MEDICAL TECHNICAL REFERENCE NOTE

Title:	**THE MEDICAL MANAGEMENT OF THE ENTRAPPED PATIENT WITH CRUSH SYNDROME**
Last revised:	**March 2023 (updated from 2011 and 2019 versions)**

1. INTRODUCTION

- The following clinical technical reference note has been developed by the INSARAG Medical Working Group (MWG) which consists of medical professionals actively involved in the urban search and rescue discipline. The MWG is comprised of representatives from multiple countries and organisations drawn from the three INSARAG regional groups.

- This technical reference note outlines a recommended approach to crush syndrome in the *austere environment of collapse structure response*. While this is not intended to be a prescriptive medical protocol, USAR teams are encouraged to develop or review their own crush syndrome protocols within the context of this document.

  There is a lack of conclusive evidence-based research into prehospital treatment of crush syndrome in the collapsed structure environment. This technical reference are to be considered a consensus by members of the MWG based on current medical literature, expertise, and experience.

  In addition, it must be understood that this technical reference has been developed for application in a *specific environment* which may be complicated by factors such as:

  - Hazards to rescuers and patients e.g., secondary collapse; hazardous material;

- Limited access to entrapped patient and affected body areas;
- Limited mobility for providers;
- Limitations of medical and rescue equipment within the confined space;[1]
- Prolonged extrication and evacuation of patient;
- Delayed access to definitive care.

2. DEFINITIONS & BACKGROUND

- Crush Injury: Entrapment of parts of the body due to a compressive force that results in physical injury and or ischaemic injury to the muscle of the affected area, most commonly discussed in the context of collapsed structure incidents. If significant muscle mass is involved, it can lead to the development of *crush syndrome* following release of the compressive force.

- Crush Syndrome: A potentially life-threatening, systemic condition that can occur after release of a compressive force that has been applied to a muscle mass. The factors that lead to the development crush syndrome include:
  - Degree of compressive force;
  - Amount of muscle mass involved (Areas associated with crush syndrome are not restricted to limbs, but include other areas of large muscle mass such as buttocks and torso);
  - Duration of compression.

- Crush syndrome may be described as a reperfusion injury that occurs when the compressive force is released. This may result in acute and or delayed-onset clinical sequelae.

[1] Advances in technology are increasingly permitting enhanced evaluation and diagnostics in the field. Practitioners are encouraged to apply these technologies as they become available and proven for use in the field.

- The primary acute pathophysiological concerns are:
  - Hypovolaemia;
  - Electrolyte imbalances including hyperkalaemia which may result in acute cardiac dysrhythmias/cardiac arrest;
  - Metabolic acidosis;
  - Acute kidney injury (AKI).

- Delayed-onset pathophysiological concerns include:
  - Renal failure;
  - Adult Respiratory Distress Syndrome (ARDS);
  - Coagulopathy;
  - Severe sepsis.

- Immediate medical care, as soon as patients are accessed in the rubble, is an **essential humanitarian activity**. Delayed medical care and or inappropriate rescue management **may result in rapid deterioration and or death of the patient** (e.g., uncontrolled rapid removal of the compressive force before initiation of medical care).

- All organisations/persons involved in USAR operations should be aware of the potentially devastating consequences of extricating patients without simultaneous medical care.

3. CLINICAL PRESENTATION

- All patients entrapped within a structural collapse environment should be considered to have some element of crush syndrome until proven otherwise. Rescuers and medical personnel should maintain a high index of suspicion of the potential for crush syndrome taking into account the following:

- Note objects, debris, or building parts laying on portions of the patient;
- There may be no obvious physical signs of crush injury and the patient's vital signs may initially be normal;
- There may be difficulty in visually inspecting body parts that are crushed due to:
  - Position of the patient;
  - Inaccessibility of an entrapped body part;
  - Dust and debris covering body parts
- Body weight alone may provide sufficient compressive force to cause crush syndrome;
- Physical signs, when present, may include:
  - Mottled, blistered, bruised, or pale skin;
  - Damaged tissue;
  - Oedema;


Photographs courtesy of Japan International Cooperation Agency (JICA)

  - Poor or absent perfusion of affected body parts;
  - General signs of shock;
  - Reddish-brown urine.

Photographs courtesy of Japan International Cooperation Agency (JICA)

- Symptoms may include:
  - Dysaesthesia (e.g.; paraesthesia; hypoaesthesia; hyperaesthesia);
  - Anaesthesia;
  - Pain:
    - ✓ Presence and level of pain may not reflect the level of severity of injury;
    - ✓ May be exacerbated on movement/release.
  - Loss of motor function of the affected limbs;
  - Decreased urine output.

- Note: Crush syndrome may be incorrectly diagnosed as a spinal cord injury. This is an important differential diagnosis to make as the treatment regimes differ significantly. If in any doubt, treat as for crush syndrome whilst protecting the spine until spinal injury can be excluded.

