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Validation of Thermography for The Diagnosis of Compartment Syndrome in The Upper Extremities Due to Electrical Burns in Patients with Altered Alertness

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ABSTRACT

Background: Compartment syndrome in the extremities is a surgical emergency that requires decompression to avoid complications, the diagnosis is made through the clinic, if there is doubt it is confirmed with the measurement of intracompartmental pressure by means of an invasive device, it is imperative for the diagnosis to measure it in patients with altered alertness.

Objective: To determine the sensitivity and specificity of thermography compared to the measurement of intracompartmental pressure with the Whiteside method as a diagnosis of upper extremity compartment syndrome in patients with electrical burns with impaired alertness. Thus achieving faster, more accessible, cheaper, reliable and non-invasive detection. It can be used by the first contact physician and/or paramedics, nurses, students for timely diagnosis and treatment, reducing the rate of sequelae and complications.

Material and methods: All patients with a presumptive diagnosis of compartment syndrome in the upper extremities secondary to electrical burn with altered alertness who were admitted to the Adolfo López Mateos Medical Center were included®.**Results:** In the present study, a sensitivity of 58% and a specificity of 100% were obtained, with a positive predictive value of 100% and a negative predictive value of 50%, as well as a prevalence of 70.58% and an incidence of 7 out of 10 patients.

Conclusion: We can conclude that the study has a good specificity and when analyzing the values present we notice that it can have a good sensitivity which is altered by the amount of the sample of the patients

KEYWORDS: Thermal imaging camera, Thermography, compartment syndrome, electrical burn, upper extremities.

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INTRODUCTION

The International Burn Society defines a burn as an injury to skin or other organic tissue caused by thermal trauma, causing tissue destruction. (1)

The most important discovery in human history was fire 1,600 years ago, an element that can cause significant injuries. Over time, several contributions have been made to the description, classification and management of burns. Records of the treatment of burns are more than 3,500 years old in cave paintings. Four hundred years later, Hippocrates describes the fat of the pig melted to impregnate bandages and cover the burned areas, he began to wash wounds avoiding infection and keeping them dry. Imotep used honey, Celsius used wine and myrrh, Galen handled burns with vinegar. Dupuytren contributes to depth-based grading system, Dr. Truman G. Blocker Jr. In 1909 he demonstrated the importance of multidisciplinary treatment. (2)

In 1948, Professor Fortunato Benaim organized the Surgery Service of the Argerich Hospital for the treatment of burns and in 1953 the Institute of Burns, Plastic and Reconstructive Surgery was created in Buenos Aires. Ivo Pintanguy was in charge of the 2,000 burns in the Great American Circus. Professor Augusto Bazán Altuna in Peru described in 1964 the technique of transplanting pig skin to treat burned children. Professor René Artiaga created the first burn center in Chile and was the first president of the Chilean Burn Society, founded in 1993. José A. Bañuelos Roda worked and made important changes for the treatment of burns at the Vall d'Hebron Hospital in Barcelona. In Mexico, Drs. Heriberto Rangel Gaspar, Samuel Fuentes Aguirre, and Armando Buitrón have contributed significantly to the management of burns. (2)

Among the burns we contemplate the electrical burns which we find in history, the first publication in 1881 in the "Journal of Bone and Joint Surgery" where Volkmann reports a contracture which bears his name refers to that it is secondary to muscular ischemia causing paralysis and contracture simultaneously. In 1914 Murphy reported prophylactic fasciotomy to prevent vascular obstruction. Paul Jepson, in 1924, while researching at the Mayo Clinic, managed to reproduce an ischemic contracture in animals, confirming that it can be prevented by performing decompression. (3)

The first recorded death from electrical burns was in 1897 in Lyon, France when a carpenter came into contact with a high-powered generator, years later; 1881 To be exact, an American named Samuel W. Smith is electrocuted by a generator in Buffalo, New York. (4)

During the First World War, many advances and discoveries were made in relation to Compartment Syndrome, whether secondary to burns, vascular injuries, firearms, as well as fractures, being authors as important as Leriche. After this, Loyd

In 1940, Griffiths began to perform sympathectomy for tone reduction. But it was not until 1975 that Mubarak et al. began to relate the increase in intracompartmental pressure as a cause, and in 1984 Rorabeck reported 28 patients with intracompartmental pressure measurement recommending decompression with pressures greater than 30 mmHg. (3)

Not only accidents marked historical changes in the management of burn patients, since wartime and the beginning of firearms important events were marked for the management of the burned patient where Renaissance surgeons mentioned that wounds by firearms were poisoned by placing boiling oil being until the Italian wars where Ambrosio Paré was a pioneer for the management of gunshot wounds and burns Applying bandages and dressings based on onion extracts, reporting pain control and better evolution. In 1907 Wilhelm Fabry was the first to classify burns into 3 degrees. Also, in the 19th century, physician Jacob Bigelow conducted the first evidence-based study using rabbits to compare different types of burn treatment. (5)

We can confirm that with new technologies and the evolution that is taking place, there are new trends and research for more effective and less invasive treatments, among which we could mention the early tangential debridement described by Zora Janzekovic in 1968. In the 21st century we see the creation of artificial skin, the use of stem cells and growth factors, artificial dermal matrices, enzymatic debridement with new products for maximum preservation of healthy tissues, and skin micrografting techniques. (6)

Currently in Mexico there are multiple organizations for the support of burn patients, among the most important we have the Mexican Association of Burns A.C. The Michou and Mau I.A.P. The Rino-Q Foundation for burned children. As well as multiple centers for the care of burn patients, one of the most important in the country is the National Center for Research and Care of Burn Patients (CENIAQ) opening its doors in 2011 with nursing, nutrition, rehabilitation, plastic surgery, intensive therapy for children and adults, currently they have 26 census beds which can be doubled in case of emergency. They have an infectious diseases and research laboratory as well as a skin bank. (Government of Mexico, 2021)

The skin is an organ that covers the human body, mainly made up of 3 layers: Epidermis, dermis and hypodermis, the latter being the deepest. The skin has multiple functions, among the most important are protection mainly from UV rays, physical and chemical agents, as well as preventing the loss of water and extracellular fluid. (7)

There are several definitions for burns, among the most widely accepted is the one described by the International Burn Society. (8) Other authors describe it as injury to the skin or other organs caused by physical and/or chemical trauma, which produces denaturation of tissue proteins, leading to an alteration of the superficial integument until the total destruction of the tissues involved. (7)
After the burn, a systemic and local response to stress is initiated. The inflammatory process may be simply local or so extensive that it cannot be controlled, and coupled with a strong inflammatory response that causes a major catabolic state with a hypermetabolic response, the patient may present serious complications, increasing the incidence of organ failure, infection, and death. (9)

The reaction triggered by stress is directly proportional to the type and degree of burn, we see that both muscle, bone, vessels, skin and basically any organ can be injured. (10)

Electrical burns are considered a special type of injury presenting a unique, complex and varied pathology, requiring an understanding of the physical properties of electricity and the interaction with the organism, since it presents superficial and deep lesions involving internal organs and tissues with multi-organ involvement. (4)

Electricity is defined as the passage of electrons from one atom to another and the movement of these is through a conductor, this is known as electrical energy. Its properties are current, voltage, resistance, conductance and intensity; all of these are directly related to the injury.

Electric current is the flow of electrons within a closed circuit, it is classified as direct or direct and alternating. The continuous one is unidirectional (it generates a single muscle contraction and withdraws the victim without being dangerous). Alternating Current: This is bidirectional (It generates muscle contractions of 40 to 110 times per second, causing tetany, it is considered very dangerous).

Voltage is the force that allows the movement of the electrons of the atom, we have low voltage (<1000 volts). It is the most frequent type of injury in relation to the home and affecting children, mainly in the hands and mouth; Contractures can cause sprain, fracture, or trauma. High voltage (>1000 volts), more frequent in work activities due to direct contact or arc, generates injuries to the skin, tissues and internal organs; It can cause rhabdomyolysis and myoglobinuria causing acute renal failure, hyperkalemia, acidosis, blood myoglobin, elevated creatine phosphokinase and nerve damage.

Lightning is considered to have a very high mortality due to high voltage and amperage, being a massive unidirectional current. (4)

Another important factor directly related to electrical injuries is resistance, this is the opposition that an object generates to the passage of current, it is measured in Ohm. The greater the resistance of the tissue, the greater the injury. Lowest Resistance Tissues (1500 Ohm) Muscle, nerves, and blood vessels. Intermediate resistance (1000 Ohm) wet skin and (5000 Ohm) dry skin, the highest resistance (9000 Ohm) bones, fat and tendons. (4)

conductance is the ability to transmit current and intensity is related to time and current flow, its unit is measured in Ampere (mAmp) we see that it is directly proportional to the injury. From 1 to 3 mAmp you will have a sensation of heat in direct current and with alternating current you will have tingling. From 20 to 50 mAmp you will have tetany with paralysis of the respiratory muscles. From 50 to 100 mAmp we will have ventricular fibrillation. >100 mAmp we will have asystole. (4)

Patients with electrical burns have a very high risk of presenting compartment syndrome due to the type of injury, since the skin has a loss of elasticity and, due to the burn, systemic and local reaction begins to increase intracompartmental pressure, reduced flow in the capillaries, absence of oxygen, accumulation of fluid and cells culminating in ischemia. nerve injury and Volkmann's contracture. (11)

Historically, temperature has been used as an indicator of health, Sir William Herchel discovered thermography in 1800, obtaining the first thermal image. All objects above absolute zero emit electromagnetic radiation, which is known as infrared. (12)

Upon the discovery of thermography it was reported as a wavelength within a range of 0.75 to 1,000 Im. An important use of thermography was for the military in World War II, where one of its main applications was in burns to assess depth, another use for the viability of injured tissues, as well as for

assessment of compartment syndrome. It quickly migrated the technology to civilian use. (Lahiri et al., 2012) (Fernández-Cuevas et al., 2015)

In 1963 Barnes demonstrated that it can provide information on physical anomalies and therefore be useful in the diagnosis of physical pathologies. Amer and Ring described its influence on diabetic neuropathy, vascular neuropathy, breast cancer detection, dermatology, chronic pain, rheumatological diseases, intestinal ischemia, gynecology, etc.(12,13)

DEFINITION

In the vast majority of cases we see that burns are underestimated, especially burns due to electricity because they hide the true injury, they are not so showy. All people are exposed to some type of burn, which can be caused by friction, cold, heat, radiation, chemicals and electricity. The vast majority are by hot liquids and solids, as well as direct fire. All kinds cause destruction by energy transfer. (9)

Each type of burn causes a different type of injury, locally generating areas of hyperemia, stasis, necroptosis as well as a systemic inflammatory response that seeks to stop and repair the damage. In burns there is not only physical damage but also psychological and economic damage that affects patients, family, friends and even society. (14)

