Surgical Escharotomy and Decompressive Therapies in Burns

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Early recognition of the need for escharotomy and other decompressive therapies is imperative for experienced burn providers, as to avoid reversible tissue ischemia and necrosis. With full-thickness burns, the eschar that develops is largely noncompliant. The predictable edema that develops during resuscitation of larger burns increases the likelihood ischemia-inducing pressure, as the underlying tissues swell within noncompliant skin, resulting in burn-induced compartment syndrome. Conventionally, this has been treated with decompressive therapies, such as escharotomy. The most recent surveys have identified that the United States and Canada both face a shortage of practicing burn surgeons. In the event of a burn disaster, many nonburn surgeons would need to provide burn care, including decompressive therapies. We reviewed the literature to provide accurate, accessible, and applicable recommendations regarding this practice following burn injury for both the practicing burn surgeon and those that would provide care in the burn disaster.

The American Burn Association's (ABA) Organization and Delivery of Burn Care (ODBC) Committee have begun to work with other governmental and nongovernmental organizations to improve response to a burn disaster in North America. One of the more pressing concerns is having adequate personnel to provide care for multiple burn patients. The most current surveys regarding the burn workforce in both the United States and Canada show that there is likely a shortage of active burn surgeons.[1–3] These studies indicate that in the event of a surge in burn care needs, many nonburn care providers would be providing first line therapies for burn patients. Although firsthand exposure to the care of burn patients is intuitively an irreplaceable experience, updated clinical practice guidelines that are accurate, accessible, and applicable to providers that do not regularly provide care for burn patients are beneficial at our present level of burn care resources. One common challenge in the early stages of caring for a severely burned patient is how to assess the need for and adequately perform escharotomies. At the ODBC's request, we reviewed the literature to provide accurate, accessible, and applicable recommendations regarding this practice following burn injury for both the practicing burn surgeon and those that would provide care in the burn disaster.

RECOMMENDATIONS

This is an update of the thorough review article by Orgill in 2009.[4] We ascribe to the prior review's classification of escharotomy within the larger field of decompressive therapies, which include fasciotomies, nerve releases, orbital releases, and decompressive laparotomies. Each guideline is followed by the Grade of Recommendation as described by the Oxford Centre for Evidence-based Medicine in 2009 (OCEBM) (http://www.cebm.net/) (Table 1).

Risk Factors

1) Circumferential or near-circumferential full-thickness burns can cause a loss of elasticity of the skin and, with continued resuscitation and concomitant soft tissue edema, can result in increased compartment pressures and loss of perfusion. (Grade of Recommendation – B)

Indications

1) Indications for escharotomy of the extremities include the absence of Doppler signals, change in pulse exam, decreased or absent oximetry signals, increased compartment pressures, or neurological symptoms. The absence of these indications, however, does not guarantee adequate perfusion and should not be used to rule-out the need for escharotomy. (Grade of Recommendation – B)
2) Full-thickness burns to the chest may cause respiratory and hemodynamic dysfunction, such as decreased tidal volumes, increased airway pressures, decreased preload, and increased tachycardia. (Grade of Recommendation – B)
3) Intraoccular pressure in patients with periorbital burns should be checked to evaluate for the need for lateral canthotomy. (Grade of Recommendation – C)

Treatment

1) Escharotomies should be performed using longitudinal incisions that extend across burned tissue and only

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Table 1. Grades of evidence

Grades of Recommendation	
A	Consistent level 1 studies
B	Consistent level 2 or 3 studies or extrapolations from level 1 studies
C	Level 4 studies or extrapolations from level 2 or 3 studies
D	Level 5 evidence or troubingly inconsistent or inconclusive studies of any level

deep enough to release the eschar, avoiding underlying neurovascular structures. Although incisions that are not deep enough are inadequate and result in tissue loss, unnecessarily deep incisions should be avoided. If return of blood flow is not achieved, additional opposing longitudinal incisions may be indicated. (Grade of Recommendation – B)

