Properties and Types of Significant Thermal Skin Burn Injuries

Risk of Significant Injury (RSI) Implementation Guidance
February 2018

Purpose

The purpose of this RSI Implementation Guidance is to define the properties and types of thermal skin burns that should be used to classify injuries as significant or not significant. The types, properties, and classification of significance of thermal skin burns described in this document are relevant to all non-lethal weapon (NLW) systems capable of causing these types of injuries.

An overly conservative estimation of RSI can add cost, schedule, and performance risks to a system development program. The intent of this work is aimed at supporting the development of an RSI estimation framework that is as accurate as possible given the available data. However, when definitive data sets are lacking, erring on the side that most people would agree is a conservative estimate for RSI allows for the establishment of methodologies and models that can make a verifiable, valid, and quantitative statement such as "the RSI of this system does not exceed X%."

Background

DoD policy (DoDD 3000.03E) states that NLWs are "developed and used with the intent to minimize the probability of producing fatalities, significant or permanent injuries, or undesired damage to materiel, but do not, and are not intended to, eliminate risk of those actions entirely." While NLWs are intended to produce reversible effects, reversibility is not required. The RSI for any given weapon shall be identified by the combat developer to assist in materiel development and enable force commanders to understand the potential risks associated with the use of specific NLWs. Characterization of the human effects resulting from NLW use shall be conducted during the materiel development process to assess the likelihood of achieving the desired effect(s) and to identify the RSI for counter-personnel systems, as well as the RSI for collateral damage to humans from counter-materiel systems.

RSI is a metric intended to evaluate the risk of a NLW (when functioning properly and employed as intended) causing permanent injury. RSI is associated with the acceptable (yet still unintended) level of non-reversibility for counter-personnel systems. For example, if the RSI of a particular NLW, device, or munition is assigned an RSI of 10%, there is a 10% probability that the target may sustain a permanent injury preventing the target from returning to his or her pre-engagement functionality.

Non-reversibility, applied to humans, is fundamentally a measure of permanent injury[1] which is defined in terms of the physical damage that restricts the employment or other activities of the person for the rest of his or her life. Many injuries can be successfully treated with advanced medical care either by preventing permanently disabling outcomes from occurring or by mitigating the impact of permanently damaged tissue or structures.[2] Therefore, the probability that an injury caused by a NLW will result in a permanently (i.e. non-reversible) disabling outcome depends on the level of medical treatment assumed. DoDI 3200.19 states that injuries that cannot be treated with limited first responder care (LFRC), presumably to prevent a permanently disabling outcome, are considered "significant." In other

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[1] Injuries that result in death represent the extreme end of "permanent injury" but nonetheless, death as an outcome fits entirely within the definition of permanent injury. That is, injuries that result in death are considered permanent injuries.

[2] Examples of treatment that mitigates the impact of rather than preventing a permanent injury include hearing aids, prosthetics, and/or corrective surgical interventions.

words, RSI is the likelihood (i.e. probability) that a NLW system will cause a permanent injury (physical damage to a person that permanently impairs physiological function and restricts the employment or other activities of that person for the rest of his or her life) assuming only LFRC level of treatment (self-aid, buddy-aid, combat lifesaver skills).

Rather than being strictly prescriptive, RSI Implementation Guidance documents like this one are intended to provide the DoD NLW community with relevant, peer-reviewed, RSI-focused human effects analysis to incorporate into developmental NLW efforts. These documents are consistent with the policy guidance in DoDI 3200.19 and can be assumed to represent a best practice for the particular topic covered.

Probability of Significant Injury Given an Injury Occurred, P(SI|IO)

Expressed as a percentage, RSI can be written as the product of two separate conditional probabilities as stated in Equation 1,

Eq. (1)
$$RSI = P(IO) * P(SI|IO)$$

where $P(IO)$ is the probability that an injury will occur and $P(SI|IO)$ is the conditional probability of significant injury, given it occurred. The purpose of this Implementation Guidance is not to define the probability of an injury occurring. Instead, this document addresses the probability of significance given the injury occurred, the $P(SI|IO)$ term of the RSI equation. However, the available data is limited and relevant data sets are not easily developed via experimentation; therefore assumptions must be made. In all cases where assumptions are made for this Implementation Guidance, the more conservative estimate is used, in this case meaning to err in the direction of estimating more injuries than will actually occur, as stated in Equation 2.