Electrical burn is a type of injury that is defined with 5 types of damage. Although it can be a direct injury (by contact), the damage is thermal and the degree of injury depends on the duration, frequency, magnitude and resistance of the tissues. We have the indirect injury (Arc-Flame and Flash) They are disruptive discharges, the current travels through an object of least resistance, but the final goal is the patient. We have electrodermal arc flash injury; It is defined as a jump of electricity between two places that are not in contact, these generate sparks, the temperature of the arc can reach 2,500 to 1,000ºC and are frequent in flexion areas such as armpit, popliteal area, wrists and elbows. The ignition injury in this generates a burn by fire due to the current setting fire to the clothing or some object with injury to the patient; and mixed, which are generated in combination. (4)

Increased intracompartmental pressure is a sign that can quickly develop into a syndrome and is strongly associated with electrical burn; This syndrome is described as the set of signs and symptoms related to the increase in intracompartmental pressure, being a closed osteomyofascial space, it can be acute or chronic, if it is acute it is essential to perform emergency surgical decompression of the compartment since there is an abrupt decrease in blood supply and perfusion pressure, concluding in ischemia and necrosis of the tissues with permanent sequelae such as Volkmann's contracture. (15,16)

They recommend that burns should not be classified as accidents since they are events produced by repeated actions with risky activities caused by lack of preventive culture, poverty, lack of regulations that regulate, prohibit, supervise and sanction risk activities. (14) (17)

Infrared thermography is a safe and low-cost technique that allows the rapid and non-invasive recording of radiant energy that is released from the body, it measures this radiation directly related to the temperature of the skin. (13)

Nowadays we see that technology has evolved to the extent that there are thermal imaging cameras the size of the palm of the hand, they use a long-wave infrared radiation sensor of 8 to 14um and capture temperature ranges from 0 to 100ºC with a temperature difference of 0.03ºC. which are connected to a smartphone and through the screen we see the temperature, an example of this is the Flir One Pro camera. (18)

EPIDEMIOLOGY

The World Health Organization (WHO) mentioned in 2018 that burns caused 180,000 deaths a year, mostly in low- and middle-income countries. In Mexico, in 2016, 625,855 people died from fatal accidents, of which burns ranked fifth. (19)

According to the 2012 National Health and Nutrition Survey (Ensanut), 124,000 people suffered non-fatal burns each year and hundreds survive with sequelae that affect their aesthetics, functionality and social space. (19)

In Mexico, the Dynamic Health System Information System reported that in 2008 burns ranked 13th in deaths, in 2012 there were 267,885 deaths due to burns, 23.4% of whom were under 5 years of age and 15.5% were between 5 and 14 years of age. Men had a higher rate, with the highest mortality rate in northern Mexico. (8)

In 2011, a tertiary hospital in Guadalajara registered an admission of around 100 patients due to burns, of which approximately 20-25% are caused by electricity. There is clear evidence that injuries above 1,000 volts cause greater damage than those at lower voltages. Thus, hospital stay, morbidity, surgical procedures and mortality are much higher. (20)

The National Epidemiological Surveillance System reported that in 2013 there were 126,786 new cases of burns, while from January to June 2014 there were 65,182, of which 56% were in adults between 20 and 50 years of age.

85% of these were when they were doing work activities and 32% in children from 0 to 19 years of age, of these 90% within their homes and 80% were for hot water. At the national level, 93% of patients were treated in public hospitals: IMSS 67.5%, Ministry of Health 19.8%, ISSSTE 3.3%, DIF, PEMEX, SEMAR, SEDENA 2.5% and others

institutions 6.9%, Table 1 shows the incidence by age and year. (14)

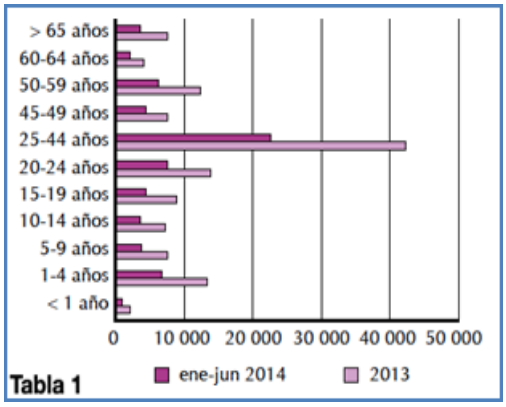


Tabla 1

At the Dr. José Eleuterio González University Hospital, they report that in 2020, in the midst of the pandemic, they found an increase in the incidence of severe burns in pediatric patients. From March to August 2020, they recorded a doubling increase in burn patients compared to 2018 and up to 8 times greater than in 2019. They describe the presentation of the accidents was at home, 35% scald, 35% electrical trauma, 30% direct fire, the age range was from 10 months to 11 years, the severity index was 92.7 points in the Garcés classification modified by Artigas. (19)

According to data from the National Fire Protection Association, 600,000 people burned in the United States in 2005, of which 25,000 required hospital management and

4,000 died. The Shrinners Hospital in Galveston, Texas, being a national and international reference hospital with excellent results in the management of burned children, mentions that between 1989 and 2008 5,260 children were hospitalized and only 145 died, average age of 7.3 years, with an average burned body surface of 55%, average time to excision was 1.6 days after hospital admission. The average length of stay in intensive care was 22.7 days. (14)

In the following image (image 1) we can see the incidence of burns in Mexico by state in 2014 (14)

In developed countries, they report an incidence of compartment syndrome secondary to burns of 7.3 per

100,000 burn patients in men and 0.7 per 100,000 women. (21)

Lugar	Estado	Casos nuevos	Lugar	Estado	Casos nuevos
1	Distrito Federal	14 476	17	Oaxaca	2 688
2	Jalisco	12 194	18	Durango	2 603
3	México	9 823	19	Quintana Roo	2 345
4	Nuevo León	9 361	20	Hidalgo	2 302
5	Veracruz	6 488	21	Yucatán	2 242
6	Chihuahua	6 243	22	Querétaro	2 181
7	Coahuila	5 154	23	Aguascalientes	2 029
8	Sonora	5 142	24	Tabasco	1 862
9	Puebla	5 075	25	Zacatecas	1 744
10	Baja California	4 872	26	Morelos	1 713
11	Sinaloa	4 557	27	Chiapas	1 681
12	Guanajuato	4 228	28	Nayarit	1 455
13	Tamaulipas	3 918	29	Colima	1 157
14	Michoacán	3 808	30	Campeche	1 058
15	Guerrero	2 895	31	Baja California Sur	901
16	San Luis Potosí	2 782	32	Tlaxcala	802

Imagen 1

Electrical burns in the United States register 1,000 deaths a year and 3,000 hospital admissions, of which 4 to 6.5% are admitted to the burn unit and 3 to 12% are admitted to general hospital and 10% culminate in amputation of a limb, the prevalence is 91.9% male compared to female 9:1 In adults it is the fourth cause of death at work. Of the people who work with electricity, 50% suffer some direct damage to the wiring and 25% from machines in poor condition. (4)

PHYSIOPATHOLOGY

Current studies show that severe burns, regardless of the cause, result in an exaggerated inflammatory response development within a few hours. It is primarily characterized by elevation of cytokines, chemokines, and acute-phase proteins, a hypermetabolic state by sustained sympathetic tone that may persist. There are several factors involved such as the severity of the burn (depth and body surface area compromised), cause of the burn, inhalation injury, exposure to toxins, added traumatic injuries, or host-related factors. Being directly proportional to the guest's response. (9)

With prolonged exposure to temperatures of 40ºC we see that protein denaturation begins, alteration to the cell membrane and loss of plasma, this process is faster with temperatures of 60ºC seeing a synergistic effect between temperature and time. As we can see in the following table (Table 2) (10)

Temperature in ºC	Exposure duration in seconds
45º	3600
54.4º	30
60º	10
69th	1

Immediately after the burn, 3 zones are formed:

coagulation zone (the greatest damage and the central part), stasis or ischemia zone (decreased perfusion with risk of necrosis), hyperemia zone (inflammatory vasodilation). (Image 2) Directly related to the local reaction triggering the inflammation phase that lasts 6 days, it begins with neutrophils and monocytes. Useful for degrading necrotic tissue and activate cascades for wound repair. Keratinocytes and fibroblasts are activated, helping to initiate the proliferative phase that lasts 15 to 20 days, and aims to restore perfusion and promote wound healing, in which collagen and elastin are deposited, transforming fibroblasts into myofibroblasts. At the end of the maturation phase lasting 1 to 2 years, there is a balance between myofibroblasts and re-epithelialization. (9) (7)

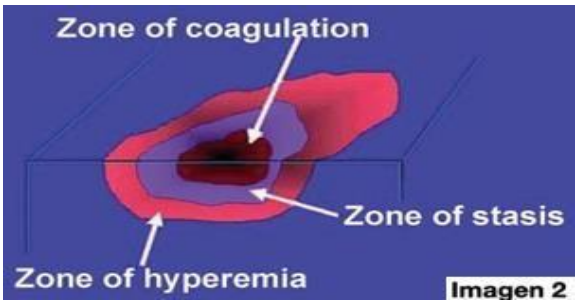


Imagen 2

It is confirmed in recent studies that heat causes the most obvious immediate injury presenting a rapid denaturation of proteins with cellular damage, causing complex injury and evolution for activation of local and systemic response, the latter when the burn exceeds 20% of the total body surface area is characterized by a hypermetabolic, hyperdynamic response with an increase in body temperature, The consumption of oxygen, glucose, carbon dioxide production, hyperglycemia, peripheral insulin resistance, glycogenolysis, proteolysis, lipolysis, loss of lean mass, muscle and bone wasting can last from 1 to 2 years after the burn, it is important to keep it under strict surveillance with high-protein diets since if it gets out of control it can become fatal. In addition to this, we find loss of the skin barrier, presenting alteration of body temperature regulation, difficulty in maintaining electrolyte balance, leaving a window for infection, the latter being the most serious with a high rate of complications, including lung, urinary, skin infections, bacteremia and sepsis by bacteria such as Pseudomona aeruginosa and Staphylococcus aureus are the predominant ones. (CENETEC, 2018)

For electrical burns, there are four mechanisms of injury. 1. Direct tissue damage: alters the resting potential of the membrane generating contraction. 2. Transformation of electrical energy into thermal energy (Joule's Law) Extensive coagulative destruction and necrosis in tissues. 3. Trauma caused by muscle contraction or falls following contact with electricity. 4. Theory of electroporation with alteration of membrane proteins with alteration of function and integrity. (4) We found non-thermal and thermal lesions. In the former, we find depolarization of excitable tissues such as the heart (cardiac arrest, ventricular fibrillation and arrhythmias), the brain (alteration to alertness, lesion in the center

respiratory and spinal cord). Thermal injuries, starting with the resistance caused by the skin, generating entry and exit points, charring them causes heating of bones with coagulation and burning of adjacent structures, and the path taken by electricity is directly proportional to the damage. (4)

For compartment syndrome we see that it occurs mainly due to the lesion which triggers edema increasing the pressure of the compartment occluding the venules and capillaries presenting fluid outflow to the third space creating a vicious circle until it completely occludes the circulation causing ischemia, there is the release of polymorphonuclear cells, leukocytes, free radicals, tumor necrosis factor, leukotrienes, waste substances between more cells, if circulation is not restored culminates in necrosis; The period of supervenience and sequelae is directly related to the time of evolution, as well as the systemic damage due to the ischemia-reperfusion phenomenon. (22)

The pathophysiology is directly related to the clinical presentation of the patient, we will see a set of signs and symptoms mentioned in multiple literatures such as the 4 p's (pallor, absence or decrease of pulses, paralysis and paresthesias) it is also commented that edema, pain at passive extension and pain disproportionate to the injury are directly in proportion to the damage. Several authors mention the absence of pulses, this is a late sign or related to vascular injury. Even with these clinical data the diagnosis cannot be confirmed, we will see that edema is palpable throughout the extremity, pain is an early and very common sign and this is disproportionate, but it is also subjective, in the literature compartment syndromes without pain have been reported. Paresthesia, although it is said that it can be the clinical sign for the diagnosis, is late with low sensitivity, paralysis is also a very late sign, pathologically speaking, the damage is already caused. It refers to the fact that 3 clinical data and the measurement of intracompartmental pressure are ideal for making the diagnosis>30mmHg. As we can see in the following table (Table 3) the specificity and sensitivity of each sign and symptom presented by the patient. (15) (23)

Table 3.