2) Enzymatic debridement may develop as an adjunctive therapy to decrease the need for escharotomy. (Grade of Recommendation – B)

Management

1) Escharotomies should be performed as soon as the need for them is identified. This includes indications as described above, but may be done prophylactically in the appropriate patient (ie, massive resuscitation needs or severe burns). (Grade of Recommendation – B)
2) Consultation or transfer to a burn center should be considered for any patient where need for eschartomy is possible. (Grade of Recommendation – C)
3) Simulation may serve as a valuable method for educating providers and assessing their competence in the performance of escharotomy. (Grade of Recommendation – B)

Special Circumstances

1) Abdominal compartment syndrome may develop in burns due to either the eschar of the abdominal wall or large volume resuscitation. Symptoms of abdominal compartment syndrome (ACS) may include, but are not limited to: poor respiratory compliance, hemodynamic instability, tube feed intolerance, and decreased urine output. If concern for ACS arises, intra-abdominal pressures (IAP) may be assessed using bladder pressure. If eschar has been adequately released and IAP > 25 mm Hg, decompression may be further achieved with a decompressive laparotomy or, if appropriate, aperitoneal catheter. (Grade of Recommendation – C)
2) Burns in conjunction with other trauma such as electrical or crush injuries may require other decompressive therapies such as fasciotomies or nerve releases. Although it is unusual for a thermal burn to require a fasciotomy, a high degree of suspicion must be maintained for potential need for fasciotomies in full-thickness burns or delayed treatment of compartment syndrome. (Grade of Recommendation – B)

OVERVIEW

Purpose

The purposes of this guideline are to review 1) the current clinical parameters used for diagnosis and treatment of compartmental hypertension and resulting ischemia in the thermally-injured patient and 2) the level of evidence that supports current practice of performing escharotomies or other decompressive therapies in the treatment of burn patients.

Users

This guideline is meant to be referenced by physicians and other health care providers who are responsible for the initial and follow-up care of burned patients.

Clinical Problem

Full-thickness burns dramatically alter the normal physiological properties of skin. With full-thickness burns, an eschar forms—a dry, leathery layer that is pale to brown in color and results in the loss of the distensibility of normal skin. As fluid resuscitation progresses in burns larger than 10%–20% TBSA, interstitial edema develops at the site of, and remote from, the burn injury. This edema is due in part to the loss of the body's ability to regulate its intravascular and extravascular fluid shifts and results in increasing compartment pressures. As the edema develops with resuscitation, further soft tissue injury may be exacerbated by a tourniquet-like effect of the noncompliant, leathery eschar places on these compartments. The noncompliant layer of skin becomes restrictive, and instead of allowing for a change in volume of the soft tissue (ie, swelling), the additional edema fluid increases the soft tissue pressure. As these pressures rise—usually 4 to 6 hours after injury—ischemia, infarction, and, if left untreated, necrosis may develop in the distal tissues. This effect has been long described, specifically in circumferential full-thickness burns to the extremities, with the recommended treatment being a single or series of longitudinal incisions through the eschar to allow the release of the elevated compartment pressures and restoration of adequate perfusion to the distal tissues.[5] Inadequate treatment, either through a failure to treat, delay in treatment, or insufficient release of compartments, can result in infarction of soft tissue—with the ensuing risks of necrosis and infection, ischemic contractures, or amputation. Current diagnosis is not standardized; there is not a universally agreed upon test that predicts the need for escharotomy. Rather, a combination of objective measures—decreased or absent oximetry or Doppler probe signals; increased compartment pressures; or neurological symptoms such as deep limb pain at rest or with passive movement, numbness, paresthesia, or paralysis—and experienced clinical judgment make up the necessary components for proper decision-making.

Although escharotomy is most commonly discussed in the setting of extremity burns, its application to other areas of the body, including the truncal and periorbital tissues, have furthered our understanding of the usage of decompressive therapies for respiratory failure, abdominal compartment syndrome, and orbital compartment syndrome.