Eq. (2)
$$P(SI|IO)_{estimated} > P(SI|IO)_{actual}$$

For thermal skin burns, as will be discussed further below, the acute injury is actually related to the disabling outcome via complications that can occur given certain burn injury attributes. In that case, Equation (1) can be expanded further as stated in Equation 3.

Eq. (3)
$$RSI = P(IO) * P(Complication|IO) * P(SI|Complication)$$

where $P(Complication|IO)$ is the probability of a complication given that an injury occurred and $P(SI|Complication)$ is the probability of a significant injury, i.e. one that is permanently disabling, given the complication. Consistent with DoDI 3200.19, both $P(Complication|IO)$ and $P(SI|Complication)$ are assumed to be the probabilities provided treatment no greater than LFRC.

The Significance of Thermal Skin Burns

Complications associated with thermal skin burns injuries have the potential to ultimately lead to serious medical outcomes. Expanded upon further in the paragraphs that follow, the severity and likelihood of such complications can be linked to burn injury category (depth and corresponding degree of burn injury), the total body surface area affected, and the anatomical location. The skin has three main functions: protection, regulation, and sensation. It acts as the body's first defense against infection and provides protection from mechanical impacts. The skin regulates body temperature, changes in peripheral circulation, and fluid balance. The skin also contains extensive innervation that transmits various environmental sensations such as temperature. Complications following a burn injury arise from the body’s vulnerabilities during the healing process: localized infection, sepsis, hypovolemia, hypothermia, increased metabolic rate, shock, and scar contracture. Given only LFRC treatment, death or permanent organ failure may result.

Table 1: Thermal Skin Burn Injury Complications

COMPLICATION	DESCRIPTION
Infection and sepsis	Open wounds can lead bacterial infections. Severe infection can lead to sepsis, an infection in the bloodstream that affects the entire body which can result in shock and organ failure.
Hypovolemia	Burns causing damage to large portions of blood vessels result in low blood volume. If there is enough blood loss, the body is unable to pump blood throughout the entire body. Other factors contributing to hypovolemic conditions include upregulation of inflammatory mediators and proapoptotic factors.
Hypothermia	Destruction of skin layers interferes with the body’s ability to regulate temperature causing an inability to regulate and maintain body heat.
Hypermetabolism	The metabolic rate increases proportionally to the increase in burn size. Large burns impact the immunity and fluid levels of an individual.
Shock	Destruction of skin layers results in loss of fluid and internal fluid circulation.
Contracture & scar tissue formation	Fibrous, thick scar tissue formation leading to deformities that severely impacts range of motion across joint areas. May permanently pull joints out of position. Often accompanied by debilitating levels of chronic pain.
Loss of sensation; nerve damage	Destruction of deeper tissues can lead to permanent nerve damage and loss of sensation.

After full physiological healing takes place, the threat of many of the above complications is diminished. However, damage to nerves and scarring secondary to burns occurs in virtually all deep burn cases (Dunne & Rawlins, 2014; Hemington-Gorse et al., 2007; Jeschke et al., 2013). Scar contracture and nerve damage may contribute and/or cause various sequelae such as reduced range of motion (ROM) from scar tissue formation and impaired function to include loss of sensation and impaired balance (Leblebici et al., 2006; Schneider et al., 2008). This can result in a permanent disability or long-term complication with or without medical treatment intervention methods beyond LFRC.

Though thermal skin burn injuries may be permanent in the sense that there is scarring or they result in persistent redness or discoloration, they may not always result in a life-long disabling injury and therefore would not always be considered a significant injury. Thermal skin burn injuries should be considered significant, as defined within DoDI 3200.19, when the administration of treatment no greater than LFRC results in either:

1) Death or permanent organ failure
2) Loss of range of motion
3) Loss of function

Injuries that are recoverable with only LFRC treatment and do not affect range of motion or impair function would not result in permanent disabilities that restrict "the employment or other activities of that person for the rest of his or her life" (DoDI 3200.19). As will be discussed, the significance of thermal skin burn injuries is dependent on the severity, extent, and location of the injury.

Severity: Medical Categorization of Skin Burns

In the medical and scientific literature, thermal skin burns are often categorized as superficial burns and deep burns. Table 2 below details these burn categories. The superficial burn category includes first-degree and superficial second-degree burns. The deep burn category includes deep second, deep third and deep fourth-degree burns.