Signs and Symptoms	Sensitivity %	Specificity %	Value Positive Predictive	Value Negative Predictive
Pain	19	97	14	98
Pain on passive movement	19	97	14	98
Paralysis or motor disturbances	13	97	11	98
Paresthesias and sensory changes	13	98	15	98
Oedema	54	76	70	63
Pressure Measurement Intracompartmental	94	98	93	99

Here we can see in the image (Image 4) which summarizes the pathophysiology of compartment syndrome (24)

CLASSIFICATION

Over the years, multiple classifications have been described for burns in which we can find according to depth, extension, areas of injury, consideration of major burns, classification for referral to referral hospital, also these are subdivided into more scales or classifications. We are going to describe the classifications most used by our country as well as those presented by the Mexican Association of Burns and the Official Mexican Standard. (8)

The Converse-Smith classification is based on the depth of the lesion: First degree or superficial, limited to the epidermis, usually have spontaneous healing with application of moisturizers or aloe vera or spontaneously. Second degree of partial thickness, involves the superficial papillary layer of the dermis, we see it erythematous, we find rapid capillary filling with acupressure, it presents phlyctenas since the waterproofing characteristic was lost, when removing them we find pain due to the exposure of the nerve endings, deep second-degree burns, injury under the reticular layer of the dermis we find them red, blue at acupressure pale but the return of color is slow or non-existent, there is no phlyctena, no follicles are found. Third degree or deep, we find completely pale without pain or filling to the aculaplesion, hard consistency, without follicles, tend to be dry. We took this classification as a basis and compared it with the classification of Benaim, ABA and According to its histological level. The prognosis of each type of injury is also assessed. (7,10)

In the following table (Table 4) we describe and compare the Benaim, Converse-Smith and ABA classifications with the histology, as well as with the prognosis presented by each type of burn patient. (8)

The following table (Table 5) describes the characteristics of each lesion by histology based on the ABA classification. (8)

BENAIM	CONVERSE-SMITH	DENOMINACIÓN ABA	NIVEL HISTOLÓGICO	PRONÓSTICO
TIPO A	Primer grado	Epidérmica	Epidermis	No necesitan injerto Debería curar espontáneamente en 7 días sin secuelas.
TIPO AB-A	Segundo grado Superficial	Dérmica superficial	Epidermis y dermis	Debería epidermizar espontáneamente en 15 días con secuelas estéticas. Si se complica puede profundizarse.
TIPO AB-B	Segundo grado profundo	Dérmica profunda	Epidermis y dermis papilar y reticular sin afectar fanéreos profundos	Habitualmente termina en injerto con secuelas estéticas y/o funcionales. Puede requerir escarectomía tangencial.
TIPO B	Tercer grado	Espesor total.	Epidermis, dermis e hipodermis (tejido celular subcutáneo), puede llegar inclusive hasta El plano óseo.	Requiere escarectomía precoz, e injerto o colgajos.

Tabla 4

Caracteristicas clinicas	Tipo A (Superficial)	Tipo AB (Intermedia)	Tipo B (Total)
	Flictenas; color rojo; turgor normal. Apariencia de quemadura de sol. Dolor intenso	<u>Superficial:</u> Color rosado, homogénea; llene capilar normal; dolor; humedad; folículos pilosos intactos. <u>Profundo:</u> Color moteado o blanco, retraso o ausencia de llene capilar; folículos pilosos no intactos. Disminución de la sensibilidad	Sin flictenas; color blanco grisáceo; sin turgor; Dermis seca , blanca o carbonizada, piel arrugada, insensibilidad Dolor ausente

Tabla 5

To assess the total body surface area burned, there are several scales of which the Mexican Association of Burns, as well as CENETEC, recommend the use of Lund and Browder since it is more accurate and useful for the pediatric patient, being indispensable for the management of the patient. This measurement is simplified in the following table and image. (Table 6, Image 3) (8)

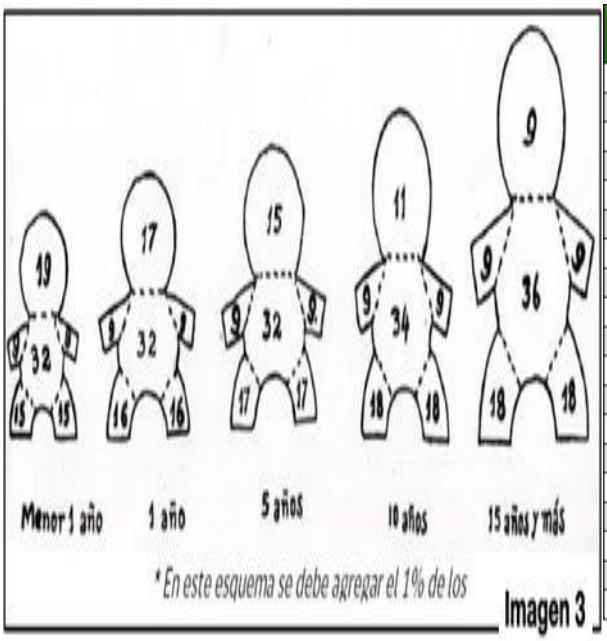


Imagen 3

AREA	EDAD EN AÑOS				ADULTO
	0-1	1-4	5-9	10-15	
Cabeza	17	15	13	9	7
Cuello	2	2	2	2	2
Tronco anterior	16	16	16	17	18
Tronco posterior	11	11	11	12	13
Glúteo derecho	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2
Glúteo izquierdo	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2
Genitales	1	1	1	1	1
Brazo derecho	4	4	4	4	4
Brazo izquierdo	4	4	4	4	4
Antebrazo derecho	3	3	3	3	3
Antebrazo izquierdo	3	3	3	3	3
Mano derecha	2	2	2	2	2
Mano izquierda	2	2	2	2	2
Muslo derecho	6	7	8	8 1/2	8 1/2
Muslo izquierdo	6	7	8	8 1/2	8 1/2
Pierna derecha	5 1/2	5 1/2	5 1/2	6	6
Pierna izquierda	5 1/2	5 1/2	5 1/2	6	6
Pie derecho	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2
Pie izquierdo	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2

Tabla 6

Another scale used in the emergency department or where the incident occurs is the Wallace template or commonly called the rule of 9, it is used for the adult as we can see in the following image. (Image 4) (8)

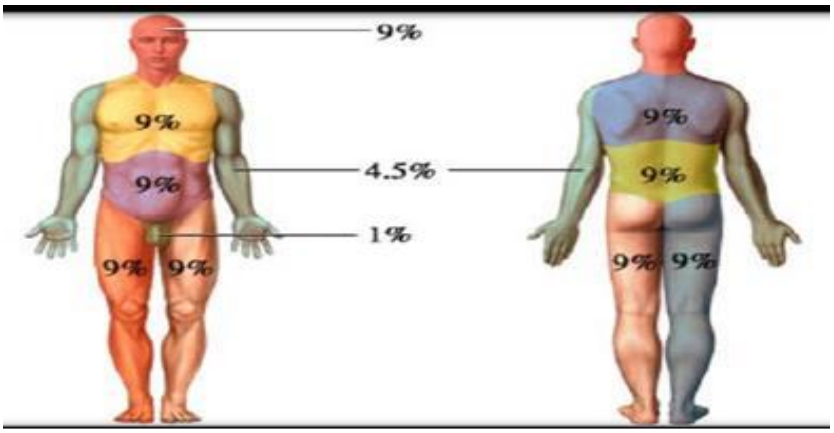


Imagen 4

Depending on how the patient feels, we will see that they are not always in a good state of alertness, as it is common to find trauma associated with burn injuries using the Ramsay scale to assess the patient's degree of sedation. The following table (Table 7) describes it in detail. (8)

Escala de Ramsay	
NIVEL DE SEDACIÓN	CARACTERÍSTICAS
1	Paciente ansioso, agitado.
2	Paciente cooperador, orientado y tranquilo.
3	Paciente dormido con respuesta a las órdenes.
4	Dormido con breves respuestas a la luz y sonido.
5	Dormido con sólo respuesta al dolor.
6	No respuesta.

Tabla 7

When the patient is in critical care, it is recommended to assess that he or she is in an adequate sedation plane so that he or she does not present pain, we have as support the observational scale of pain in critical care described in the following Table (Table 8). (8)

Expresión facial	Relajado, neutro	0
	Tenso (ceño frunciso, cejas bajadas, orbitas de ojos contraidas)	1
	Muecas	2
Movimientos corporales	Ausencia de movimientos	0
	Protección (movimientos lestos, cautelosos, se toca o frota el sitio donde le duele)	1
	Agitado	2
Tensión muscular	Relajado	0
	Tenso, rígido	1
	Muy tenso o muy rígido	2
Adaptación ventilador (pacientes intubados)	Bien adaptado al ventilador	0
	Tose, pero se adapta	1
	Lucha con el ventilador	2
Vocalización (pacientes extubados)	Habla con tono normal o no habla	0
	Suspiros, gemidos	1
	Gritos, sollozos	2

Tabla 8

For the ideal management of the patient, it is essential to know what the reference criteria are for sending the patient to a referral hospital, since in the most recent studies it has been shown that survival increases when they are managed with the treatment and measures required without wasting significant time, we see what they are in the following table (Table 9) (8)

Criterios de referencia a un centro de quemados
Quemaduras de espesor parcial de más del 10% de superficie corporal
Quemaduras que afectan la cara, las manos, los pies, los genitales, el perineo o las articulaciones mayores
Quemaduras de tercer grado en cualquier grupo de edad
Quemaduras eléctricas, incluyendo lesiones por rayos
Quemaduras químicas
Lesión por inhalación
Lesiones por quemaduras en pacientes con trastornos médicos preexistentes que podrían complicar el manejo, prolongar la recuperación o afectar la mortalidad
Cualquier paciente con quemaduras y traumatismos concomitantes (como fracturas) en los cuales la lesión por quemaduras presenta el mayor riesgo de morbilidad o mortalidad. En tales casos, si el trauma representa un mayor riesgo inmediato, el paciente puede inicialmente estabilizarse en un centro de trauma antes de ser transferido a una unidad de quemados. El juicio del médico será necesario en tales situaciones y debe estar en armonía con el plan de control médico regional y los protocolos de clasificación
Niños quemados en hospitales sin personal o equipo calificado para el cuidado de niños
Lesiones por quemaduras en pacientes que requieren intervención social, emocional o de rehabilitación especial