PROCESS

Pubmed 2008–2017 was reviewed for "escharotomy" and "decompressive therapies," as well as published works on escharotomy and decompressive therapies related to burns. Each article was reviewed and evaluated according to the OCEBM Levels of Evidence (https://www.cebm.net/2009/06/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/). Articles are summarized with their Levels of Evidence in Table 2.

SCIENTIFIC FOUNDATION

Compartment hypertension is a well-recognized phenomenon. In some cases, the deeper fascial layer may become the most restrictive layer—disallowing further changes in volume (ie, swelling) leading to deeper underlying soft tissue injury. As interstitial and intracellular fluid accumulates, instead of a resultant change in volume, pressure increases beneath the now-restrictive fascial layer, and compartment hypertension results. Similarly, with circumferential full-thickness extremity or truncal burns, an inelastic leathery eschar forms, which may cause a tourniquet-like effect to the distal tissues as edema progresses and compartment pressures rise. With the rise of these compartment pressures, venous, lymphatic, and arterial flow can cease, resulting in vascular compromise. The classic signs of vascular compromise include the "six P's": pain, pallor, pulselessness, paresthesia, paralysis, and poikilothermia. Although these signs and symptoms are typically thought of in nonthermal trauma settings to indicate the need for fasciotomies, in burn patients, the restrictive layer is the more superficial inelastic eschar itself.

Although the "six P's" are certainly a memorable mnemonic for the concern for vascular compromise, the actual clinical usage of this mnemonic is limited, as escharotomies should be performed as early as possible in a threatened limb. The factors used to determine the need for escharotomy have evolved from nonspecific, often subjective, clinical signs to objective measurements that allow for more consistent performance of escharotomies. In Pruitt's classic paper on escharotomy, the indications for interventions were 1) cyanosis of the distal unburned skin; 2) impaired capillary refill; or 3) progressive neurological changes.[5] The use of objective measurements, including Doppler signals,[6,7] pulse oximetry,[8] and compartmental pressures,[9] has all been previously used with success. The authors wish to remind that each of these modalities must be interpreted within the broader context, as they are capable of both promoting false reassurance, as well as triggering a potentially unnecessary procedure.

Doppler signals provide a simple, noninvasive method to monitor pulses in the distal extremities. The major caveat to the use of a Doppler probe is that one must correctly interpret the flow signals, rather than just recognize the presence of signals. Although the presence of triphasic flow is physiological, the presence of biphasic or monophasic flow is abnormal and should be interpreted as such. Incorrectly establishing flow in the presence of abnormal signals can delay treatment or result in long-term dysfunction.[6]

In general, the use of pulse oximetry is another simple, noninvasive method to detect hypoxia. Bardakjian[8] used pulse oximetry to determine the need for escharotomy with oxygen saturation levels less than 95%. Orgill[4] in the guidelines presented from 2009 recommended acting on a level of less than 90% as a more practical threshold. Absolute numbers should be used with caution, as patients may present with various normal levels of oxygenation. Acute changes from baseline oxygenation or differences between burned and unburned extremities may also be taken into account when using pulse oximetry to evaluate for compartment syndrome.

Compartmental pressures offer a more invasive, but direct, means to monitor and evaluate the need for escharotomy. Saffle[9] recommended a threshold of 30 mm Hg for escharotomy, despite the presence of Dopplerable pulses. This resulted in no long-term morbidity. In contrast, the use of Doppler pulses alone, even in the presence of compartment pressure in excess of 60, resulted in longer recovery time for those patients with high compartmental pressures. The inference the authors make is that, when done correctly, early escharotomy prior to hard signs of vascular compromise reduces long-term morbidity from the burn wound without any increase in morbidity from the procedure itself. As with other modalities, accurate measurement of compartment pressure can be somewhat user- and patient-dependent, so any decision based on these findings should be made within the larger context of the patient's physiology.

