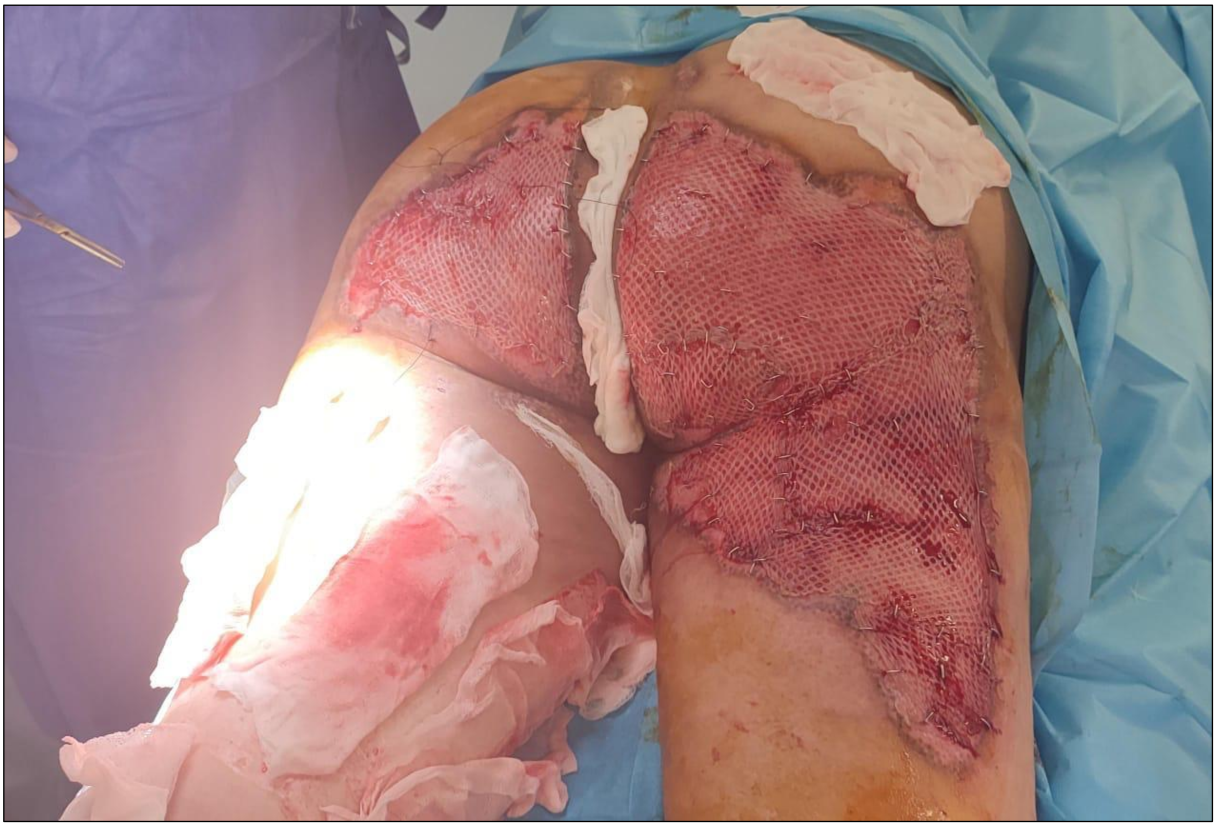


Figure 60: 2 Tangential excisions of the posterior left thigh + 1 Tangential excision of the top right buttock using a Dermatome and a Meshed skin graft of the burned area. (Photo’s taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

Figure 61: Evolution of the excision and grafted wounds. (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

Figure 62: Evolution of the excision and grafted wounds after 10 days. (Photo's taken in the plastic surgery and burns department of the Mohamed VI university hospital in Tangier)

Conclusion

Severe burns remain a constant challenge for the medical world as a whole, and for plastic surgeons and intensive care specialists in particular. It is always fraught with consequences at both individual and collective level.

It also reflects the social conditions in which certain sections of the population live.

The management of severe burns poses major problems in developing countries, at all stages of their development.

At the end of this epidemiological study, we can say that great efforts still need to be made to reduce the number of cases of burns.

Prevention must form part of a vast global programme comprising active and passive actions, taking account of local specificities. Active prevention will aim to change people's behaviour, protect households from manufacturing faults (gas cylinders and cookers) or electrical faults, and provide greater protection for workers. Passive prevention will aim to improve the socio-economic conditions of the population.

Finally, it should be pointed out that currently, our hospitals do not dispose the necessary and enough resources to deal with a disaster involving a massive influx of burn victims.