Tabla 9

Among the classifications we have the severely burned patient, which we could classify as such when he meets one of the following criteria that we see in the table. (Table 10) (8)

Criteria for naming the great burn
Severity index >70 points or with AB or B burns >20% of surface area corporal total.
> 65 years of age with 10% or more AB or B burns
Respiratory or smoke inhalation burns
High-voltage electrical burns
Polytraumatized patients
Burns with associated serious pathologies

DIAGNOSIS

For the diagnosis of compartment syndrome, multiple technologies have been established supported by the patient's clinic. Commenting that the most reliable way so far is to have 3 or more data suggestive of compartment syndrome plus the measurement of intracompartmental pressure >30 mmHg. When the patient is in an altered state of alertness, sedated or intubated, the only way we have is to measure the intra-institutional pressure since the patient does not have the clinic. The multiple authors comment that it continues to be a challenge, since it is difficult to recognize it and it is complicated when the patient is under sedation or in a lot of pain, it is difficult to assess the severity with third-degree burns, there are even several reports in the literature of patients that for these reasons it was not possible to make an adequate assessment performing fasciotomies if necessary. The same is true in patients with electrical burns, as the damage continues and is further enhanced when the patient's fluid correction is performed. (25)

The intracompartmental pressure (Delta pressure) has been confirmed to be the ideal one to determine the real pressure at which we are going to take the diastolic pressure of the patient and we are going to subtract the intracompartmental pressure obtained if it is equal to or greater than 30mmHg you can think about performing fasciotomies, in the same way they recommend performing serial measurements every 30min to 2 hours to determine the evolution and performance of fasciotomy. (23)

Due to the difficulty of making the diagnosis, flowcharts have been performed to facilitate the management and diagnosis of these patients, as we can see in the following image. (Image 5) (21)

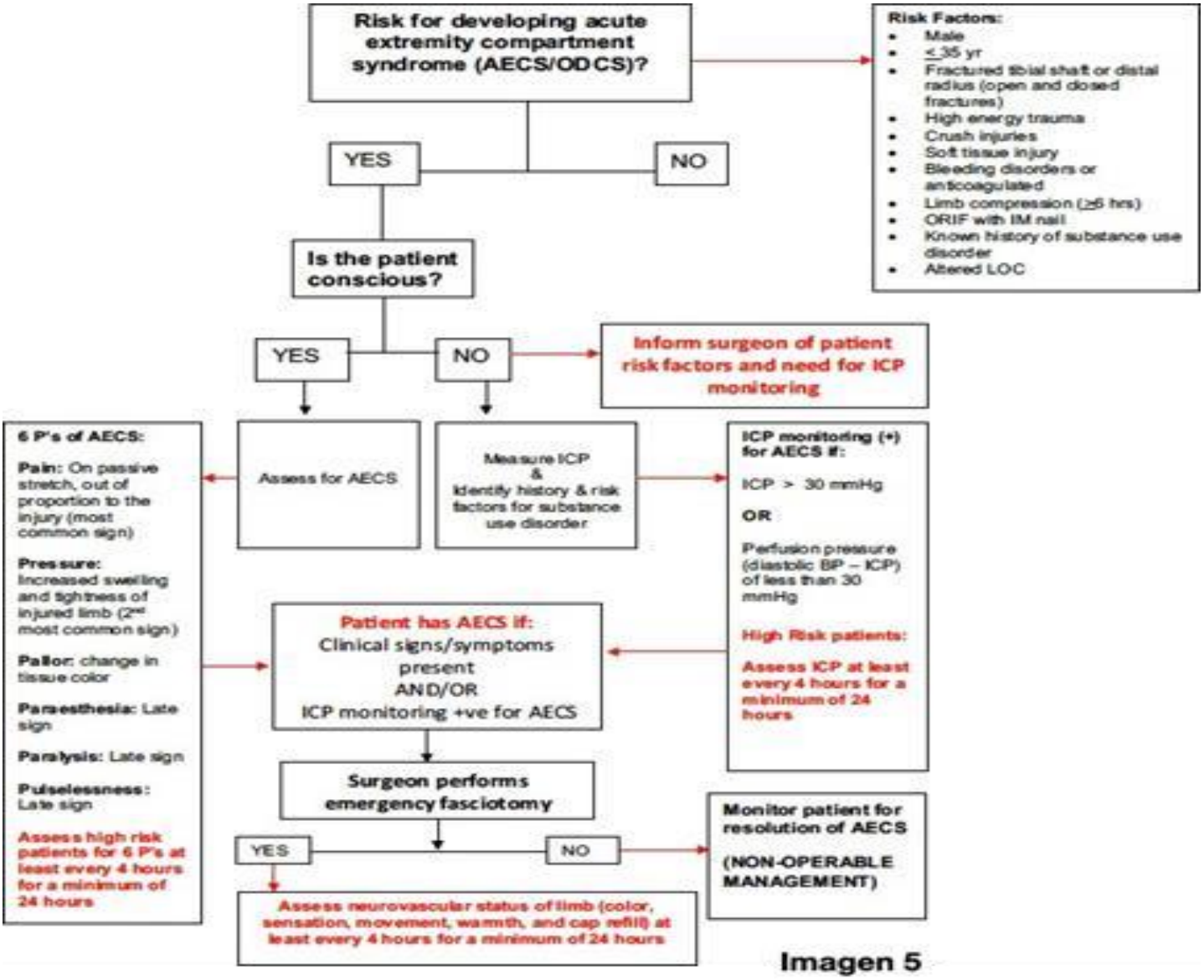


Imagen 5

Over time, multiple options for the diagnosis of compartment syndrome have been investigated, reporting more than 38 modalities mainly focused on the measurement of intracompartmental pressure from non-invasive to invasive methods, as well as biological and pH methods. Among the best known are infrared spectrometry, direct pressure measurement with Stryker as well as with the whiteside method (variation of 1mmHg against Stryker), Slit catheter, invading blood pressure, pulsed light ultrasound, magnetic resonance imaging, computed tomography, molecular biomarkers among others. (11)

CPG Recommendations for the Use of Intracompartmental Pressure Measurements to Aid in the Diagnosis of ACS

Recommendation	Strength	Description of Level of Evidence
ICP measurement	Moderate ★★★	Moderate evidence supports that ICP monitoring assists in diagnosing ACS.
Serial ICP monitoring	Moderate ★★★	Moderate evidence supports the use of repeated/ continuous ICP monitoring and a threshold of diastolic blood pressure minus ICP >30 mmHg to assist in ruling out ACS.
ICP in late presentation ACS	Consensus ★	In the absence of reliable evidence, it is the opinion of the workgroup that compartment pressure monitoring does not provide useful information to guide decision making when considering fasciotomy for an adult patient with evidence of irreversible intracompartmental (neuromuscular/vascular) damage.

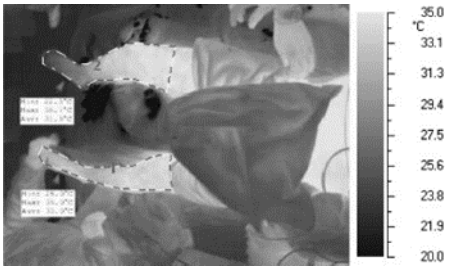
ACS = acute compartment syndrome, CPG = clinical practice guideline, ICP = intracompartmental pressure

Imagen 6

We have tables of recommendations for diagnosis according to the American Clinical Practice Guidelines, as we can see in the following image. (Image 6) (26)

More than 38 non-invasive methods have been studied to make the diagnosis of compartment syndrome such as infrared spectroscopy, thermography, surveillance of compartments with ultrasound, among others, which do not provide good sensitivity and specificity, are very expensive and operator dependent which require impeccable techniques for an effective diagnosis. (11)

The gold standard for the diagnosis of compartment syndrome is the measurement of intracompartmental pressure, which is an invasive but effective method. There is a piece of equipment called Stryker which is not marketed in Mexico or in many countries of low socioeconomic level, which is why new methods such as Whitside are created, it consists of taking several products such as an 18G needle, sterile saline solution, manual pressure gauge, hoses and connection in ¨T¨ or 3-way connector and the measurement of the three compartments of the forearm is carried out always in the same place, thus obtaining a measurement which is subtracted from the diastolic pressure and this will be the perfusion pressure, if this is greater than or equal to 30mmHg we will have the diagnosis of Compartment Syndrome or soft tissue suffering. (11)



With the thermographic method, when there is edema of tissues and compartments, there begins to be a decrease in perfusion pressure, which

As a result, it presents a decrease in temperature from distal to proximal, which may be reflected as ischemia. Methods that are preferred when there is doubt about the diagnosis. As we can see in the following image, the right lower extremity presents compartment syndrome after a trauma, in which we see a decrease in distal temperature compared to

The contralateral limb. (L. Katz et al., 2007; L. M. Katz et al., 2008) (Sellei et al., 2021)

TREATMENT

For the management and treatment of the burn patient, it should always be managed prioritizing the AUC, multiple flow charts have been presented to facilitate and simplify the management of the burn patient, once having the ABC of the The patient continues with the secondary review and ABCDEF management in which fluids have to be managed as a priority, there are multiple formulas, the most used is the Parkland formula and currently the follow-up is under the mean hourly diuresis, reaching a target of .5 to 1 ml/kg/hr, we have multiple flow schemes but in all of them the absolute

surveillance of the patient in critical care is conclusive. for adequate monitoring and surveillance, (Image 8) (1,8)

In the image below we describe the Parkland formula. (Image 9) (8)