Table 2: Burn Classification and Injury Outcome (Rice & Orgill, 2015; The University of New Mexico; United States Department of Health and Human Services, 2011)

Burn Category	Burn Degree	Thickness	Skin Layer Involved	Injury Healing Outcome
Superficial	1st Degree	Superficial/epidermal	▪ Epidermis	▪ Damage only to outermost skin layer ▪ No blister ▪ Dry, red, painful ▪ Blanches with pressure (similar to sunburn) ▪ Generally heals within 6 days without scarring
	Superficial 2nd Degree	(Superficial) Partial Thickness	▪ Epidermis ▪ Portions of the dermis	▪ Damage to entire epidermis and upper third of dermis ▪ Painful, red, weeping ▪ Blanches with pressure ▪ Generally heals in 7-21 days ▪ Scarring unusual
Deep	Deep 2nd Degree/3rd Degree	(Deep) Partial Thickness	▪ Epidermis ▪ Dermis (deeper) including hair follicles and glandular tissue	▪ Damage to entire epidermis and most of the dermis ▪ Painful to pressure only ▪ Almost always blisters ▪ Wet or waxy ▪ Dry ▪ Variable mottled colorization ▪ Heals in 3-9 weeks if no infection present ▪ Causes hypertrophic scarring ▪ Joint involvement typically yields dysfunction
	3rd Degree	Full thickness	▪ Epidermis, dermis (all layers) ▪ Subcutaneous tissue	▪ Entire dermis destroyed ▪ No to low pain due to nerve destruction ▪ Waxy white to leathery gray to charred black skin ▪ Dry inelastic skin ▪ Does not blanch with pressure ▪ No blisters ▪ Without surgery wounds heal by contracture and severe scarring ▪ Complete spontaneous healing not possible; requires specialized care
	4th Degree	4th Degree	▪ Extends through skin into underlying tissues such as fascia,	▪ Extends into muscle, tendon, or bone ▪ Appears severe ▪ Without surgery wounds heal by contracture and severe scarring

			muscle, tendon, and/or bone	▪ Complete spontaneous healing not possible; requires specialized care

Burn injury severity is tied to burn depth and more specifically, underlying tissue damage. In this way, burn depth is a predictor of healing potential and final outcome. The superficial burn category relates to burn injuries affecting the epidermis down to the upper layers of the dermis. Superficial burn injuries generally heal on their own with minimal, if any, scarring.

The deep burn category involves damage to deeper dermal layers (to include hair follicles and glandular tissue), subcutaneous tissue, and extends beneath the skin into underlying fascia, muscle, tendon and/or bone. Deep burns result in hypertrophic scarring and contracture. Contracture scars can affect muscles and nerves and as discussed later, range of motion may be impacted. For the purposes of this document, a deep 2nd degree burn is defined as a burn affecting ≥50% the dermis.

Extent – Total Body Surface Area (TBSA):
The rule of nines is an assessment tool used to estimate the body surface area of the burn injury to the skin, expressed as a percentage of total body surface area. In this approach, the body is divided into sections of multiples of 9%. To apply the rule of nines, all areas of the body sustaining second-degree, third-degree and fourth-degree burns are added together and linked to treatment recommendations.

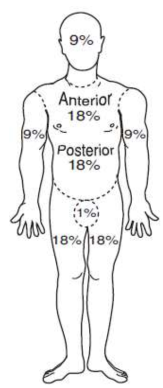


Figure 1: Rule of Nines Showing Distribution of Body Surface Area for Adult[3] (The Office of the Surgeon General Borden Institute, 2013)

As in burn depth, the extent of burn injury is a critical factor in predicting final outcome (Helm & Walker, 1992; Dunn & Rawlins, 2014; Fauerbach et al., 2001, Dyster-Aas et al, 2007). Widespread burns can lead to the complications outlined above. Due to the correlation between a larger TBSA and an increased likelihood for complications (to include fatality), $P(Complication|IO)$, the American Burn Association (ABA) and others recommends treatment beyond LFRC for partial thickness and full thickness burns covering a TBSA greater than 10% (American Burn Association, 2006a & 2006b; Committee on Trauma, American College of Surgeons, 2014; Hettiaratchy & Papini, 2004).