Abstract

Title: Epidemiological and clinical characteristics of severe burn patients: Experience of the Plastic Surgery Department and burns in the Mohamed VI University Hospital of Tangier.

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Rapporteur: Pr Dehhaze Adil

Key words: Severe burns - Prognosis – burn management - Skin grafts.

Introduction: Burns cause skin destruction responsible for a local and general inflammatory response. The objective of our study is to describe the epidemiological, clinical and evolutionary profile of burn patients.

Material and methods: This is a retrospective study including 73 patients ranging from 10 months to 83 years old, treated in the Reconstructive and Plastic Surgery Department and burns in the Mohamed VI University Hospital of Tangier during the period from October 2021 to December 2023. The elements analysed are demographic data, clinical characteristics, pathological history and parameters of the patient's vital prognosis.

Results:

Thermal burns were the most common with 69 cases.

They are secondary to scalding in 49.3% of cases and to flame in 46.2%, electric burns account for 5%.

The burn was generally 2nd degree (36% of cases) with a majority of 56%, presented TBSA below 20%. The most affected parts are the upper, lower limb and head and neck.

33% of patients benefited from skin graft.

The average hospital stay was 9,3 days.

The case fatality rate is 7%.

Conclusion: Treatment of a severe burn patient should be done promptly. It is based on a few principles that optimize hemodynamic and haematosis to ensure local treatment. But prevention is the best method of struggle. Thus, a considerable number of accidents can be prevented.

Titre: Caractéristiques épidémiologiques et cliniques des brûlures sévères: Expérience du service de reconstruction et chirurgie plastique et des grands brûlés du CHU Mohamed VI de Tanger.

Auteur: BELLAFKIH Ayman

Rapporteur: Pr Dehhaze Adil

Mots clés: Brûlures sévères - Pronostic – Traitement initial – Greffes cutanées.

Introduction: Les brûlures entraînent une destruction de la peau responsable d'une réponse inflammatoire locale et générale. L'objectif de notre étude est de décrire le profil épidémiologique, clinique et évolutif des patients brûlés.

Matériel and méthodes: Il s'agit d'une étude rétrospective incluant 73 patients âgés de 10 mois à 83 ans, traités dans le service de reconstruction et chirurgie plastique et des brûlures du CHU Mohamed VI de Tanger durant la période allant d'octobre 2021 à décembre 2023. Les éléments analysés sont les données démographiques, les caractéristiques cliniques, les antécédents pathologiques et les paramètres du pronostic vital du patient.

Résultats:

Les brûlures thermiques sont les plus fréquentes avec 69 cas.

Elles sont secondaires à l'ébouillantement dans 49,3% des cas et à la flamme dans 46,2%, les brûlures électriques représentent 5%.

La brûlure est généralement du 2ème degré (36% des cas) avec une majorité de 56%, présentant une surface corporelle brûlée inférieure à 20%. Les parties les plus touchées sont les membres supérieurs, inférieurs et la tête et le cou.

33% des patients ont bénéficié d'une greffe de peau.

La durée moyenne d'hospitalisation a été de 9,3 jours.

Le taux de mortalité est de 7%.

Conclusion: Le traitement d'un grand brûlé doit être réalisé rapidement. Il repose sur quelques principes qui permettent d'optimiser l'hémodynamique et l'hématose afin d'assurer un traitement local. Mais la prévention est la meilleure méthode de lutte. Ainsi, un nombre considérable d'accidents peuvent être évités.

العنوان: الخصائص الوبائية والسريرية للحروق الشديدة: تجربة قسم الجراحة الترميمية والتجميلية والحروق في المستشفى الجامعي محمد السادس بطنجة.

المؤلف: بلفقيه أيمن

المقرر: الأستاذ عادل الدهاز

الكلمات المفتاحية: الحروق الشديدة - التشخيص - العلاج الأولي - ترقيع الجلد.

مقدمة: تؤدي الحروق إلى تدمير الجلد، وهو المسؤول عن الاستجابة الالتهابية الموضعية والعامة. والهدف من دراستنا هو وصف الملامح الوبائية والسريرية والتطورية لمرضى الحروق.

المواد والطرق: هذه دراسة بأثر رجعي شملت 73 مريضًا تتراوح أعمارهم بين 10 أشهر و83 عامًا، عولجوا في قسم الجراحة الترميمية و التجميلية والحروق في مستشفى محمد السادس بطنجة خلال الفترة من أكتوبر 2021 إلى ديسمبر 2023. تم تحليل البيانات الديموغرافية والخصائص السريرية والتاريخ المرضي ومعايير التشخيص الحيوية.