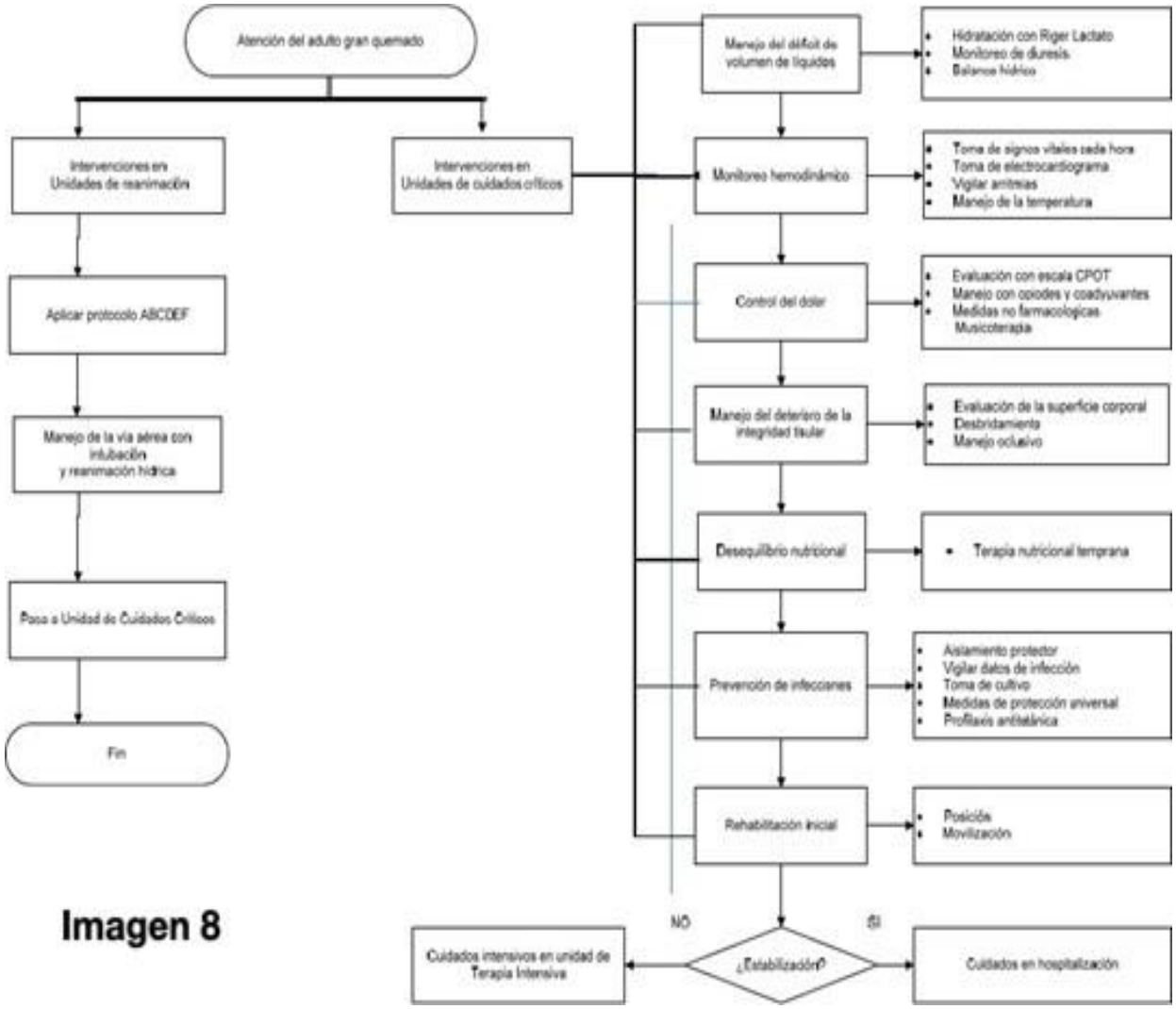


Imagen 8

Fórmula de Parkland.

Total del volumen a pasar en primeras 24 horas desde el momento del accidente: 3-4ml* kg* % superficie corporal quemada, ajustando según balance hídrico y monitoreo hemodinámico.

No se debe insistir en aporte de volumen sin considerar otras causas de hipoperfusión además de la hipovolemia, como la depresión cardíaca secundaria, especialmente en quemaduras toráxicas y pacientes de edad avanzada.

Imagen 9

For the treatment of patients with compartment syndrome, fasciotomies are essential, with time being the most important thing, as it is directly proportional to the future evolution in relation to the functional and aesthetic sequelae that may occur. In the forearm, the 3 compartments must be released, it can be a Henry-type fasciotomy to fly or to fly ulnar to respect and
Take care of the nerve endings, as well as venous drainage, in hand is performed dorsal and lateral to release the
10 compartments. Simplified and explained in the image below. (Image 10) (16,24)

Anatomical region	Compartments	Surgical approach
Forearm	Three: volar, dorsal, lateral. The volar compartment is the most frequently involved.	Volar incision. Dorsal incisions.
Hand	Ten: Hypothenar, Thenar, Adductor pollicis, N.4 dorsal interosseus, N.3 palmar interosseus.	Two longitudinal incisions over 2nd and 4th metacarpals. Longitudinal incision radial side of 1st metacarpal. Longitudinal incision over ulnar side of 5th metacarpal. Carpal tunnel decompression.

Imagen 10

The complications of fasciotomies can be listed according to the percentage of presentation. (24)

- Alteration in sensation 77%
- Dry, flaky skin 40%
- Pruritus 33%
- Wound discoloration 30%
- Extremity edema 25%
- Hypertrophic scars 26%
- Recurrent ulcers 13%
- Muscle herniation 13%
- Wound pain 10%
- Tendon entrapment 7%

The time to make the diagnosis and make the decision to perform the fasciotomy are directly proportional to the survival of the tissues to ischemia, we have a maximum of 6 hours for the best survival of the tissues and minimize the percentage of sequelae. Likewise, it is essential to adhere to diagnostic methods that are less invasive and morbid for patients, as well as with lower costs. (25)

I. STATEMENT OF THE PROBLEM

Burns are a real public health problem as they are a significant cause of morbidity and mortality, with an estimated 322,000 people dying worldwide each year and at least
100,000 have disabilities with physical, psychological and social impact secondary to permanent sequelae and amputations, and the largest number of these types of injuries occur in low- and middle-income countries, with the highest percentage being males with a ratio of 9:1 of whom are of active working age. Most burns are caused by scalding, direct fire and electrical burns, the latter being the most disabling and the most sequelae, as well as the most morbid. (8)

According to a study conducted at the Tacubaya Pediatric Hospital in 2011, the costs for the management of uncomplicated burn patients are $98,000 Mexicans. From admission to discharge, uncomplicated patients are those who do not require more than 1 admission to the operating room for definitive treatment and with a maximum hospital stay of 7 days. (López Concepción., 2011)

When searching for the topic, we noticed that there is no research on the subject in our country, since the vast majority of articles are from the United States and Europe. In our country, there are few or no results or options to consider for this health problem.

A frequent complication of misdiagnosed or late-diagnosed electrical burns is compartment syndrome that can end in Volkmann's contracture leaving sequelae of partial or total disability or even amputations, these burns present a diagnostic challenge since this type of burns apparently do not present significant injury, but due to their pathology they are the most serious burns. In addition to this, although the patient presents adequate state of alertness, the clinic is very subjective, being necessary the confirmation with the measurement of intracompartmental pressure, if we find an alteration to the state of alertness it is essential to take the measurement, for this it is necessary to be trained and know the method, thus making a correct measurement. (4)

In the world, up to 38 methods have been researched for the diagnostic support of intracompartmental pressure, the most reliable is the direct measurement with the Stryker equipment which is an invasive method that is not marketed in Mexico, other methods such as the measurement of biomarkers apart from high cost take a long time, it can be measured with infrared spectrometry but the cost is excessively high, For this reason, Whiteside's method is adopted, having the disadvantage that it is operator dependent, a learning curve is required and in the same way getting the materials to assemble it as well as knowing how to assemble it so that the measurement can be correct, all this implies expense for the hospital for supplies and time which is vital for the patient apart from being necessary for the patient to be under sedation for be an invasive method. (11) This last method is the one used at the Adolfo López Mateos Medical Center, in which in 2022 115 burn patients were treated, of which 35 were due to electrical burns, in the latter 25 they were admitted to the operating room to perform emergency fasciotomies. Clinical experience demonstrates the high incidence of this health problem.

II. JUSTIFICATION

The following study focused on a method for early detection of Compartment Syndrome in patients diagnosed with burns; As has been reported in various publications, the incidence of burns in Mexico and the world is a public health problem, specifically in electrical burns, when we talk about male adults of active working age, where the most common complication is Compartment Syndrome and the main sequelae is Volkmann's contracture or amputation. These could be reduced by improving early diagnosis and timely treatment.

A non-invasive and easy-to-use method for the early detection of Compartment Syndrome was validated, which can be used by all health personnel including paramedics, students, nurses, first contact physicians, emergency area, as well as intensive care, with the ease of having a thermal imaging camera and a mobile device. which could reduce costs and complications, once it has been validated and implemented in this Medical Center.

It was considered important to carry out this study to demonstrate the validity and reliability of thermography in the early diagnosis of compartment syndrome since normally the measurement of intracompartmental pressure is performed with an invasive method that requires a learning curve and is normally done by the Interconsultant physician rather than by the first contact physician. emergency or intensivist, this causes valuable time to be lost since the sequelae are directly related to the time of evolution, therefore, by having a timely diagnosis, using thermography, the time for treatment is reduced by not having to carry out the mobilization to a clean area, surgical material, as well as medical and nursing personnel, resulting in a reduction in hospital stay, the number of admissions to the operating room, the number of medications used, thus the complications and sequelae of the patient would be lower, as well as the expenses required to measure the intracompartmental pressure with the Whiteside method, concluding in less economic investment by the hospital and patients.

The research on the validation of thermography for the diagnosis of intracompartmental pressure helps us mainly in making an early and timely diagnosis to reduce the percentage of complications and sequelae in patients with Compartment Syndrome; Above all, considering that they are young patients of active working age, and if the hospital stay is reduced, they will have the possibility of returning to their working life in fewer days. For the hospital, it translates into lower expenses for the use of the operating room, medicines, days of hospitalization and use of health personnel.

Obtaining the final result, it is confirmed that a secondary objective of this work is to participate in national and international scientific events, as well as the publication in a high-impact scientific journal to increase the number of investigations in our country, as well as information for interested personnel, managing to reduce this health problem in our country.

Validation of Thermography for The Diagnosis of Compartment Syndrome in The Upper Extremities Due to Electrical Burns in Patients with Altered Alertness

I. MATERIAL AND METHODS

Type of study

Quantitative	x	Qualitative		Mixed	
Prospective	x	Retrospective		Ambispective	
Observational	x			Experimental	

Study Design

Observational:				
Cross-sectional survey:	Descriptive		Analytic	
Cases and controls:				
Cohort:	Prospective	x	Retrospective	
Experimental:				
Quasi-experimental				
Clinical trial:	Simple Blind		Double-blind	

Other (In case of qualitative studies)

II. UNIVERSE

Patients who were admitted to the Adolfo López Mateos Medical Center in 2023 with electrical burns with an injury of >80% of the circumference of one or both upper extremities in patients with altered alertness.

III. SAMPLE

Of the 36 patients admitted to the Adolfo López Mateos Medical Center in 2023 for electrical burns, only 17 of them met the inclusion criteria.

IV. SAMPLING

In probabilistic, by consecutive cases

V. UNIT OF ANALYSIS AND OBSERVATION

Individual

VI. SELECTION CRITERIA (INCLUSION, EXCLUSION AND ELIMINATION)

a. Inclusion criteria

- Men & Women
- Patients admitted for a diagnosis of electrical burn >80% of the circumference of one or both upper extremities Patients with impaired alertness
- Patients or guardian of the patient who agrees to participate in the study

b. Exclusion Criteria

- Patients with third-degree burns on the affected hand.
- Patients with a previous diagnosis of autoimmune and/or vascular disease that alters the temperature of the upper extremities (Arthritis, Sx. Sjögren, Sx. Raynaud, Sx. Achenbach, etc.)

c. **Removal Criteria (If applicable)**

- Patient who died during the data registration process.
- Patients with incomplete monitoring
- Patients who decide (or whose guardians decide) not to continue participating in the study

VII. PROCEDURES

With the approval of the ethics and research committee of the health institute of the State of Mexico, the research began.