It is important to note that these modalities have been validated when used to serially assess the need for escharotomy when the patient may still have normal findings, as the interstitial edema may not be evident at the initial assessment. It is highly recommended that frequent reassessment of these patients be performed with the modality of choice for 12–48 hours, as the initial reading is not typically predictive of the need for escharotomy.[6,10,11]

In the presence of a developing clinical picture of a restrictive lung defect during resuscitation, escharotomy may be required for the restoration of flow or normal pulmonary mechanics, and the actual procedure has undergone significant changes over time. Pruitt[5] discusses these in his classic paper, as the procedure has evolved in terms of the number, location, and depth of incision(s).[12–14] Although there is no published standard of care, common incisions for both truncal and extremity escharotomies are shown in Figures 1 and 2. Singularly, Barros[15] discusses their institutional use of a grid escharotomy for decompressive therapy; however, no trial comparing the effectiveness or long-term outcomes between traditional medial and lateral escharotomy vs grid escharotomy has been undertaken.

In addition to the number and location of escharotomy, the depth of incision is a detail that requires some attention. It is important to note that these incisions are not fasciotomy incisions and are only needed to decompress the subcutaneous tissues. It is typically only necessary to perform these incisions through the dermis and dermal bands, leaving as much subcutaneous tissue unviolated as possible. Incisions down to the fascia are rarely needed and add significant morbidity to these injuries. Escharotomy by itself is associated with a prolonged hospital stay,[16] and inadvertent fasciotomies may lead to even more pronounced length of stay, as well as higher rates of disability.

Table 2. Evidentiary table

Reference	Description of Study	Data Class	Conclusion/Remarks
Rosenberg L, et al.	Multicenter, randomized, controlled clinical trial evaluating an enzymatic debridement	1b	Escharotomy was a secondary end point in this study, none of the enzymatically debrided hand burns required escharotomy whereas 10% of the standard of care hand burns required escharotomy
Fishcer, et al.	Single-institution retrospective review of patients with near-circumferential burns treated with enzymatic debridement	2b	No patient in their cohort required operative escharotomy
Ferguson, et al.	Single-institution retrospective review of patients undergoing nerve decompression	2b	Long-term surveillance of peripheral nerve compression is essential and may improve functionality even late in the wound healing phase
Ur R, et al.	Single-center high-fidelity simulator with validated assessment tool	2c	High-fidelity simulator with assessment tool was capable of discerning between experienced and inexperienced performance of forearm escharotomy
Strang GS, et al.	Systematic review of current literature regarding assessment and management of intra-abdominal pressure in severely burn patients	3a	Elevated intra-abdominal pressure with large burns to the trunk should first be managed with escharotomy with symmetric bilateral anterior axillary line incisions and a subcostal escharotomy
Hussain A, et al.	Meta-analysis of prognostic factors determining length of stay	3b	Escharotomy was a significant contributor to length of stay
Burd A, et al.	Single-center 5 year review with limited review of current literature	4	Escharotomy is a process with a goal for decompression and could be included in the primary assessment as the "D" in A, B, C, D, E assessment
Schulze S, et al.	Single-center review of prior hand amputations following burn injuries	4	No correlations were drawn between hand escharotomy timing, technique, and amputation rates
Shichinohe R, et al.	Multicenter, retrospective analysis of factors that functional outcomes for burned hands	4	Factors negatively correlating with functional outcome in hand burns were primarily escharotomy and days from graft to complete wound healing.
Wu C, et al.	Single-center retrospective analysis of lower extremity nerve decompression following escharotomy or fascitomy	4	Possible compression by hypertrophic scarring at lower extremity fasciotomy site can result in peroneal nerve compression
Strang, et al.	Systematic review of cases of IAH/ACS	4	Reviews current practices in the diagnosis, management, and prevention of IAH/ACS
Hershberger, et al	Single-center retrospective analysis of patients who underwent decompressive laparotomy for ACS	4	Decompressive laparotomies should be performed on all burn patients who develop ACS when less-invasive measures fail
Barros M, et al.	Review of current literature with a focus on extremity escharotomy	5	Review of concepts with attention to indication, timing, technique, anesthesia, and complications of extremity escharotomy incision
Feldmann M, et al.	Single-center expert opinion in pediatric hand burn	5	Expert opinion that does not quantify experience or outcomes but does advocate for interosseous muscle compartment release through 2 or 3 longitudinal dorsal incisions
Foot C, et al.	Single-center report of simulator modifications for chest escharotomy	5	Chest escharotomy can be performed on a modified simulator
Kamolz L, et al.	Review of managing hand burns	5	Review of available literature and expert opinion in managing hand burns which advocates for fasicotomy of the intrinsic muscles following exam
Kupas D, et al.	Case series for chest escharotomy in the prehospital setting	5	Limited study involving two patients that underwent chest escharotomy by physician members of a helicopter crew
Ali, et al.	Single-center study of a low-fidelity arm escharotomy simulator	5	Low-fidelity simulator using foam and a prosthetic arm wrapped in leather resulted in favorable survey experience by international burn course participants