نتائج:

كانت الحروق الحرارية هي الأكثر شيوعًا، حيث بلغت 69 حالة.

وكانت الحروق الحرارية ثانوية بسبب السلق في 49.3% من الحالات والحروق بالنار في 46.2%، بينما كانت الحروق الكهربائية تمثل 5% من الحالات.

كانت الحروق عمومًا من الدرجة الثانية (36% من الحالات)، وكانت معظمها (56%) تشمل مساحة سطح الجسم أقل من 20%. كانت المناطق الأكثر تضررًا هي الأطراف العلوية والسفلية والرأس والرقبة.

تلقى 33% من المرضى ترقيعًا جلديًا.

كان متوسط الإقامة في المستشفى 9.3 أيام.

كان معدل وفيات الحالات 7%.

استنتاج: يجب أن يتم علاج مريض الحروق بسرعة. ويستند هذا العلاج إلى عدد من المبادئ التي تمكّن من تحسين ديناميكية الدم ونزيف الدم من أجل ضمان العلاج الموضعي. ولكن الوقاية هي أفضل طريقة لمكافحة ذلك. وبهذه الطريقة، يمكن تجنب عدد كبير من الحوادث.

Bibliography

[1] World Health Organisation (WHO), « Burns ». Consulté le: 2 décembre 2023. [En ligne]. Disponible sur: https://www.who.int/news-room/fact-sheets/detail/burns

[2] M. Z. Albanna et J. H. Holmes, Éd., *Skin tissue engineering and regenerative medicine*. London, UK ; San Diego, CA, USA: Elsevier/AP, Academic Press is an imprint of Elsevier, 2016.

[3] Y. Gilaberte, L. Prieto-Torres, I. Pastushenko, et Á. Juarranz, « Anatomy and Function of the Skin », in *Nanoscience in Dermatology*, Elsevier, 2016, p. 1‑14. doi: 10.1016/B978-0-12-802926-8.00001-X.

[4] H. Yousef, M. Alhajj, et S. Sharma, « Anatomy, Skin (Integument), Epidermis », in *StatPearls*, Treasure Island (FL): StatPearls Publishing, 2023. Consulté le: 23 décembre 2023. [En ligne]. Disponible sur: http://www.ncbi.nlm.nih.gov/books/NBK470464/

[5] R. T Sataloff, *Sataloff's Comprehensive Textbook of Otolaryngology Head & Neck Surgery: Facial Plastic and Reconstrusctive surgery. Anthony P. Sclafani (editor)*, First Edition: 2016. in 2016. UK: Jaypee Brothers Medical Publishers, 2016.

[6] T. J. Schaefer et K. D. Szymanski, « Burn Evaluation and Management », in *StatPearls*, Treasure Island (FL): StatPearls Publishing, 2023. Consulté le: 24 décembre 2023. [En ligne]. Disponible sur: http://www.ncbi.nlm.nih.gov/books/NBK430741/

[7] D. N. Herndon, Éd., *Total burn care*, Fifth edition. Edinburgh: Elsevier, 2018.

[8] C. M. Waghmare, « Radiation burn—From mechanism to management », *Burns*, vol. 39, n° 2, p. 212‑219, mars 2013, doi: 10.1016/j.burns.2012.09.012.

[9] M. G. Schwacha, « Macrophages and post-burn immune dysfunction », *Burns*, vol. 29, n° 1, p. 1‑14, févr. 2003, doi: 10.1016/S0305-4179(02)00187-0.

[10] M. G. Dehne, A. Sablotzki, A. Hoffmann, J. Mühling, F. E. Dietrich, et G. Hempelmann, « Alterations of acute phase reaction and cytokine production in patients following severe burn injury », *Burns*, vol. 28, n° 6, p. 535‑542, sept. 2002, doi: 10.1016/S0305-4179(02)00050-5.

[11] K. M. Jastrow *et al.*, « Early Cytokine Production Risk Stratifies Trauma Patients for Multiple Organ Failure », *J. Am. Coll. Surg.*, vol. 209, n° 3, p. 320‑331, sept. 2009, doi: 10.1016/j.jamcollsurg.2009.05.002.

[12] Y. Yamada *et al.*, « Tumor necrosis factor-α and tumor necrosis factor receptor I, II levels in patients with severe burns », *Burns*, vol. 26, n° 3, p. 239‑244, mai 2000, doi: 10.1016/S0305-4179(99)00137-0.

[13] A. Lyons, J. L. Kelly, M. L. Rodrick, J. A. Mannick, et J. A. Lederer, « Major Injury Induces Increased Production of Interleukin-10 by Cells of the Immune System With a Negative Impact on Resistance to Infection »:, *Ann. Surg.*, vol. 226, nº 4, p. 450- 460, oct. 1997, doi: 10.1097/00000658-199710000-00006.