1. We carried out the identification of patients with burns who were admitted to the Adolfo López Mateos Medical Center through an interconsultation carried out by the emergency service, once we had knowledge of the burn patient, we continued with the scrutiny, we will focus on those patients who present electrical burn with alteration to the state of alert and with subjective diagnosis of Compartment Syndrome in the upper extremities, this will be; Any patient with a circumferential burn or greater than 80% of the circumference in the upper extremities.

2. The information was collected with the filling out of the Data Collection Form, the (Subjective) interrogation will be indirect directed to the patient's companion, whether it is a family member, employer, work colleague, paramedic, emergency physicians and/or first contact physicians. The objective information will be directly with the patient, being; Intracompartmental Pressure Measurement, Temperature Measurement with Thermography, Vital Signs, etc.

3. Once the ABCDE protocol was carried out by the emergency department, the patient proceeded to uncover with sterile gloves and perform cleaning of the compromised upper extremities with surgical soap, removing all types of necrotic tissue, contamination or chemicals that the patient presents, the removal of the surgical soap with abundant 0.9% saline solution was carried out at a temperature of 33ºC plus/minus 3ºC. Drying was performed with sterile compresses. Sterile fields were placed under the affected limb and we will leave it in the supine position without manipulation for a period of 15 minutes for body thermoregulation. The patient should always be completely supine.

4. While the 15 minutes have elapsed, the device for measuring intracompartmental pressure is assembled by the Whiteside method, which requires: 1 manual pressure gauge, 1 20cc syringe, 1 18G needle, 50ml of 0.9% saline solution, 2 hose extension for solution and 1 connector in ¨T¨ or wrench of 3. The assembly of this will be as follows:

a. 15cc of saline solution was taken with the 20cc syringe.

b. The 2 hoses will be plugged into the "T" connector each at different ends and through the center of the "T" connector the syringe.

c. Pass 5cc to the end of the needle without spilling the liquid in order to purge the hose. This will be done by closing the passage to the 3 or ¨T wrench pressure gauge

d. Once this has been done, the 3 valve is opened again and it will be ready to take the intracompartmental pressure after taking the temperature.

5. The Flir One Pro thermal imaging camera is connected to the mobile device, both devices are turned on and the previously downloaded FLIR ONE application is opened, the thermal imaging camera is placed at a distance of 60cm with 90º of angulation and 3 temperatures will be recorded with a photograph and/or video, the recordings will be of the distal phalanx, proximal phalanx of the 3rd finger and center of the hand of the compromised limb.

6. With the limb in the same position (Supine), intracompartmental pressure is taken from the 3 compartments of the forearm, anterior, lateral and posterior, following the following steps. Prior to taking the pressure, the patient's blood pressure should be checked and recorded, since the correct measurement is the perfusion pressure, which is the diastolic pressure minus the pressure obtained by Whiteside's method.

a. For the anterior compartment, the palmaris longus tendon was located up to its muscular belly (proximal third of the forearm) right there the needle of the pressure gauge is placed at 90º, 2 mm or until the fascia is perforated and the plunger of the gauge is pressed, which should be at the same height of the arm and

7. They infiltrate 2cc noticing that the pressure gauge increases the measurement from 0mmHg to the pressure presented by the patient, to confirm it can be pressed just in

front and behind the needle noticing an increase in pressure and a decrease when releasing the pressure.

a. For the lateral compartment in the same supine position and we locate the junction in the proximal third of the forearm of the brachioradialis and extensor carpi radialis longus, we place the needle and it will be inserted 2mm or until perforating the fascia to infiltrate 2cc and we perform the same maneuvers previously described.

b. For the posterior compartment, it is placed in the prone position and the proximal third of the forearm is located on the ulnar bone, we find the extensor carpi ulnaris, the needle is placed inserting it 2mm or until perforating the fascia and 2cc are infiltrated and we perform the same procedure previously described.

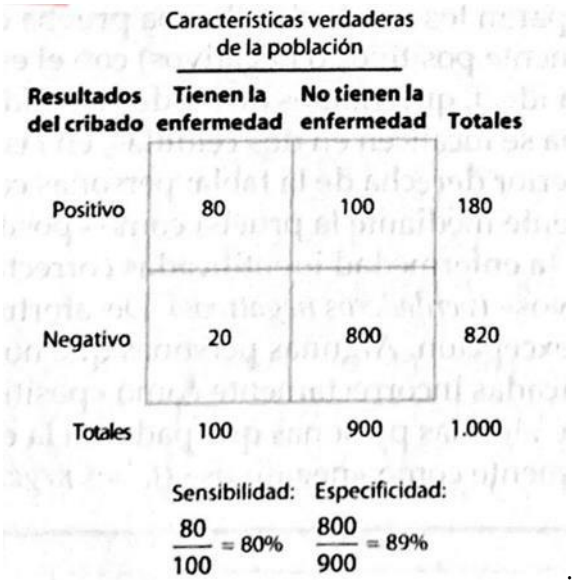
8. The data obtained are recorded on the data collection card and the limb will be covered again with a sterile compress.

9. This procedure should be repeated every 2 hours for 6 hours or else until an infusion pressure equal to or greater than 30mmHg is found.

STATISTICAL DESIGN (DATA ANALYSIS PLAN)

To assess the validity we see that it contains 2 components, sensitivity and specificity, sensitivity being the test to identify patients who have the disease and specificity to those who do not have the disease. To be able to assess this it is necessary to have a test (Gold Standard) which in our case the measurement of intracompartmental pressure, with this we could compare the results of a dichotomous test in order to correctly identify true positives and negatives, as well as false true and negative.

For this reason, the sensitivity and specificity of thermography were assessed by means of a 2x2 contingency table, with the measurement of intra-sharenetal pressure being our gold standard. As we can see in the following image in which the screening test exercise was performed to determine sensitivity and specificity



The formula for obtaining sensitivity is as follows. Sensitivity = VP/(VP+FN)

Where:

VP= True Positive FN= False Negative

The formula for obtaining specificity is as follows. Specificity = VN/(FP+VN)

Where:

VN = True Negative FP = False Positive

ETHICAL IMPLICATIONS

This research study "Validation of thermography for the diagnosis of compartment syndrome in the upper extremities due to electrical burn in patients with altered alertness" in a group of adult patients in the State of Mexico was designed in accordance with the national and international regulations for medical research on human beings embodied in the Declaration of Helsinki of the World Medical Association adopted by the 18th World Medical Assembly. Helsinki, Finland, June 1964 and amended by the 64th General Assembly, Fortaleza, Brazil, October 2013. The General Health Law and the Regulations of the General Health Law on Health Research. In compliance with the above, the researchers related to the project and its execution in Mexico carried out a course on good clinical practices and followed the guidelines of these for the conduct of the research

Considering that the General Health Law establishes in Title Five, Research for Health, Single Chapter, Art.96, numeral III, that research for health includes the development of actions that contribute to the prevention and control of health problems that are considered a priority for the population; In this sense, the ease of being able to make a timely diagnosis, at a low cost and with greater ease feasible due to the high cost of care and complications generated in our country, the objective of this study was to validate the sensitivity and specificity of thermography for the diagnosis of compartment syndrome in patients with altered state of alertness.

In accordance with the requirements of the Regulations of the General Health Law on Health Research, this protocol was submitted for evaluation and opinion by a research ethics committee duly registered with the National Bioethics Commission (CONBIOÉTICA) and the Federal Commission for the Promotion of Research.

Protection against Sanitary Risks (COFEPRIS) and no research activity will be carried out until the approval of both committees is obtained. cThis study is defined as a risk-free investigation, in accordance with Article 17, numeral II of the Regulations of the General Health Law on Health Research "... studies that use retrospective documentary research techniques and methods and those in which no intervention or intentional modification is made in the physiological, psychological, and social variables of the individuals participating in the study, among which are considered: questionnaires, interviews, review of clinical records, and others, in which the patient is not identified or sensitive aspects of his behavior are addressed."

		*Informed consent required			
Risk-free	**X**	**Minimal risk**		**Greater than minimal risk**	

VIII. RESULTS

In the present study carried out in 2023 at the Adolfo López Mateos Medical Center to obtain the sensitivity and specificity of thermography for compartment syndrome secondary to electrical burn, 17 patients were included, whose selection process is shown in Diagram 1.

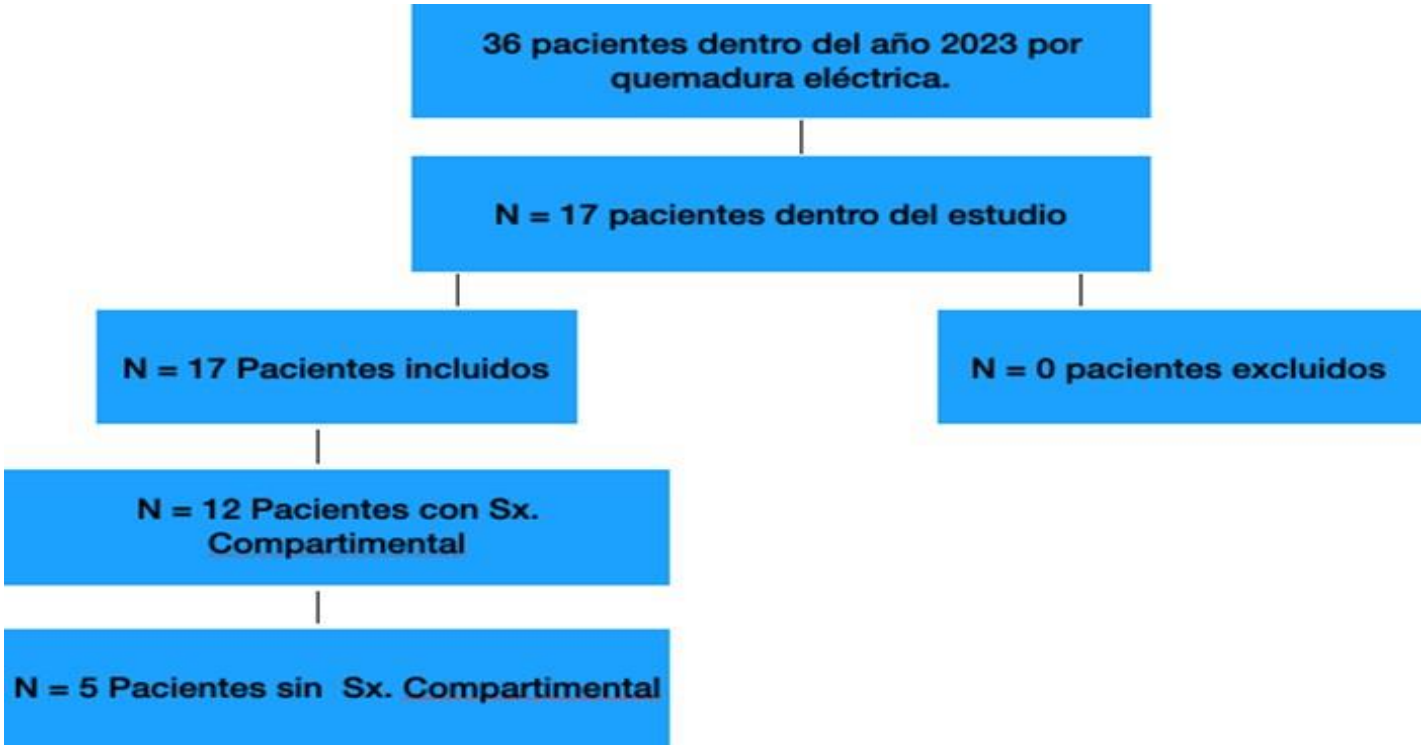


Diagram 1. Selection of the sample in the study.