Location

[3] Figure 1 represents surface area percentages as applied to an adult. A separate tool, the Lund and Browder chart, is useful when making age-adjusted estimates of relative body surface area in children (Hettiaratchy & Papini, 2004; Bertin-Maghit, et al, 2000).

Disabling burn injury outcomes can also be linked to anatomical location. Burns to sensitive areas of the face, hands, feet, and genitalia increase the likelihood that a burn injury will result in disability. As discussed above, the extent of burn severity is tied to the underlying skin tissue layer that sustains damage. The absolute thickness of the different skin tissue layers varies across the human body. For instance, the epidermal layer on the soles of the feet measures approximately 1.5 mm in thickness, while the epidermal layer of the face, specifically the eyelid, measures approximately 0.05 mm (Whitton & Everall, 1973; Ha et al., 2005). The dermal thickness also varies depending on anatomical location: approximately 3mm thick on the soles of feet compared to 0.6mm on the eyelids (Burns et al., 2004).

Due to variability of skin thickness and to the various contours across the body not all areas, given equal thermal exposure, will result in uniform burn severity. This is an important consideration as certain areas of the body, when coupled with severity, are more susceptible to injury as thinner skin layers are destroyed more quickly. This can lead to an increase in burn injury complications. Thus, no absolute depth measurement, e.g. in millimeters, for injury significance can be defined.

In the same way, certain areas of the body, when coupled with severity, are more susceptible to scarring and contracture complications, limiting mobility and leading to potentially disabling disfigurement and loss of function. (Leblebici et al., 2006; Schneider et al., 2008). The ABA recommends referral to a burn center, patients with burns covering hands, feet, genitalia, or major joint areas (ABA, 2006b). Literature sources recommend deep partial thickness burn injuries to areas of the body requiring flexibility and mobility to enable motor function activities undergo skin grafting and excision to minimize a loss in functionality due to contracture formation (Alsbjörn, et al., 2007; Dunne & Rawlins, 2014; Jeschke et al., 2013).

Burns can give rise to large areas of scarring which can greatly influence quality of life (Stella et al., 2008). Scar tissue is dense, fibrous tissue that binds up and ties down tissue needed for free movement. As skin heals from a deep tissue burn it can tighten causing the surrounding skin to pull together, resulting in what is known as a burn scar contracture. As scar tissue builds up, muscles become shorter and weaker. Tension on tendons causes tendinosis and can cause nerves to become trapped. As a result, range of motion can be reduced along with loss of strength, chronic pain, tingling, and numbness. Schnieder et al. also found that, along with pain and other factors, contracture scars can contribute to reduction in ability to maintain balance (Schneider et al., 2011).

The most virulent scarring tends to occur in deep dermal burns that heal spontaneously over the course of three or more weeks, particularly in highly elastic skin (Harrison & MacNeil, 2008). For the purposes of this document we assume spontaneous healing would be associated with limited first responder care level of treatment.

Hands and Feet

Moore et al. sums up the risk of burns to the hand:

"The thin, highly mobile dorsal skin, the sensory-enriched palmer skin, and the delicately balanced musculotendinous systems are all at risk with a hand burn… The resulting loss of function from burns that include or are specific to the hands can have a devastating effect on numerous life roles of the patient at any age." (Moore et al., 2009) Further, although hands only account for approximately 3% of the total body surface area, deep burns to the hand can be associated with higher post-burn unemployment even with specialized care (Fauerbach et al., 2001). Kowalske reports that burns to the hand are a leading cause of impairment (Kowalske et al., 2007).

Similarly, deep burns to the feet can be associated loss of foot function, joint deformities, and post-burn contracture deformities (Shakirov 2011). Hemington-Gorse et al. reports that infection and hypertrophic scarring can occur with deep partial and full thickness burns to the feet (Hemington-Gorse et al., 2007).

Major Joints

Contracture scar tissue formation due to deep thermal burns on major joints, including the shoulder, elbow, neck, wrist, ankle, knee and hip, can lead to reduced range of motion and loss of strength. Leblebici et al. found that joint scar contracture resulted in significantly lower scores on a quality of life questionnaire for burn injury survivors (Leblebici et al. 2006). Richard et al. found that "the relative location of the burn wound to a joint and its associated skin crease is an important factor related to rehabilitation efforts" (Richard et al. 2009). To reduce scar contracture formation, surgical strategies are often implemented.