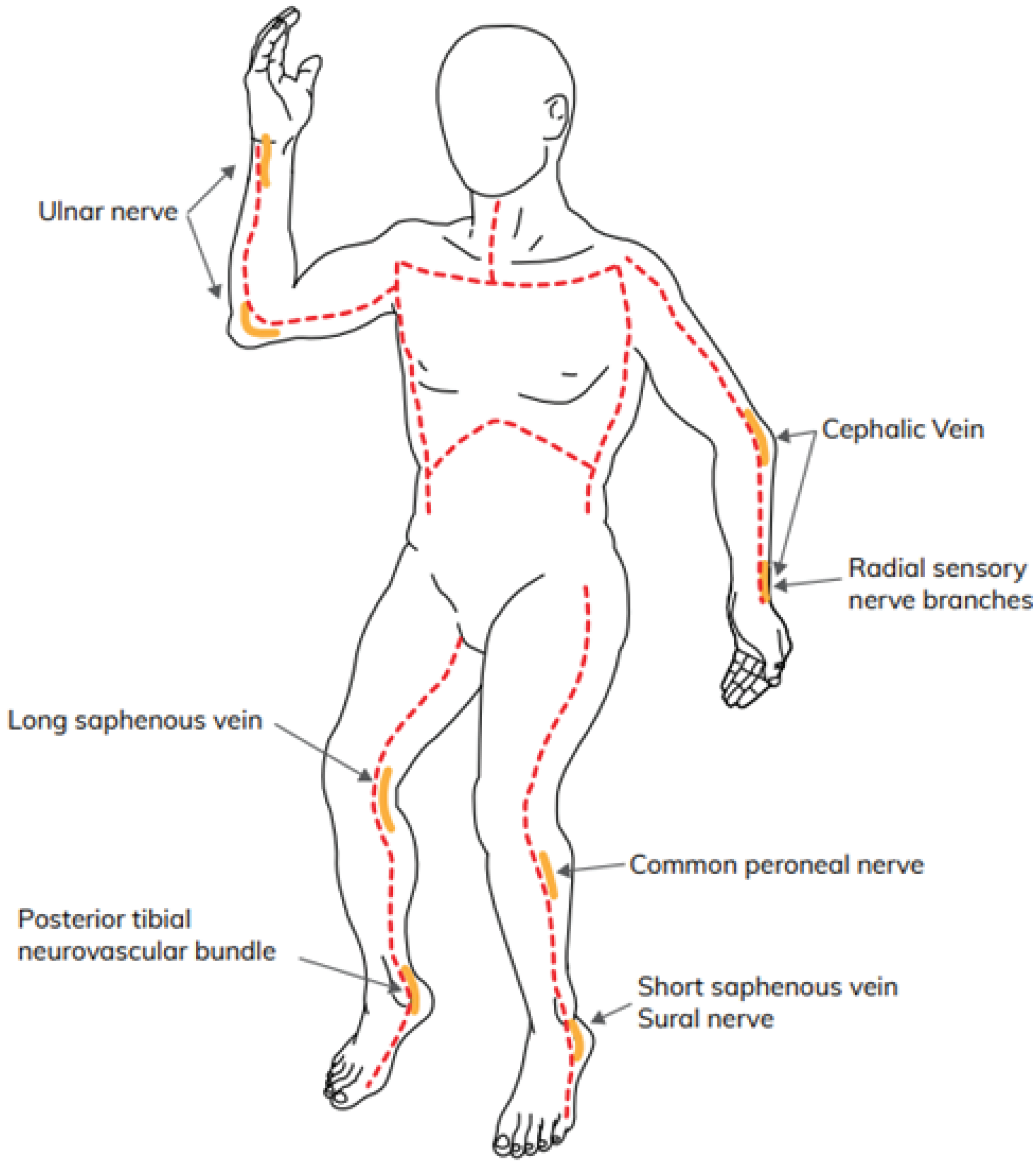

Figure 1. Truncal and extremity escharotomy incisions.

The technique of hand escharotomy requires some special discussion, given the attention paid to it over the review period. Although the majority of extremity burns can be evaluated for improvement in perfusion using a Doppler, hands and digits do not provide such feedback, as the intrinsic muscles of the hand can still necrose despite present Doppler signal.[10] As such, Feldman[17] and Kamolz[18] recommend decompression of the intrinsic muscles, through escharotomy and fasciotomy, respectively. Despite optimal treatment, poor functional outcomes[19] and the possibility of amputation[20] remain given the severity of the insult and potential morbidity of the procedure.

Kupas[21] presents the rare cases of two patients that underwent chest wall escharotomy out-of-hospital by physician members of an air medical team with reported improvement in respiratory dynamics. Admittedly, this is a rarely needed procedure in the emergent setting, as escharotomies are rarely needed within a few hours of a burn; however, the need for timely intervention by adequately trained providers remains imperative. Changes in the current curriculum of general surgical training, as well as trauma training do not mandate experience with decompressive techniques. As such, simulation that provides valid training for the performance of decompressive techniques is imperative for their appropriate usage during burn disasters or when timely burn center referral is not an option. Several techniques have been described over the study period, including the use of moulage,[22] as well as extremity simulators.[23,24]

