Introduction

The management of massive lower limb trauma, or mangled leg, presents an uncommon and complex problem. Massive lower limb trauma is associated with considerable morbidity and mortality.

Amputation of a limb is a devastating event in a person’s life. Trauma is the second leading cause of major lower limb amputation and most commonly affects young adults. Survivors expect to live for 40-50 years and require prosthetic care for life. Several authors have noted that trauma-related amputation leads to significantly lower physical and social functioning compared to the normal age-matched population.

This guideline has been based on the best available evidence for the management of the mangled lower limb; however, these principles can be applied to the management of all mangled limbs.

Background

Mangled lower limbs (MLL), pose an immediate and complex decision-making challenge between limb salvage and primary amputation.

Treatment options are:

1. Primary amputation - amputation within the first 24 hours of injury.
2. Early secondary amputation - amputation within five days of injury.
3. Delayed secondary amputation - amputation after the first hospitalisation.
4. Limb salvage.

Early amputation of severely mangled limbs result in fewer complications and operative procedures; shorter hospitalisations; lower hospital costs; faster return to work and lower perceived disability with Prosthetic ambulation more successful for the below versus above knee amputees.

In this guideline the mangled limb is defined as a Gustilo type III-B & III-C open tibial fracture (Appendix 1).

Mechanism

Tibial fractures are the most common long bone fracture. The most frequent mechanisms of injury are motorcycle accidents (28%), motor vehicle accidents (24%), domestic accidents (13%), pedestrian accidents (12%), crushing lesions (8%), firearm accidents (2%), and miscellaneous causes such as work and sports-related accidents (13%). Approximately 70% of all open tibial fractures resulting from road traffic accidents will be Gustilo type III in severity. Consequently, blunt injuries are approximately five time more common than penetrating injuries.
Blunt mechanisms of injury are associated with higher risks of amputation. Some studies have shown that in patients hospitalised with blunt limb trauma, up to 38% have an associated vascular injury, 24% have arterial occlusion and 21% have a significant incidence of threatened limb viability. In comparison to penetrating trauma, blunt mechanisms are associated with greater severe soft tissue injuries and have been reported to result in a three to seven-fold increase in risk of amputation. Crush injuries have the worst prognosis, with 82% of crush/avulsion injuries leading to amputation.

Anatomy

The leg is divided into four fascial compartments. These are bounded by the crural fascia and separated by the interosseous and fibula membrane, and the anterior, posterior and transverse intermuscular septa. The four compartments are the anterior, lateral (or peroneal), superficial posterior and deep posterior compartments (Appendix 1 and 2).

The anterior compartment encloses the dorsiflexors of the foot. These include the tibialis anterior, extensor digitorum longus, extensor hallucis, and peroneus tertius. The main neurovascular supply to the anterior compartment includes the deep peroneal nerve and the anterior tibial artery (and its associated vessels).

The lateral compartment includes the peroneus longus and brevis muscles, whose primarily function is eversion of the foot. These two muscles are innervated by the superficial peroneal nerve, which is also contained in this compartment.

The posterior aspect of the leg is separated into two compartments - superficial and deep. The superficial posterior compartment is the largest of the 4 compartments but contains only muscle. These include the plantar flexor muscles - the soleus, the gastrocnemius, and the plantaris. The deep compartment contains the plantar flexor muscles - the tibialis posterior, flexor hallucis longus, and flexor digitorum longus. This compartment also houses the tibial nerve and the posterior tibial arteries, and their corresponding veins. The contents of the compartments of the leg are presented diagrammatically in Appendix 1 & 2.

In lower limb trauma, the compartmental anatomy can become extremely important due to potential internal bleeding and swelling/oedema in the leg which can lead to the development of acute traumatic compartment syndrome. It should be noted that some authors propose the possibility of the tibialis posterior muscle occupying a separate, fifth compartment in some people, making it the most vulnerable to compartment syndrome.

The shaft of the tibia is subcutaneous and easily palpable. As such it has a high propensity for open fractures to occur - a characteristic reflected in tibial fracture being the second most common type of open fracture, behind fractures of the hand phalanges.

At the junction between the upper and lower third of the tibial diaphysis, the posterior tibial artery is at its closest proximity to its posterior aspect. Hence fractures around this region must be carefully examined for arterial injury due to an increased risk of injury.