4. GENERAL MANAGEMENT STRATEGY

- For the general approach to patient treatment in the confined space environment, please see *MWG_Provision of Medical Care in an Austere Environment Specifically in a Confined Space* which describes overall patient approach, assessment, monitoring, and care.[2] If relevant, see also *MWG Amputations and Dismemberment*.[2]

- It is imperative that patient assessment and treatment begin as soon as the patient is accessed.

- In the collapsed structure environment, rescuers should assume some level of crush injury predisposing to crush syndrome. Factors to assess include:
    - Time of compression: Crush syndrome may develop after only one hour of compression;
    - Force: The compressive force can be from one's own body weight in a static position on a hard surface of from an external source;
    - Muscle mass involved: The greater the muscle mass involved, the higher the risk for development of crush syndrome (e.g. proximal limb, gluteal, pectoralis).

- Entrapped patients may appear stable whilst the compressive force is in place with potentially rapid deterioration when it is removed.

- The removal of the compressive force is one of the most critical phases of the extrication. Therefore, the method and timing of the removal of the compressive force should be closely *coordinated between the rescue technicians and the medical personnel*.

- At the same time, removal of the compressive force should not be unnecessarily delayed as the severity of crush syndrome is proportional to the duration of compression.

[2] https://www.insarag.org/uncategorized/medical-technical-reference-library/

- The method and means of extrication and egress should be prepared prior to the removal of the compressive force.

- The required medical treatment and extrication equipment should be immediately available.

- Method of transport should be pre-established (this may include unconventional means such as private vehicle with USAR medical team accompanying the patient).

- Appropriate receiving healthcare facility and route should be pre-identified.

- When possible, pre-notification of the receiving facility should occur.

5. MEDICAL MANAGEMENT FOR CRUSH SYNDROME IN THE USAR ENVIRONMENT

- Currently there is no strong scientific evidence to support any single definitive fluid regime for the collapsed structure environment.

- However, fluid administration remains the cornerstone of therapy for the medical management of crush syndrome.

- In the USAR environment, fluid loading of the patient with suspected crush injury is recommended as one of the most important actions **prior** to release of any compressive force.

- The USAR environment may preclude an ability to definitively monitor haemodynamic, electrolyte and metabolic status of the patient. Some of the

following may be possible and have been successfully used in the collapsed structure environment:
  - Cardiac monitoring for signs of hyperkalemia;
  - Portable sonography for evaluation of hydration status and perfusion;
  - Point of care testing for metabolic derangements.

- Hyperkalemia can be challenging to diagnose in the USAR environment. Indicators may include:
  - ECG changes (e.g., peak t waves, widened qrs, bradycardia);
  - POC testing;
  - Hemodynamic compromise unresponsive to fluid resuscitation.

- Fluid therapy:
  - There are multiple reasons for fluid administration during various stages of the extrication:
    - Volume replacement as required to achieve haemodynamic stability;
    - Fluid loading to compensate for the sequestration of intravascular fluid into the interstitial space when compressive force is released;
    - Maintenance of adequate renal perfusion and prevention of renal damage. This may require the use of volumes of fluids that may exceed volumes usually administered to a trauma patient.

Critical elements of fluid management include:

1) Early administration
2) Initiating oral intake if possible
3) Rapidly securing intravenous access followed by
4) 1-1.5 litres per hour of warmed potassium-free solutions for the first two hours (adult patients).
5) Preparing for additional boluses when compressive force is released.

- Fluid administration routes:
  - Consider the following methods of vascular access:
    - Peripheral;
    - Intraosseous (IO);
    - Venous cutdown (less desirable in confined space);
    - Central (least desirable, consider the risks associated with central venous access within a confined space).
  - If vascular access is not immediately possible, consider alternative routes of fluid administration recognising their limited effectiveness (slow rate of absorption) and potential side effects (e.g. regurgitation):
    - Oral;
    - Orogastric;
    - Nasogastric;
    - Rectal;
    - Subcutaneous (avoid administration in crushed area).

- Intravenous Fluid type:
  - Preferably use warm, isotonic solutions;
  - Avoid potassium containing solutions;
  - Volume:
    - There is no strong scientific evidence to support any particular dose of administration. Many authors recommend an initial fluid load of 1 to 1.5 litres per hour for the adult patient in the first 2 hours until hydration status can be verified. In reality, each

crush patient may have varying fluid requirements and must account for other sources of on-going (dehydration) or future fluid loss (extravasation). Providing too much fluid is a distinct possibility as well.

- Individual fluid requirements may be difficult to assess in the collapsed structure environment but some considerations include:
  - ✓ Time to release of the compressive force;
  - ✓ Preloading the patient with fluid immediately prior to release of the compressive force to prevent significant hemodynamic compromise due to sequestration. This may be achieved by rapid fluid boluses.
- Fluid infusions require constant re-evaluation of the patient. Parameters to consider include:
  - ✓ Improved vital signs;
  - ✓ Improved mental status;
  - ✓ Urine production;

> Monitoring haemodynamic status using urinary output can be difficult to assess in the USAR environment, however:
>
> - Encourage patient to urinate into a container if possible if they feel the need;
> - Make note of times patient urinates;
> - Observe the colour and estimate the volume, if possible;
> - It is not generally advisable to attempt bladder catheterization within a confined space;
> - The lack of urine production in the first few hours is not a reliable indicator of anuria.