Areas Around the Mouth

The morphology of the skin around the mouth makes this area particularly vulnerable for resulting in disabling outcomes from burn injuries. As with major joints, the skin around the mouth is needed for proper movement and functioning. Burn scar contractures can lead to reductions in the range of motion of the mouth and can lead to loss of function of the lips to properly articulate sound and speech. Loss of range of motion in the skin around the mouth can also affect a person's ability to eat and express emotions (Clayton et al., 2015).

Areas Around the Eyes

Properly functioning eyelids are critical for protecting the eye. Burn scar contracture in the skin around the eye can lead to eyelid ectropion, where the lower eyelid turns outwards, and lagophthalmos which refers to the lack of ability to fully close the eyelid. This loss of the range of motion around the eye can prevent proper eye lubrication and increase the likelihood of infection and corneal scars. For this reason deep partial-thickness (or worse) burns around the eye and the eyelid region often necessitate "early surgery for contraction and eyelid retraction" (Malhotra et al., 2009). Even with skin grafting, this area is particularly difficult to successful treat (Mandrekas et al., 2002 & Kostakoglu et al., 1999).

Genitalia and Perineum

Burns to the genitalia and perineum are comparatively rare because this area is anatomically well-protected. Most cases involve chemical burns or scalding. However, although rare, when burns do occur, particular care has to be taken to prevent infection. As Michielsen et al. reports, "(b)urns to the genitals and perineum are frequently exposed to fecal contamination. This includes a risk of infection, which might result in sepsis, delayed wound healing and graft loss" (Michielsen et al., 2010). 3rd and 4th degree burns are likely significant anywhere on the body, but due to the increased risk of infection, deep 2nd degree burns to this area require extra care to prevent them from turning into, via infection, full thickness wounds (Rutan, 1993).

Standard of Care as a Surrogate for P(SI)

As shown in Equation 3, the RSI for a burn injury can be expressed as the product of the probabilities of injury occurrence, complication occurring given the injury, and disabling outcome given the occurrence of the complication, all assuming only LFRC level of treatment. Ideally, to calculate RSI we would access epidemiological data sets that include a cohort that received only a LFRC-like treatment. Given such data, we could then extract the relevant frequencies of a complication given certain burn attributes and outcomes given the complication occurred; or even more directly, the frequency of disabling outcomes given a burn. However, although there is a not a lack of epidemiological data in the medical and scientific literature, to our knowledge there is no available data set that neatly fits our requirements. This is perhaps not too surprising given the critical complications that burn injuries can cause. As such, there is a lack of data on the efficacy of LFRC-type treatment with respect to burns of varying severity and TBSA. Presumably, burn victims that would (or could) be reported on in the medical literature are those that seek treatment in a medical facility where they will likely receive beyond LFRC-type treatment. So where we may be able to get data on the probability of a disability for various burn injury attributes given hospital-level treatment, we are not able to extrapolate to the outcome given LFRC. We can be somewhat confident that LFRC treatment will result in a worse outcome statistically - why else go to a hospital - but how much worse it will be quantitatively, is unknown.

To make estimates for the actual expected rate of significant injury for burn injuries, we will have to use an indirect method. There is information in the medical literature and in guidelines established by interest organizations like the American Burn Association that define the attributes of a burn injury where certain medical interventions would be recommended. By summarizing this information we can define a standard of care based on the burn attributes and then use this as surrogate predictor of significance in place of the actual conditional probabilities that do not seem to exist in the literature. The explicit assumption here is that if the attributes of the burn injury are such that the standard of care would go beyond that which can be provided by LFRC, then

$$P(Complication|IO) * P(SI|Complication) = 100\%.$$

Conversely if the standard of care for the burn injury is in line with what can be provided with LFRC then the injury will never be significant.

$$P(Complication|IO) * P(SI|Complication) = 0\%.$$

Standard of care will be used in the following section as a surrogate for "significance" for some of the burn attribute categories. However, we are careful not to directly adopt standard of care recommendations that may be primarily diagnostic in nature. In those cases, we go a step further and try to map the injury attributes more directly to the disabling outcomes listed in the "The Significance of Thermal Skin Burns" section of this paper.