The mean age of the sample included in the study was 28.4 years, of which 88.2% were men and 11.8% were women, as shown in Figure 2

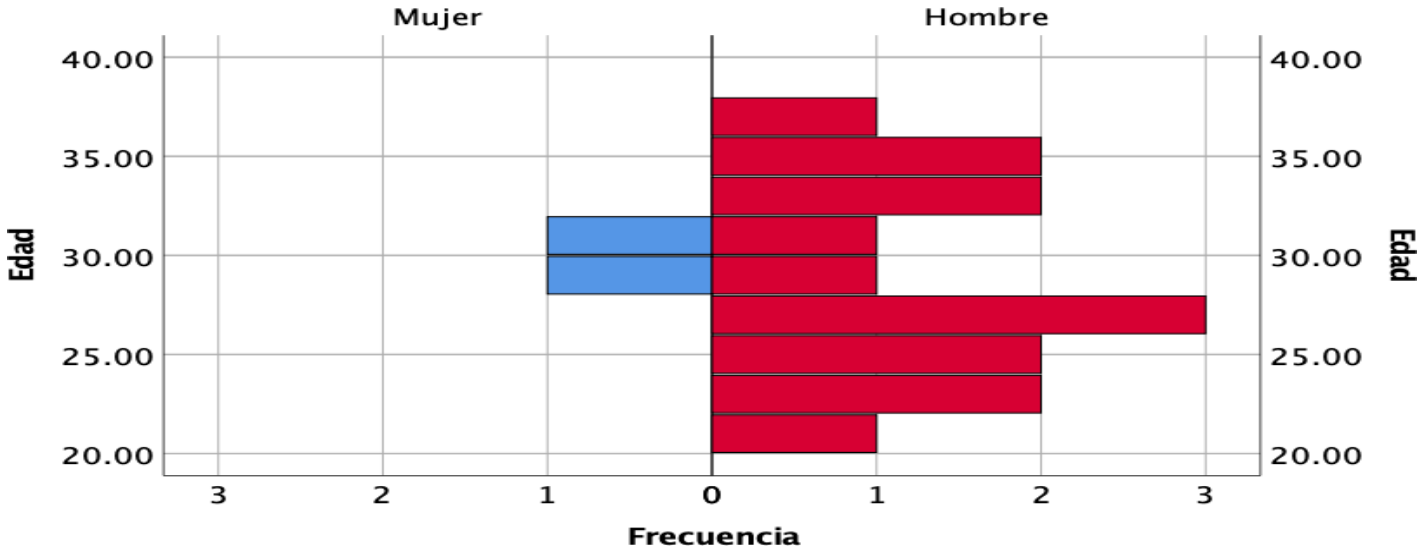


Tabla 1. **Características clínicas de la muestra al inicio del estudio.**

		n	%
Sexo Biológico	Mujer	2	11.8%
	Hombre	15	88.2%
Indice de masa corporal	Bajo peso		0.0%
	Peso normal	10	58.8%
	Sobre peso	5	29.4%
	Obesidad	2	11.8%
patológicos	Ninguno	14	82.4%
	Diabetes Mellitus	1	5.9%
	Hipertensión Arterial	1	5.9%
	Diabetes e Hipertensión	1	5.9%
	Otros		0.0%
Escala Fitzpatrick	Clara Pálida		0.0%
	Blanca Clara		0.0%
	Clara	2	11.8%
	Morena	7	41.2%
	Muy Morena	7	41.2%
	Muy Obscura	1	5.9%
corportal total quemada	30.00	2	11.8%
	34.00	1	5.9%
	35.00	1	5.9%
	38.00	3	17.6%
	40.00	2	11.8%
	42.00	1	5.9%
	44.00	1	5.9%
	45.00	2	11.8%
	50.00	2	11.8%
	52.00	1	5.9%
	56.00	1	5.9%
		Media	Desviación estándar
Edad		28.41	4.62
Reanimación hídrica inicial		1029.41	624.26
Temperatura ambiente incial		28.47	3.22
Temperatura Inical		35.53	.51

In Table 1 we see that we have a higher percentage in male gender being 88.2%, female 11.8%, talking about body mass index

we can see a predominance in normal weight with 58.8% followed by overweight 29.4%. Regarding the pathological personal history, we have 82.4% of healthy patients, followed by 5.9% for patients with diabetes, as well as diabetes and diabetes.

hypertension. For the Fitzpatrick scale we have 41.2% for brown and very brown skin, followed by light skin with 11.8%. Based on the percentage of total body surface area burned, we have a predominance of 17.6% for 38% of SCTQ, followed by 11.8% for 30%, 40%, 45%,

50% SCTQ.

For the initial water resuscitation we have an average of 1029.41ml, we also have a

Initial ambient temperature was 28.47ºC and the patient's temperature was 35.53ºC with a diastolic pressure of 64.71mmHg.

In graph 2 we can see the bar graph in which a fitzpatricks IV and V predominate with 41.18%, for the average initial water resuscitation was 1029.41ml and we see an ambient temperature of 28.47ºC

Tabla 2: Tomas repetidas de presión intracompartimental, termografía, reanimación y temperaturas

Resuscitation 1029.41 □ 624.26 Ambient Temp. 28.47 □ 3.22. Initial Temp. 35.53 □ .51

BASAL	Intracompartmental pressure	C. Previous 21.76 □ 6.96	C. Posterior 20.59 □ 7.16	C. Lateral 21.29 □ 6.61
	Thermography	Distal phalanx 3er finger	Proximal phalanx of the 3rd finger	Centro de la mano
		22.12 □ 3.46	22.47 □ 3.47	24.35 □ 2.71
	Resuscitation 2164.10 □ 646.67	Temp. With. 29.43 □ 2.77	Temp. Cen. 35.31 □ 0.44	
2HORAS	Intracompartmental pressure	C. Previous 24.29 □ 6.17	C. Posterior 23.43 □ 7.04	C. Lateral 24.14 □ 6.20
	Thermography	Falange distal 3rd finger	Proximal phalanx of the 3rd finger	Center of the hand
		21.07 □ 3.25	21.43 □ 3.11	23.86 □ 2.35
	Resuscitation 2796.48 □ 1160.38	Temp. With. 30.33 □ 2.83	Temp. Cen. 35.22 □ .26	
4HORAS	Intracompartmental pressure	C. Previous Lateral 25 □ 5.72 5.23	C. Posterior 25 □ 5.43	C. 25.11 □
	Thermography	Distal phalanx 3er finger	Proximal phalanx of the 3rd finger	Center of the hand
		21.22 □ 3.23	21.22 □ 3.19	23.44 □ 2.83
	Resuscitation 4117.20 □ 1042.39	Temp. With. 30.40 □	4.39	

Intracompartmental pressure obtained by whitside's method.

In Table 2 we can see the standard deviation according to the mean, which according to the basal water resuscitation we have a very high variability due to the high administration of fluids according to the percentage of burns. For the different compartments ranging from 6.61 to 7.16 and for temperature we see an even smaller deviation going from 2.71 to 3.46. We see at 2 hours that we still have a high standard deviation for resuscitation, but for the ambient temperature as the central one decreases being 0.44 to 2.77. Likewise for pressures ranging from 6.17 to 6.20 and temperatures for thermography 2.35 to 3.25. For the 4 hours we see a high standard deviation for resuscitation of 1160.38 but for the temperatures we see that it goes from .26 to 2.83 as well as the intracompartmental pressures having a narrower variability curve from 5.23 to 5.72, likewise for thermography going from 2.83 to 3.23 and for the 6 hours we can see in the same way a high standard deviation for resuscitation of 1042.39 but thus decreasing for the Temperatures being .27 for the plant and 4.39 for the environmental, for the intracompartmental pressure measurements we see a narrower curve which goes from 2.17 to 2.30 the same pattern is respected for the thermography that goes from .80 to 1.14. We can see that as time goes by, the standard deviation or variability curve gets narrower.

We began to describe those who underwent the procedure, noting that our mean at the beginning was 24.17 with a standard deviation of 5.72 compared to those who were not 16.00 with a standard deviation of 5.52 we see that temperatures, for example, ambient temperature, we see that it is 3.22 and for the central temperature it is .51, having a very low variability. For intracompartmental pressures we see a very constant variability or standard deviation between the in the different compartments we have a difference of □ 1 for both patients who underwent dermoasciotomy and those who did not. Likewise, if we analyze the pressure measurement at 2 hours for patients who underwent the procedure, we see that the pressure increases and reduces the standard deviation, in this case we see a pressure difference between compartments of less than 1mmHg, for patients who did not undergo dermoasciotomy, we have an increase in pressure, the highest being 18.6 with a standard deviation of □ 4.67. For the 4 hours we see in the case of patients who underwent dermochasciotomies the narrowest standard deviation curve reaching a minimum of .58 and a higher mean pressure of 30.75 □ .25 mmHg further reducing compared to the previous ones. For patients who did not undergo dermoasciotomy, we see an increase in intracompartmental pressure to 21 □ .60, in this case the standard deviation curve is further reduced to 1.67 as a minimum, and 2.07 maximum. Finally, for the 6 hours we have only patients who did not present compartment syndrome in whom we see a decrease in compartment pressure of approximately 2mmHg, reducing the risk of compartment syndrome, we have in these patients a standard deviation of 2.17 as a minimum and 2.30 as a maximum. Also noticing a reduction in the curve.

Tabla 4. Toma repetida de temper

Tabla 4. Toma repetida de temperatura con o sin síndrome compartimental

Thermography	Dermofasciotomy			
	Yes		no	
	Media	Standard deviation	Media	Standard deviation
3rd distal phalanx thermography finger	21.00	3.16	24.80	2.77
Proximal phalanx thermography 3rd finger	21.33	3.26	25.20	2.39
Initial thermography center of the hand	23.42	2.47	26.60	1.95
2-hour phalanx thermography distal 3rd finger	19.22	2.28	24.40	1.52
2-hour phalanx thermography Proximal 3rd finger	19.78	2.44	24.40	1.52
Thermography 2 hours center of the hand	22.44	1.42	26.40	1.14
distal 3ª dedo	18.00	.82	23.80	1.30
Termografía 4 horas falange Proximal 3ª dedo	18.00	.82	23.80	1.10
Termografía 4 horas centro de la mano	20.50	.58	25.80	.45
Termografía 6 horas falange distal 3ª dedo	.	.	25.60	1.14
Termografía 6 horas falange Proximal 3ª dedo	.	.	25.80	1.10
Termografía 6 horas centro de la mano	.	.	27.20	.84

Table 4 shows that among the patients who underwent dermoasciotomies, there was a significant decrease in temperature at each intake, both by segment and by hours in the distal phalanx, and we see the lowest temperature in the case of the initial one is 21ºC with a standard deviation of □

3.16 The highest temperature was recorded in the center of the hand, being 23.42 with a standard deviation of □ 2.47, in this case for patients who did not undergo dermoasciotomy we see a higher temperature of 24.8ºC for the distal phalanx with a standard deviation of 2.77 and for the center of the hand of 26ºC □ 1.95. For the temperature taken at 2 hours in the patients who underwent the procedure, we see a decrease in temperature of 1º on average, having the minimum for the distal phalanx of 19.22 □ 2.28 and the highest in the center of the hand of 22.44 □ 1.42, in the same way we noticed a decrease in temperature for patients who did not undergo dermoasciotomy, but less than 1º, even less than the procedure group. We notice that in both the standard deviation becomes narrower. In the case of the 4 hours for the group that underwent dermoasciotomy we see a minimum temperature of 18.00 for the distal and proximal phalanx with a standard deviation of .82 for the center of the hand the temperature reduced to 20 □ .58, for the group that did not undergo dermoasciotomy we see that the temperature continues to decrease reaching the minimum 23.8 for the distal and middle phalanx with a standard deviation of 1.3 and 1.10 respectively for the center of the hand we have 25.8 □ .45 although it decreases according to its control we see

that it does not decrease as much as the group that undergoes dermochasciotomies and finally for 6 hours we noticed an improvement in the temperature of the patients presenting 25.6 □ 1.14 for the distal phalanx, 25.80 □ 1.10 and 27.20 □ .84 for the center of the hand in which we see narrowing for the curve in standard deviation.