  - ✓ Skin turgor;
  - ✓ Production of tears;
  - ✓ Moist mucous membranes;

        - ✓ Advanced technology as mentioned above (e.g. field sonography in the rubble pile).
    - ▪ Special consideration should be given to the administration of fluid in the following:
        - ✓ Children and infants (e.g. initial bolus 15-20ml/kg);
        - ✓ Those with lower muscle mass (potentially reduced fluid volumes):
            a. Elderly;
            b. Chronically malnourished.
        - ✓ Patients with known co-morbid conditions e.g.; heart failure (potentially reduce fluid volumes).

- Other General recommendations:
    - Insulate fluids in cold environments;
    - Use pressure infuser devices in conjunction with rate control devices to aid with fluid administration. The confined space environment often precludes being able to place the intravenous fluid container above the level of the patients heart thereby preventing fluid flow or resulting in blood back flow up the administration set. Do not delay fluid administration waiting for equipment as manually squeezing the bag is an effective interim measure;
    - Ensure vascular access sites are adequately secured;
    - Use IV extension tubing to facilitate easier administration of fluid and medication;
    - Use two sites of intravenous access, if possible;
    - Adhere to aseptic technique as much as possible;
    - Maintain a record of fluid administered.

- Medications:
  - As crush syndrome is associated with acute renal failure, medications with known nephrotoxic effects must be avoided if at all possible e.g.; non-steroidal anti-inflammatory drugs (NSAIDs).
  - Patients presenting with possible acute renal failure may accumulate excessive doses of an administered drug due to inability of urinary excretion leading to toxicity.
  - The medical literature and USAR experience support the early administration of the following medications:
    - Alkalization: Sodium Bicarbonate 8.4% (e.g., 50 ml IV in an average adult patient) prior to removal of the compressive force. Although there is no strong scientific evidence to support additional bolus doses, this may be considered in prolonged extrications. Subsequent slow intravenous infusion (pre or post release) may assist with alkaline diuresis which is thought to aid renal protection (e.g., can be accomplished by adding the sodium bicarbonate to a hypotonic solution and slowly infusing).
    - Analgesia: Appropriate and adequate analgesia is not only important for patient comfort, it may assist with patient extrication. Selection of analgesic may be influenced by the scope of practice, duration of action, renal elimination, effect on the haemodynamic profile and need for airway support.
    - Antibiotics: Due to significant contamination of wounds in crush injury, consider administration of broad spectrum (including anaerobes) intravenous or intramuscular antibiotics (in non-damaged tissue); avoid nephrotoxic antibiotics (e.g. aminoglycosides).

- If hyperkalaemia is suspected, the following are well established treatments for this entity:
  - Sodium Bicarbonate 8.4%;

- Calcium 10%;
- Beta-2 agonist;
- Intravenous dextrose and insulin;
- Oral potassium bending agent (when practical and if prolonged transfer to tertiary care is expected).

- Notes regarding medications:
  - Suxamethonium chloride is contra-indicated due to its potential for exacerbation of hyperkalaemia;
  - Furosemide can have unfavourable heamodynamic side effects and causes acidification of the urine. Therefore, its use in this environment is discouraged;
  - There are many pharmaceutical interventions that have been proposed, tested in lab settings, or utilised in the field (e.g., mannitol, dexamethasone, acetazolamide, allopurinol). There is little conclusive evidence for their use and there are potential complications.

- Tourniquets:
  - The routine use of tourniquets in the management of crush syndrome is not supported by scientific evidence.
  - There are isolated case reports and poorly referenced publications that suggest the use of tourniquets for crush syndrome. Caution should be applied in interpreting these as conclusive evidence for the routine use of tourniquets.
  - Limbs at risk of crush injury are often difficult to accurately assess in the collapsed structure environment, and application of a tourniquet could turn a low perfusion state into a no perfusion state, worsening limb injury.

  - The use of tourniquets should be reserved for otherwise uncontrollable, life-threatening haemorrhage. Tourniquets used for this purpose should be appropriately designed and applied for arterial occlusion.

- Post release of the compressive force:
  - During and immediately following removal of the compressive force, reassess the patient’s clinical condition as it may rapidly deteriorate;
  - Repeat patient assessment frequently as deterioration can occur in a delayed fashion as well (e.g., during extrication or transport);
  - Evaluate for haemorrhage from removed limbs;
  - Reassess vascular access for integrity;
  - Coordinate the extrication and evacuation with the rescue team as per pre-planned strategy;
  - Monitor for signs of acute hyperkalaemia;

- Compartment syndrome:
  - Following the release of the compressive force, patients may develop a compartment syndrome. Current medical literature and experience discourages the use of fasciotomies *in the austere collapsed structure environment* due to the potential for bleeding and/or sepsis which may be life threatening.

MEDICAL TECHNICAL REFERENCE NOTE

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