Attributes of Significant Burn Injuries

Table 2 consolidated some of the ways burn severity is categorized in the medical literature. However, terms like "superficial", "superficial partial thickness", and "deep partial thickness" are not used in a consistent manner and are not always clearly mapped to terms like "1st degree burn" or "2nd degree burn". This fact makes it difficult to utilize multiple sources for "standard of care" recommendations and to be able to compare any similarities or differences. It does seem clear, though, that injury outcome predictions considering injury severity are related to the depth of damage relative to skin layer structure. For the purposes of this section we define:

1. 1st degree - burns with damage limited to the epidermis;
2. Superficial 2nd degree - burns with damage to the entire epidermis but only part of the dermis, specifically less than 50% of the dermal layer
3. Deep 2nd degree – burns with damage to more than or equal to 50% of the dermal layer
4. 3rd degree – burns with damage to the entire epidermis and dermis and extend into the subcutaneous tissue
5. 4th degree burns – burns with damage that extends through all layers of the skin and into the underlying tissues such as fascia, muscle, tendon and/or bone.
6. Full thickness burns – includes both 3rd and 4th degree burns

As mentioned previously, the absolute thickness (i.e. in length units such as millimeters) of skin layers varies across the body and between individuals. So, although for example, the epidermis thickness in the skin on the dorsal aspect of the forearm may differ from the epidermis thickness of skin on the shoulder, the definition of burn severity will be tied to the local relative skin layer/structure thicknesses rather than an absolute depth.

In our review of the literature we found that all first degree burns are very likely to spontaneously heal and do not require care beyond LFRC to prevent disabling outcomes. Therefore, 1st degree burns, regardless of extent and location, are not considered significant injuries (American Burn Association, 2006b; Jeschke et al., 2013; United States Department of Health and Human Services, 2011).

On the other end of the spectrum full thickness burns, i.e. 3rd and 4th degree burns, result in severe damage of the skin tissue. Additionally, 4th degree burns cause damage to underlying musculature, tendons and bones. Regardless of the size or location of the burn, all 4th degree burns result in permanent injuries or would require advanced medical care beyond LFRC to prevent complications and permanently disabling outcomes. Although less severe, the standard of care for 3rd degree burns, regardless of size or location, is beyond LFRC (American Burn Association, 2006b). Using the standard of care as a surrogate for significance, then we assume all full thickness burns, regardless of location or TBSA are classified as significant injuries.

The significance of non-full thickness burns is dependent upon the size and location on the body where the burn is sustained in addition to associated complications inherent to physiological healing mechanisms. Due to the correlation between a greater TBSA and an increased likelihood for complications, burn injuries sustained over large parts of the body require advanced medical care. Therefore, as is consistent with American Burn Association and American College of Surgeons guidelines (American Burn Association, 2006b & American College of Surgeons, 2014), burns that are 2nd degree or more worse which cumulatively cover 10% or more of the TBSA are categorized as significant injuries.

As mentioned above, burn location can be a significant predictor of disabling outcomes from burn injury. Burns to major joints including ankles, knees, hips, shoulder, elbow, wrists, and neck can form contractures and limit range of motion. The same is true for skin areas around the mouth, eyes, perineum, and genitalia. In addition to loss of range of motion, burns to the latter group could lead to additional complications and loss of function. In our survey of the literature, as referenced above, we assume the standard of care for a deep 2nd degree burn to these sensitive areas will exceed LFRC capability in order to prevent loss of function, loss of range of motion, or other complications. Professionals prefer to excise and skin graft deep second-degree and greater burns as soon as possible to minimize the loss in functionality and associated risk of forming contractures/stiffness in the healing skin resulting in loss of range of motion (Dunne & Rawlins, 2014; Jeschke et al., 2013; Leblebici et al., 2006; Shakirov, 2011). Therefore any deep 2nd degree (or worse) burn to areas on or around the feet, ankles, knees, genitalia, perineum, hips, shoulders, elbows, wrists, hands, neck, mouth, or eyes is considered significant.

Certainly the size of a burn on these sensitive areas is a factor in the extent of any disabling outcome. One could imagine, for example, a very small and isolated deep 2nd degree burn on the shoulder that formed a contracture scar but would not result in any noticeable loss of range of motion. Medical literature, however, does not appear to be extensive concerning ROM limitations when extremely small deep burns are left to heal on their own. In the absence of more definitive data, we assume that any deep 2nd degree or worse burn to these sensitive areas, regardless of size, is a significant injury.

Summary of Results

The following equations and flow chart summarize the above results.