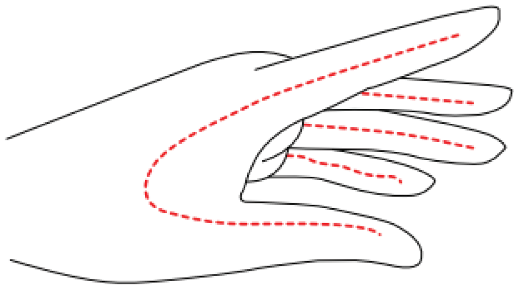

Figure 2. One common hand and finger escharotomy.

The future of escharotomy may be supplemented by enzymatic escharectomy during resuscitation—decreasing the need for operative intervention for burn-induced compartment syndrome. In a multicenter, prospective, randomized, controlled clinical trial, Rosenberg[25] demonstrated the usage of enzymatic debridement in the treatment of burns, and secondarily, as a potential adjunct to decompressive therapy. Although not a primary endpoint, the need for escharotomy among hand burns was 0% for those patients treated with enzymatic, bromelain-based topical gel, compared with 10% for those treated with the current standard of care. In a separate cohort study, Fischer[26] described treating 20 extremities that had been deep partial to full thickness burns covering more than two-thirds the circumference of the extremity with enzymatic debridement. This cohort showed that operative escharotomy was not necessary for any extremity treated with enzymatic debridement. Of note, at time of submission, this particular enzymatic debrider is in clinical trial and has not received FDA approval. In addition, this adjunctive therapy has not been the subject of a randomized control trial for treatment of burn-induced compartment syndrome and there are many unanswered questions,[27] but it has been the subject of two studies that have shown early promising results.