Tabla 5. Toma repetida de temperatura ambiente y central del paciente con y sin síndrome compartimental

TABLE 5

	Compartment syndrome			
	Yes		No	
	Media	Desviación estándar	Media	Desviación estándar
Temperatura ambiente Initial	29.00	2.98	27.20	3.77
Temperatura Inical	35.33	.33	36.00	.61
Temperatura ambiente 2 hours	29.78	2.86	28.80	2.77
Temperatura central 2 horas	35.14	.27	35.60	.55
Temperatura ambiente 4 hours	30.50	1.73	30.20	3.70
Temperatura central 4 horas	35.13	.25	35.30	.27
Temperatura ambiente 6 hours	.	.	30.40	4.39
Temperatura central 6 horas	.	.	35.30	.27

The temperature was determined with a Flir one Pro thermographic camera, a unit of measurement in degrees Celsius.

Table 5 assesses the mean and standard deviation of the ambient temperature as the central thermoture of our patients. We noticed that the baseline ambient temperature has a more important variation than the rest of them, having in patients who underwent dermoasciotomy a mean of 29 □ 2.98 and in those who did not undergo a procedure of 27.1 □ 3.77 for the patient's temperature we have 35.33 □ .33 in those who underwent a procedure and in those who did not have 36 □ .61 which we noticed less than 1ºC for the 2 hours we have an ambient temperature closer to the average in both groups with a variation a little more than 1ºC and for the measurement of the core temperature we have 35.14 □ .27 for the first group and 35.6 □ .55 having a variation of less than .5ºC thus reducing the standard deviation gaps, likewise for the 4 hours we see an ambient temperature of 30.5 □ 1.73 for the first group and 30.20 □ 3.70 for the second group with a core temperature of 35.13 □ .25 and the second group with a core temperature of 35.30 □ .27 in which we see a difference of .17ºC as the last for the 6 hours we see in the

The group that did not undergo dermoasciotomies at an ambient temperature of 30.4 □ 4.39 and central temperature of 35.3 □ .27 In general, we see a variation in the minimum core temperature between each group and hour according to the average of each.

Table 6. 2x2 Contingency Table

		Compartment syndrome		
		Present	Absent	
Temperature obtained by thermography 16ºC ± 1ºC	Present	7	0	7
	Absent	5	5	10
		12	5	Total = 17

Tabla 6.1 Descripción de tabla 2x2

A = 7	Patients with thermography < 17°C **with** compartment syndrome
B = 0	Patients with thermography < 17°C **without** compartment syndrome
C = 5	Patients with thermography >17°C **with** compartment syndrome
D = 5	Patients with thermography >17°C **without** compartment syndrome

In Table 6.1 we explain the 2x2 contingency table presented in Table 6, for which we will use the temperature of 16 ±1ºC as a screening for the diagnosis of compartment syndrome. we have 7 patients of which they have a temperature of 16 ±1ºC and we reach the diagnosis of compartment syndrome, we place them in the box "A" likewise, we have 4 patients of whom we reach a temperature of 18ºC and we obtained a diagnosis of compartment syndrome with intracompartmental measurement, as well as 1 patient withtemperature of 19ºC and diagnosis of compartment syndrome, being 5 in total, which we placed in box "C", for box "B" we do not have patients since none of them presented a temperature of 17ºC without presenting compartment syndrome and in box "D" we have 5 patients who did not present compartment syndrome with temperature greater than 17ºC

.

Sensitivity

= (A)/(A+C) (7)/(12) = 0.58

Specificity

= (D)/(B+D) (5)/(5+0) = 1

We see the formula used to obtain the sensitivity, in this case it is the result of the "A" box between the result of the "A" plus "C" box, obtaining a sensitivity of 58.3%

We see the formula used to obtain the specificity in this case would be the result of the
"D" between the result of the "B" plus "D" box obtaining a specificity of 100%

Positive Predictive Value		Negative Predictive Value	
= (A)/(A+B)	(7)/(7+0) = 1	= (D)/(C+D)	(5)/(5+5) = 0.5

We use the formula to obtain the Positive Predictive Value in which the result of the box "A" is obtained by the result of the "A" box plus "B" obtaining a positive Predictive Value of 100%

We use the formula to obtain the Negative Predictive Value in which the result of the "D" box is obtained by the result of the "C" plus "D" box, thus obtaining a negative Predictive Value of 50%

WITH THIS WE CAN OBTAIN THE PREVALENCE BEING 70.58% AS WELL AS THE INCIDENCE OF THE STUDY BEING 7 OUT OF 10 OR 70 OUT OF 100.

DISCUSSION

The incidence of patients due to electrical burns is high in our state, as reported in the literature. (21). We see in the present study that in 2023 we presented 36 patients with this condition, not all of them presented compartment syndrome, but we do see a high incidence this only in our hospital, not counting referral hospitals for burns. (14)

Compartment syndrome secondary to electrical burn occurs mainly in males as referred to in the articles, this is due to the labor issue since our patients present, consequently we see that the average age of the patients is an active productive age, presenting in the studies an average of 25 to 44 years, surpassing by a significant percentage the rest of the ages, In our study we see an average of 28 years having patients from 18 to 74 years old. For work activities, we see a predisposition for masons, mostly followed by painters, who are the most affected. (14)

During their recovery, the patients were asked the reason or cause and we noticed that 100% of them did not have the safety equipment, the vast majority due to discomfort and the rest due to ignorance, being a preventable cause (4)

In the case of our patients, BMI did not influence since the patients were of normal weight, the vast majority of whom were 10 and overweight 5 patients, as explained in the literature, without presenting any important difference, in the same way we can see it with the history of importance in the case of presenting diabetes mellitus, we cannot see in this study a significant difference since we have only 2 patients, For the Fitzpatrick scale, we found that we have an average for brown and very brown skin, having 7 patients of each, without presenting a significant difference because they are within the same percentage of skin tone (11)

In the case of patients who have a higher percentage of total body surface area burned, despite being patients with a diagnosis of severe burning, we present a higher severity index, but a conclusion cannot be reached since there are few patients and several aspects such as the amount of exposure time, the amount of voltage, and among others, have an influence. But of those who did not undergo dermoasciotomy, we have a surface area greater than 42% and a surface area of less than 30%. (10)

For all patients we have an increase in temperature as well as intracompartmental pressure at 4 hours after the start of the study, even for patients who did not present compartment syndrome. Fluid resuscitation was the same for all patients during the first 8 hours of the incident, the ambient temperature remained at an average of 29ºC □ 2ºC without being significant according to the studies, in the same way we noticed an average body temperature of 35.5 □ .5ºC without becoming significant for any variation in the thermography. Comments (21)

For patients who presented compartment syndrome, we noted a thermography temperature less for the distal phalanx, followed by the proximal phalanx and then the center of the hand, although as the intracompartmental pressure increases, the temperature decreases sequentially. (17,28) For intracompartmental pressure, we observed a greater increase in pressure for the anterior compartment, and this is not statistically significant, as described in our literature (11).

In patients who did not present compartment syndrome, we noticed the same incidences as in those who did, with the difference that after 6 hours they presented a notable improvement and decrease in pressure, as well as an increase in temperature by thermography at the different points. The 4 hours were the peak of the highest prevalence for intracompartmental pressure and lower temperature. (17,28)

We can see that we obtained from the study a sensitivity of 58% in which it results in that percentage to detect the disease and a specificity of 100% resulting for patients who do not have disease, summarizing we can trust the method to rule out patients with compartment syndrome but it is not so sensitive to diagnose it as such, We previously mentioned that the sample is small, being an important factor that can alter its sensitivity, we also obtained a positive predictive value of 100% and a negative predictive value of 50%, presenting an incidence of 7 out of 10 and a prevalence of 70.8% (17,18)

CONCLUSION

1.- The temperature of 17 patients was taken in the distal and proximal phalanx of the 3rd finger, as well as in the palm of the hand of the patients who presented the inclusion criteria. A baseline thermography was taken and then every 2 hours until 6 hours were completed or the diagnosis of intracompartmental syndrome was presented. We noticed a continuous decrease as the intracompartmental pressure increased, as well as a lower temperature in the distal phalanx, a little higher in the proximal phalanx and higher in the palm of the hand, we see that in the patients who presented compartment syndrome the temperature was 17ºC mostly followed by 18ºC.

2.- The pressure of the anterior, lateral and posterior compartments of the affected forearm was recorded by the whiteside method in patients who presented the inclusion criteria. We were able to obtain a constant pressure with a variation of 2mmHg between each compartment and being the previous one the one with the highest pressure compared to the rest of the compartments, we took as a cohort method a perfusion pressure or delta pressure of 30mmHg, this is obtained by taking the intracompartmental pressure and subtracting it from the diastolic pressure of the patient.

3.- For the whitside method, we note that the main complications we will have are the difficulty in placing what is necessary at the patient's level, since it is necessary to have at least 2 operators to correctly perform the measurement, mainly because the patient cannot support because an inclusion criterion is that the patient presents alteration in alertness. Another difficulty arises when assembling the whitside method, as it is common for it to leak if the assembly is not carried out correctly.

For the thermographic method, the main complication we found was the placement of the limb in a correct position for taking the temperature, for the use of the camera no complications were found.

4.- With the results obtained in the present study, we found that the incidence was 7 in 10 patients, that is, 70.58%.

5.- Analyzing the results of the study, we conclude that the sensitivity of the thermographic method is 58%, with a specificity of 100%, presenting a positive predictive value of 100% and a negative predictive value of 0.50 (50%), with the detailed analysis of the results, it is believed that we can use this method as a complement to the clinical clinic of the patients, as well as to other diagnostic methods in patients who present compartment syndrome, since we see a decrease in the As the intracompartmental pressure of the patients

increases, by doing this we can increase the evidence obtaining more patients and make this method more reliable.

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