[14] J. Martyn, R. S. Wilson, et J. F. Burke, « Right Ventricular Function and Pulmonary Hemodynamics during Dopamine Infusion in Burned Patients », *Chest*, vol. 89, nº 3, p. 357- 360, mars 1986, doi: 10.1378/chest.89.3.357.

[15] H. R. Adams, C. R. Baxter, et S. D. Izenberg, « Decreased contractility and compliance of the left ventricle as complications of thermal trauma », *Am. Heart J.*, vol. 108, nº 6, p. 1477- 1487, déc. 1984, doi: 10.1016/0002-8703(84)90695-1.

[16] T. W. Merriam, « Myocardial Function Following Thermal Injury », *Circ. Res.*, vol. 11, nº 4, p. 669- 673, oct. 1962, doi: 10.1161/01.RES.11.4.669.

[17] A. Rawlingson, « Nitric oxide, inflammation and acute burn injury », *Burns*, vol. 29, nº 7, p. 631- 640, nov. 2003, doi: 10.1016/S0305-4179(03)00079-2.

[18] E. Bittner et R. Sheridan, « Acute Respiratory Distress Syndrome, Mechanical Ventilation, and Inhalation Injury in Burn Patients », *Surg. Clin. North Am.*, vol. 103, nº 3, p. 439- 451, juin 2023, doi: 10.1016/j.suc.2023.01.006.

[19] T. F. Huzar, T. George, et J. M. Cross, « Carbon monoxide and cyanide toxicity: etiology, pathophysiology and treatment in inhalation injury », *Expert Rev. Respir. Med.*, vol. 7, nº 2, p. 159- 170, avr. 2013, doi: 10.1586/ers.13.9.

[20] A. Sabry, I. Wafa, A. B. El-Din, A. M. El-Hadidy, et M. Hassan, « Early markers of renal injury in predicting outcome in thermal burn patients », *Saudi J. Kidney Dis. Transplant. Off. Publ. Saudi Cent. Organ Transplant. Saudi Arab.*, vol. 20, nº 4, p. 632- 638, juill. 2009.

[21] K. W. Markell *et al.*, « Abdominal Complications after Severe Burns », *J. Am. Coll. Surg.*, vol. 208, nº 5, p. 940- 947, mai 2009, doi: 10.1016/j.jamcollsurg.2008.12.023.

[22] T. L. Palmieri *et al.*, « Effect of blood transfusion on outcome after major burn injury: A multicenter study* »:, *Crit. Care Med.*, vol. 34, nº 6, p. 1602- 1607, juin 2006, doi: 10.1097/01.CCM.0000217472.97524.0E.

[23] M. S. Park *et al.*, « Combining Early Coagulation and Inflammatory Status Improves Prediction of Mortality in Burned and Nonburned Trauma Patients », *J. Trauma Inj. Infect. Crit. Care*, vol. 64, nº 2, p. S188- S194, févr. 2008, doi: 10.1097/TA.0b013e318160a5a3.