Although much of the discussion regarding escharotomies focuses on extremity injury and the potential for loss of function or limb, escharotomy continues to be but one element of a broader discussion regarding decompressive therapies for symptomatic compartmental hypertension.[28] Decompressive procedures are a mechanical solution not only for the musculoskeletal and integumentary systems, but also the neurological, cardiopulmonary, gastrointestinal, and renal systems. The timely identification and treatment of cardiopulmonary insufficiency secondary to chest wall burns remains a vital consideration in total or near circumferential thoracic burns.[21,29]

Furthermore, the development of intra-abdominal hypertension, most commonly due to large volume resuscitation irrespective of burn to the abdomen itself, is associated with extremely high morbidity and mortality.[30–32] The timely recognition of abdominal compartment syndrome, which presents as intra-abdominal hypertension (bladder pressure >20–25 mm Hg) and organ dysfunction (eg, elevated peak pressures, oliguria, feeding intolerance, tachycardia, and hypotension despite adequate resuscitation),[33] is imperative for any chance at positive outcome. Recent studies advocate[34–36] for the initial use of escharotomy using an "H" incision across the thorax prior to decompressive laparotomy. Use of a percutaneous peritoneal catheter has been described[37] to avoid progression of intra-abdominal hypertension to abdominal compartment syndrome, with slightly over a 50% success rate. The empirical observation is that the abdominal compartment hypertension is usually associated with significant ascites. Evacuation of the ascites, especially if there is relatively minimal bowel dilatation, appears to sometimes reduce the intra-abdominal volume sufficiently to return pressures to safe levels.

The development of orbital compartment syndrome has been demonstrated during resuscitation of severe burns in several case series, most recently by Singh.[38] With a similar underlying mechanism between orbital compartment syndrome and extremity or truncal compartment syndromes, orbital compartment syndrome can lead to compression or ischemia of the optic nerve or retinal vessel occlusion. The complaints of vision changes or loss are not easily communicated in severely burned patients, as they are often sedated, intubated, or otherwise unconscious. Periodic evaluation of intraocular pressure (IOP) with a tonometer is recommended for periorbital burns or those with large resuscitations. Based on Singh's case series, orbital decompression should be considered for those with IOP greater than 30 mm Hg.

Although routine fasciotomy had long been a mainstay of treatment for electrical burns with presumed compartment syndromes, prior published clinical practice guidelines recommended following the use of selective fasciotomy as published by Mann.[39] By following the signs and symptoms of compartment syndrome as demonstrated by the "6 P's" (pain, pallor, paresthesia, paralysis, pulselessness, and poikilothermia), selective fasciotomy preserved more tissue and decreased the need for fasciotomy, as the need for amputation was not caused by compartment syndrome, but rather the injury itself.

Finally, decompressive therapies may be selectively applied during the remodeling phase of wound healing, as hypertrophic scarring and other components of healing can result in neuropathies at one or multiple sites.[40] Nerve decompression[41] has been shown to improve sensory and motor dysfunction with relatively low morbidity in patients well into the recovery period.

SUMMARY

Decompressive therapies, including escharotomy, remain a mainstay in the treatment of the burned patient. As tissues swell, either secondary to local inflammation or resuscitation (or both), compressive forces can occlude vessels and damage nerves. Ischemia to tissues can lead to necrosis and, finally, organ failure. Decompression must be used in a timely fashion to restore perfusion and prevent secondary injury. This is true in extremity injuries when pulses are lost, as well as truncal injuries when ventilation is impaired or end organs are compromised secondary to intra-abdominal hypertension. The decision as to when intervention is necessary remains a clinical one. Prior clinical practice guidelines have been unable to offer any definitive threshold at which intervention should be undertaken, and interval research has not yet yielded a conclusive result. This remains a great challenge, as decompressive therapies are not without risks. Future research may show that enzymatic debridement allows for decompression without the potential morbidity of incisions, iatrogenic injuries (avoidable or otherwise), or prolonged hospital stays.

Once escharotomy has been performed, frequent re-assessment is key to ensure adequacy of the intervention. This may be done through a variety of modalities—Doppler, pulse oximetry, or compartment pressures; however, as previously discussed, no single modality has proven to be without its shortcomings. Whatever modality is used, the provider should use physical exam findings, as well as objective measurements, to justify intervention.

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