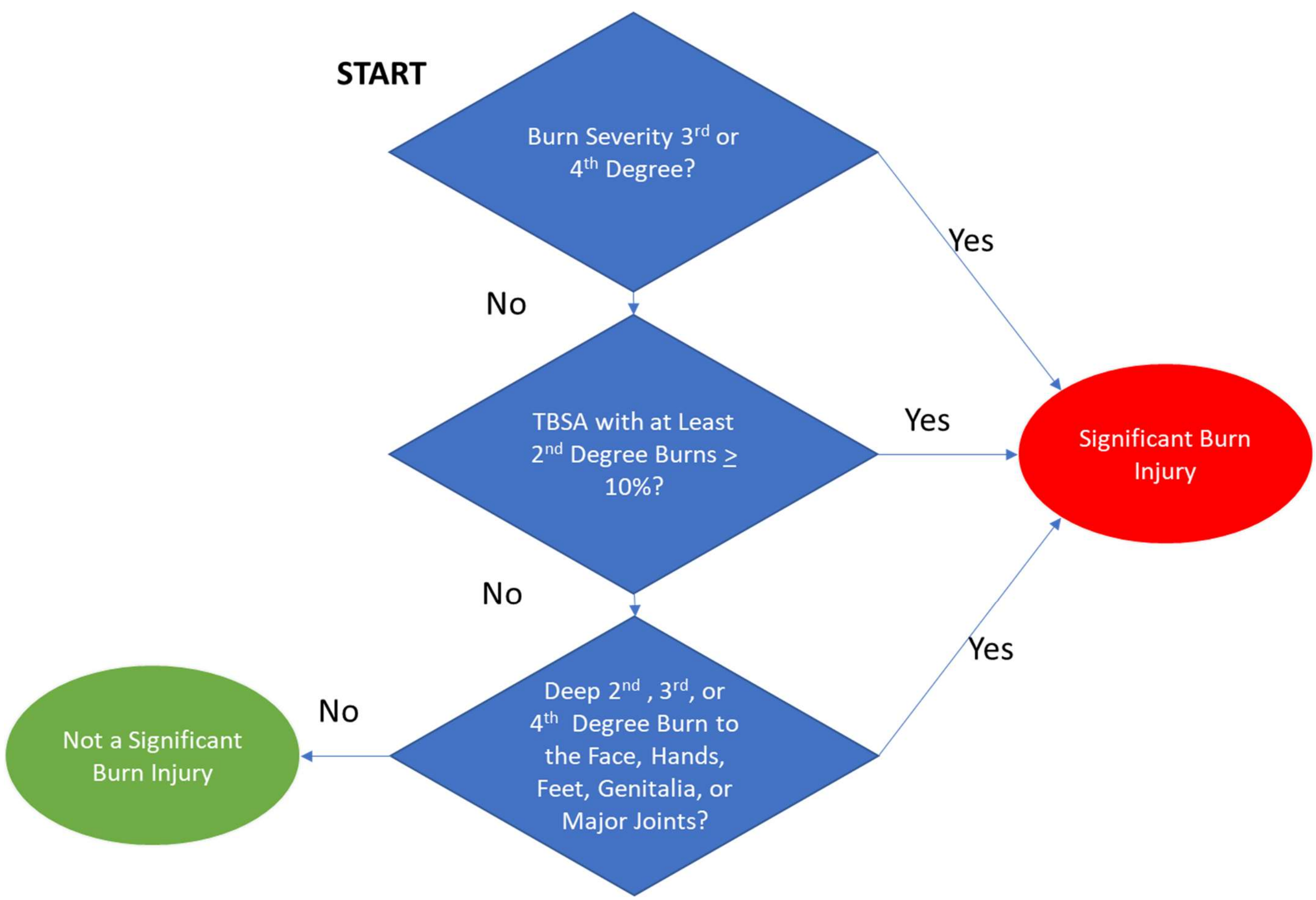
$P(SI|IO)_{1st\ degree\ burn} = 0\%$

$P(SI|IO)_{3rd\ or\ 4th\ degree\ burn} = 100\%$

$P(SI|IO\ _{TBSA\ with\ at\ least\ 2nd\ degree\ burn\ \geq 10\%} = 100\%$

$P(SI|IO\ _{Deep\ 2nd\ degree\ or\ worse\ burn\ on\ senstive\ location} = 100\%$

Figure 2: Burn Significance Flow Chart



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