[24] J. P. Barret et P. A. Gomez, « Disseminated intravascular coagulation: a rare entity in burn injury », *Burns*, vol. 31, nº 3, p. 354- 357, mai 2005, doi: 10.1016/j.burns.2004.11.006.
[25] R. L. Sheridan, *Burns: a practical approach to immediate treatment and long-term care*, First edition. London: Manson Publishing, 2012.
[26] R. A. Moore, A. Waheed, et B. Burns, « Rule of Nines », in *StatPearls*, Treasure Island (FL): StatPearls Publishing, 2023. Consulté le: 8 janvier 2024. [En ligne]. Disponible sur: http://www.ncbi.nlm.nih.gov/books/NBK513287/
[27] A. Murari et K. N. Singh, « Lund and Browder chart-modified versus original: a comparative study », *Acute Crit. Care*, vol. 34, nº 4, p. 276- 281, nov. 2019, doi: 10.4266/acc.2019.00647.
[28] K. A. Stockton, C. M. McMillan, K. J. Storey, M. C. David, et R. M. Kimble, « 3D photography is as accurate as digital planimetry tracing in determining burn wound area », *Burns J. Int. Soc. Burn Inj.*, vol. 41, nº 1, p. 80- 84, févr. 2015, doi: 10.1016/j.burns.2014.04.022.
[29] A. K. W. Cheah, T. Kangkorn, E. H. Tan, M. L. Loo, et S. J. Chong, « The validation study on a three-dimensional burn estimation smart-phone application: accurate, free and fast? », *Burns Trauma*, vol. 6, déc. 2018, doi: 10.1186/s41038-018-0109-0.
[30] B. Arnoldo, M. Klein, et N. S. Gibran, « Practice Guidelines for the Management of Electrical Injuries »:, *J. Burn Care Res.*, vol. 27, nº 4, p. 439- 447, juill. 2006, doi: 10.1097/01.BCR.0000226250.26567.4C.
[31] G. E. Darling, M. A. Keresteci, D. Ibañez, R. A. Pugash, W. J. Peters, et P. C. Neligan, « Pulmonary complications in inhalation injuries with associated cutaneous burn », *J. Trauma*, vol. 40, nº 1, p. 83- 89, janv. 1996, doi: 10.1097/00005373-199601000-00016.
[32] M. A. A. Iustitiati et B. S. Nata'atmadjaa, « Comparison of Abbreviated Burn Severity Index (ABSI) Score with R-Baux Score as a predictor of mortality in burn patients », *J. Rekonstr. Dan Estet.*, vol. 7, nº 2, p. 43- 50, déc. 2022, doi: 10.20473/jre.v7i2.41216.
[33] D. Sutton et M.-D. Wright, *Cooling for Thermal Burns: Clinical Effectiveness and Guidelines*. in CADTH Rapid Response Reports. Ottawa (ON): Canadian Agency for Drugs and Technologies in Health, 2019. Consulté le: 21 janvier 2024. [En ligne]. Disponible sur: http://www.ncbi.nlm.nih.gov/books/NBK541209/
[34] A. R. Cai, E. I. Hodgman, P. B. Kumar, A. J. Sehat, A. L. Eastman, et S. E. Wolf, « Evaluating Pre Burn Center Intubation Practices: An Update », *J. Burn Care Res.*, vol. 38, nº 1, p. e23- e29, 2017, doi: 10.1097/BCR.0000000000000457.

[35] D. G. Greenhalgh, « Management of Burns », *N. Engl. J. Med.*, vol. 380, nº 24, p. 2349- 2359, juin 2019, doi: 10.1056/NEJMra1807442.
[36] M. G. A. Baartmans *et al.*, « Early management in children with burns: Cooling, wound care and pain management », *Burns*, vol. 42, nº 4, p. 777- 782, juin 2016, doi: 10.1016/j.burns.2016.03.003.
[37] L. Zhang, A. Labib, et P. G. Hughes, « Escharotomy », in *StatPearls*, Treasure Island (FL): StatPearls Publishing, 2024. Consulté le: 24 janvier 2024. [En ligne]. Disponible sur: http://www.ncbi.nlm.nih.gov/books/NBK482120/
[38] D. P. Orgill et N. Piccolo, « Escharotomy and Decompressive Therapies in Burns »:, *J. Burn Care Res.*, vol. 30, nº 5, p. 759- 768, sept. 2009, doi: 10.1097/BCR.0b013e3181b47cd3.
[39] R. V. Ormiston et R. Marappa-Ganeshan, « Fasciotomy », in *StatPearls*, Treasure Island (FL): StatPearls Publishing, 2024. Consulté le: 24 janvier 2024. [En ligne]. Disponible sur: http://www.ncbi.nlm.nih.gov/books/NBK556153/
[40] A. M. Lachiewicz, C. G. Hauck, D. J. Weber, B. A. Cairns, et D. Van Duin, « Bacterial Infections After Burn Injuries: Impact of Multidrug Resistance », *Clin. Infect. Dis.*, vol. 65, nº 12, p. 2130-2136, nov. 2017, doi: 10.1093/cid/cix682.
[41] « Recommandations relatives à l'utilisation des antibiotiques chez le brûlé à la phase aiguë – Texte long », *Ann. Fr. Anesth. Réanimation*, vol. 28, nº 3, p. 265-274, mars 2009, doi: 10.1016/j.annfar.2008.12.020.
[42] B. Wise et Z. Levine, « Inhalation injury », *Can. Fam. Physician Med. Fam. Can.*, vol. 61, nº 1, p. 47-49, janv. 2015.
[43] M. J. Muller et D. N. Herndon, « The challenge of burns », *The Lancet*, vol. 343, nº 8891, p. 216-220, janv. 1994, doi: 10.1016/S0140-6736(94)90995-4.
[44] P. Bukovčan et J. Koller, « Treatment of Partial-Thickness Scalds by Skin Xenografts », in *Burns, Infections and Wound Management*, vol. 2, M. A. Shiffman et M. Low, Éd., in Recent Clinical Techniques, Results, and Research in Wounds, vol. 2. , Cham: Springer International Publishing, 2017, p. 95-104. doi: 10.1007/15695_2017_28.
[45] V. K. Vicic, M. Radman, et V. Kovacic, « Early initiation of enteral nutrition improves outcomes in burn disease », *Asia Pac. J. Clin. Nutr.*, vol. 22, nº 4, p. 543-547, 2013, doi: 10.6133/apjcn.2013.22.4.13.
[46] N. N. Lam, N. G. Tien, et C. M. Khoa, « Early enteral feeding for burned patients—An effective method which should be encouraged in developing countries », *Burns*, vol. 34, nº 2, p. 192-196, mars 2008, doi: 10.1016/j.burns.2007.03.010.

[47] J. Allard *et al.*, « Validation of a new formula for calculating the energy requirements of burn patients », *J. Parenter. Enter. Nutr.*, vol. 14, nº 2, p. 115-118, mars 1990, doi: 10.1177/0148607190014002115.
[48] O. E. Suman, R. P. Mlcak, D. L. Chinkes, et D. N. Herndon, « Resting energy expenditure in severely burned children: Analysis of agreement between indirect calorimetry and prediction equations using the Bland–Altman method », *Burns*, vol. 32, nº 3, p. 335-342, mai 2006, doi: 10.1016/j.burns.2005.10.023.
[49] L. Cynober *et al.*, « Recommandations nutritionnelles chez le grand brûlé », *Nutr. Clin. Métabolisme*, vol. 19, nº 3, p. 166-194, sept. 2005, doi: 10.1016/j.nupar.2005.07.001.
[50] J.-J. Lin, X.-J. Chung, C.-Y. Yang, et H.-L. Lau, « A meta-analysis of trials using the intention to treat principle for glutamine supplementation in critically ill patients with burn », *Burns*, vol. 39, nº 4, p. 565-570, juin 2013, doi: 10.1016/j.burns.2012.11.008.
[51] E. Barbosa *et al.*, « Supplementation of Vitamin E, Vitamin C, and Zinc Attenuates Oxidative Stress in Burned Children: A Randomized, Double-Blind, Placebo-Controlled Pilot Study »:, *J. Burn Care Res.*, vol. 30, nº 5, p. 859-866, sept. 2009, doi: 10.1097/BCR.0b013e3181b487a8.
[52] T. Mayes, M. M. Gottschlich, J. Khoury, et R. J. Kagan, « Investigation of Bone Health Subsequent to Vitamin D Supplementation in Children Following Burn Injury », *Nutr. Clin. Pract.*, vol. 30, nº 6, p. 830-837, déc. 2015, doi: 10.1177/0884533615587720.
[53] A.-F. Rousseau *et al.*, « Vitamin D status after a high dose of cholecalciferol in healthy and burn subjects », *Burns*, vol. 41, nº 5, p. 1028-1034, août 2015, doi: 10.1016/j.burns.2014.11.011.
[54] M. M. Berger, « Antioxidant Micronutrients in Major Trauma and Burns: Evidence and Practice », *Nutr. Clin. Pract.*, vol. 21, nº 5, p. 438-449, oct. 2006, doi: 10.1177/0115426506021005438.
[55] M. Blake, R. Roadley-Battin, et T. Torlinski, « Prophylactic anti-coagulation after severe burn injury in critical care settings », *Acta Medica Litu.*, vol. 26, nº 1, p. 38-45, 2019, doi: 10.6001/actamedica.v26i1.3954.
[56] A. Mokline, G. R, H. Fraj, M. B. Saad, L. Thabet, et A. Messadi, « Optimizing Prophylactic Anticoagulation in Burns is Associated with Low Incidence of Venous Thromboembolic Complications », *Med. Res. Arch.*, vol. 11, nº 6, 2023, doi: 10.18103/mra.v11i6.3960.
[57] R. Richard *et al.*, « Burn Rehabilitation and Research: Proceedings of a Consensus Summit »:, *J. Burn Care Res.*, vol. 30, nº 4, p. 543-573, juill. 2009, doi: 10.1097/BCR.0b013e3181adcd93.

[58] M. Ibnouzahir *et al.*, « [Epidemiology of burns in Marrakech: 152 cases considered] », *Ann. Burns Fire Disasters*, vol. 24, nº 1, p. 3-6, mars 2011.
[59] A. Boufars *et al.*, « Profil épidémiologique de 291 patients brûlés à l'hôpital militaire d'instruction Mohamed V de Rabat, Maroc », *Rev. DÉpidémiologie Santé Publique*, vol. 64, p. S141, mai 2016, doi: 10.1016/j.respe.2016.03.067.
[60] H. Droussi *et al.*, « Epidemiology and treatment of paediatric burns in a large children's hospital in Morocco: Analysis of 394 cases », *Afr. J. Emerg. Med.*, vol. 3, nº 3, p. 110-115, sept. 2013, doi: 10.1016/j.afjem.2013.04.002.
[61] S. Salama, A. Fayed, et A. Gadallah, « Epidemiological Study about Childhood Burns in the Burn Unit of Ain Shams University Hospitals », *Egypt. J. Plast. Reconstr. Surg.*, vol. 0, nº 0, p. 0-0, janv. 2024, doi: 10.21608/ejprs.2024.259869.1327.
[62] S. Elkafssaoui *et al.*, « Facteurs prédictifs de mortalité des brûlés : étude sur 221 adultes hospitalisés entre 2004 et 2009 », *Ann. Chir. Plast. Esthét.*, vol. 59, nº 3, p. 189-194, juin 2014, doi: 10.1016/j.anplas.2012.02.006.
[63] A. Zahid *et al.*, « [Epidemiological profile of children burns admitted at the National Center for Brules, Morocco] », *Ann. Burns Fire Disasters*, vol. 24, nº 4, p. 171-174, déc. 2011.
[64] Mitiche B, Behioul M, Hadjem K, et Tabi S, « Brûlures graves chez l'adulte – A propos de 600 cas Ann. Burns and Fire Disaster », *Ann Burns Fire Disaster*, vol. XII, nº n. 1, mars 1999.
[65] J. Wasiak, A. Spinks, K. Ashby, A. Clapperton, H. Cleland, et B. Gabbe, « The epidemiology of burn injuries in an Australian setting, 2000–2006 », *Burns*, vol. 35, nº 8, p. 1124-1132, déc. 2009, doi: 10.1016/j.burns.2009.04.016.
[66] C. Song et A. Chua, « Epidemiology of burn injuries in Singapore from 1997 to 2003 », *Burns*, vol. 31, nº 1, p. S18-S26, janv. 2005, doi: 10.1016/j.burns.2004.10.005.
[67] Messaadi A., Bousselmi K., Khorbi A., et Chebil M., « Etude prospective de l'épidémiologie des brûlures de l'enfant en Tunésie . », *Ann. Burns Fire Disasters 2004*, vol. XIV, nº 17, p. 173-18, 2004.
[68] M. F. Geyik, M. Aldemir, S. Hosoglu, et H. I. Tacyildiz, « Epidemiology of burn unit infections in children », *Am. J. Infect. Control*, vol. 31, nº 6, p. 342-346, oct. 2003, doi: 10.1016/S0196-6553(02)48226-0.
[69] K. G. Williams, M. Schootman, K. S. Quayle, J. Struthers, et D. M. Jaffe, « Geographic Variation of Pediatric Burn Injuries in a Metropolitan Area », *Acad. Emerg. Med.*, vol. 10, nº 7, p. 743-752, juill. 2003, doi: 10.1197/aemj.10.7.743.

[70] Wassermann D et Rieu M., « De la physiologie à la thérapeutique et au pronostic des brûlures », *Rev. Prat.*, nº 30, p. 507-21, 1980.
[71] D. Wassermann, « Critères de gravité des brûlures. Épidémiologie, prévention, organisation de la prise en charge », *Pathol. Biol.*, vol. 50, nº 2, p. 65-73, mars 2002, doi: 10.1016/S0369-8114(01)00271-1.
[72] A. Rigou et B. Thélot, *Hospitalisations pour brûlures à partir des données du programme de médicalisation des systèmes d'information, France métropolitaine, 2008: synthèse*. in Maladies chroniques et traumatismes. Saint-Maurice: Institut de veille sanitaire, 2010.
[73] R. Albertyn, S. W. Bickler, et H. Rode, « Paediatric burn injuries in Sub Saharan Africa—an overview », *Burns*, vol. 32, nº 5, p. 605-612, août 2006, doi: 10.1016/j.burns.2005.12.004.
[74] Boccara D. J., « Evaluation Clinique, Photographique, et évolutive de La profondeur des brûlures : A Propos De 1002 Cas ». Thèse Doctorat Médecine, Paris, 2008.
[75] Hamdaoui A., « Profil épidémiologique des brûlures chez l'enfant. » Thèse Doctorat Médecine, Fez, n°82, 2011.
[76] J. F. Kelly *et al.*, « A novel means to classify response to resuscitation in the severely burned: Derivation of the KMAC value », *Burns*, vol. 39, nº 6, p. 1060-1066, sept. 2013, doi: 10.1016/j.burns.2013.05.016.
[77] A. Lawrence *et al.*, « Colloid Administration Normalizes Resuscitation Ratio and Ameliorates "Fluid Creep": », *J. Burn Care Res.*, vol. 31, nº 1, p. 40-47, janv. 2010, doi: 10.1097/BCR.0b013e3181cb8c72.
[78] M. B. Klein *et al.*, « The Association Between Fluid Administration and Outcome Following Major Burn: A Multicenter Study », *Ann. Surg.*, vol. 245, nº 4, p. 622-628, avr. 2007, doi: 10.1097/01.sla.0000252572.50684.49.
[79] R. J. Navickis, D. G. Greenhalgh, et M. M. Wilkes, « Albumin in Burn Shock Resuscitation: A Meta-Analysis of Controlled Clinical Studies », *J. Burn Care Res.*, vol. 37, nº 3, p. e268-e278, 2016, doi: 10.1097/BCR.0000000000000201.
[80] S. H. Park, M. R. Hemmila, et W. L. Wahl, « Early albumin use improves mortality in difficult to resuscitate burn patients », *J. Trauma Acute Care Surg.*, vol. 73, nº 5, p. 1294-1297, nov. 2012, doi: 10.1097/TA.0b013e31827019b1.
[81] M. H. Müller Dittrich, W. Brunow De Carvalho, et E. Lopes Lavado, « Evaluation of the "Early" Use of Albumin in Children with Extensive Burns: A Randomized Controlled Trial* », *Pediatr. Crit. Care Med.*, vol. 17, nº 6, p. e280-e286, juin 2016, doi: 10.1097/PCC.0000000000000728.

[82] Bougassa S, « La prise en charge des brûlures graves de l'enfant en milieu de Réanimation. » Thèse Doctorat Médecine, Rabat, 2008.
[83] E. N. Khorasani et F. Mansouri, « Effect of early enteral nutrition on morbidity and mortality in children with burns », *Burns*, vol. 36, n° 7, p. 1067-1071, nov. 2010, doi: 10.1016/j.burns.2009.12.005.
[84] D. Church, S. Elsayed, O. Reid, B. Winston, et R. Lindsay, « Burn Wound Infections », *Clin. Microbiol. Rev.*, vol. 19, n° 2, p. 403-434, avr. 2006, doi: 10.1128/CMR.19.2.403-434.2006.
[85] Carsin H. et Béver H.L., « Brûlure. », in *Brûlure.*, vol. II, in EMC : Urgences., no. 2006, vol. II. , Paris: Elsevier SAS, 2006, p. (24-116-E-15).
[86] E. Cantais, P. Goutorbe, Y. Asencio, A. Montcriol, et E. Meaudre-Desgouttes, « Réanimation et anesthésie du brûlé chez l'adulte », *EMC - Anesth.-Réanimation*, vol. 4, n° 4, p. 1-14, janv. 2007, doi: 10.1016/S0246-0289(07)45531-1.
[87] Tadili M., « Brulure grave de l'adulte à la phase aigüe : étude épidémiologique et attitudes thérapeutiques pratiques. » Thèse Doctorat Médecine, Marrakech, 2016.
[88] S. Mzezewa, K. Jonsson, M. Aberg, et L. Salemark, « A prospective study on the epidemiology of burns in patients admitted to the Harare burn units », *Burns*, vol. 25, n° 6, p. 499-504, sept. 1999, doi: 10.1016/S0305-4179(99)00041-8.
[89] J. A. Garcia-Espinoza, C. I. Navarro-Delgadillo, A. Costa-Dulché, D. Flores-Soto, G. Barrera-García, et C. Márquez-Espriela, « Epidemiology of burn injuries: 2 years' experience in a specialized hospital in Mexico City », *Ann. Burns Fire Disasters*, vol. 32, n° 4, p. 261-266, déc. 2019.
[90] Larour S. et Fortin J., « Epidémiologie du centre des brulés de Meknès », *Ann Burns Fire Disaster*, vol. VI, n° 1, mai 2005.

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طنجة

سنة 2024 رقم الأطروحة: TM 09/24

الخصائص الوبائية والسريرية للحروق الشديدة: تجربة قسم الجراحة الترميمية والتجميلية والحروق في المستشفى الجامعي محمد السادس بطنجة.

أطروحة قدمت ونوقشت علانية يوم: 17/04/2024

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دكتورة في الطب

الكلمات الرئيسية: الحروق الشديدة - التشخيص - العلاج الأولي - ترقيع الجلد.

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