The Guideline

The recommendations presented in this document are based around the following key decision nodes in the management pathway:

The following five key decision nodes in the decision to amputate or salvage a mangled lower limb were identified:

1. When should primary amputation be performed as damage control surgery?
2. What are the indications for primary amputation?
3. How does clinical assessment contribute to the decision about early amputation?
4. How do severity scores contribute to decision between amputation or salvage?
5. How do patients characteristics contribute to decision making about early amputation?
6. When should secondary amputation be performed?
For each key decision node in the management process, a summary of the recommendations is presented in tabular form. Due to the lack of published evidence concerning the management of acute limb compartment syndrome, many of the following recommendations are based upon the consensus opinion of a multidisciplinary team of experts involved in trauma care at the Royal Melbourne Hospital.

Where the recommendations are based on literature evidence, the NHMRC Level of Evidence is stated (see appendix 3.0 NHMRC Levels of Evidence) 33.

**Recommendations**

### 1. When should primary amputation be performed as damage control surgery?

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>In patients with a mangled lower extremity, primary amputation should be considered if any of the following are found in combination:</td>
<td></td>
</tr>
<tr>
<td>Temperature &lt;34°C</td>
<td>III-2</td>
</tr>
<tr>
<td>pH &lt; 7.2</td>
<td></td>
</tr>
<tr>
<td>Serum lactate &gt; 6mmol/L</td>
<td></td>
</tr>
<tr>
<td>Prothrombin time &gt; 16 seconds</td>
<td></td>
</tr>
<tr>
<td>Partial thromboplastin time &gt; 60 seconds</td>
<td></td>
</tr>
<tr>
<td>&gt;10 units blood transfused</td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure &lt; 90mmHg for &gt; 60min</td>
<td></td>
</tr>
<tr>
<td>This follows the Definitive Surgical Trauma Care (DSTC) protocol of indications for damage control surgery 34.</td>
<td></td>
</tr>
</tbody>
</table>

### 2. What are the indications for primary amputation?

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete anatomical disruption of the tibial nerve (except in isolated stab injuries)</td>
<td>IV</td>
</tr>
<tr>
<td>Massive crush injuries to: Proximal # of tibia with ischemia &gt; 6 hours 18</td>
<td>IV</td>
</tr>
<tr>
<td>Near complete traumatic amputations involving devascularisation or loss of muscles in all four crural compartments</td>
<td>Consensus</td>
</tr>
<tr>
<td>Massive contamination where debridement would: result in removal of structures critical to limb salvage (e.g. tibial nerve); put the patient’s life at risk;</td>
<td>Consensus</td>
</tr>
<tr>
<td>Associated mangled ipsilateral foot</td>
<td>Consensus</td>
</tr>
</tbody>
</table>
### How does clinical assessment contribute to the decision for early amputation?

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism of injury: Prognosis</td>
<td>III-3 to II</td>
</tr>
<tr>
<td>Explosive</td>
<td>Worst 41</td>
</tr>
<tr>
<td>Crush</td>
<td>Very poor 25, 36, 38-41</td>
</tr>
<tr>
<td>Blunt high energy</td>
<td>Poor17-22</td>
</tr>
<tr>
<td>Penetrating high energy</td>
<td>Poor-fair 17-24</td>
</tr>
<tr>
<td>Blunt low energy</td>
<td>Fair-good 17-24</td>
</tr>
<tr>
<td>Penetrating low energy</td>
<td>Good 17-24</td>
</tr>
<tr>
<td>* NB Prognosis in the absence of absolute indications for amputation</td>
<td></td>
</tr>
</tbody>
</table>

#### Fracture Characteristics:
- Gustilo type III-B and III-C fractures have the poorest prognosis 14, 18, 35, 37

#### Soft tissue Injury:
- Severe soft tissue injury is the most important variable influencing amputation and significantly increases the risk of complications (non-union, chronic infection, pain) and amputation 35, 42
- Adequate soft tissue coverage must be available for salvage to be considered

#### Vascular Injury:
- Warm ischemia time >6hrs significantly increases the risk of poor outcome if salvage is attempted 12, 21, 36, 38-40, 43
- Number of vessels injured correlate with risk of amputation 44
- More distal vascular injuries increase risk of amputation 4, 11, 12, 16, 17
- Failed revascularisation should warrant early amputation

#### Nerve Injury:
- Plantar sensation cannot be used to predict posterior tibial nerve integrity 5
- Limb salvage in patients with incomplete disruption of the posterior tibial nerve have poor outcomes 5, 11, 18, 29, 45
- Posterior tibial nerve integrity must be visually inspected before making a decision

### How do patients characteristics contribute to decision making about early amputation?

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking increases complications (time to union, non-union, infection) associated with limb salvage</td>
<td>II</td>
</tr>
<tr>
<td>Patients over the age of 50 generally have poorer outcomes after salvage 10, 16, 18, 41, 53, 69, 73, 96, 97</td>
<td>III-3</td>
</tr>
<tr>
<td>Patients with pre-existing cardiovascular and neurological co-morbidities have greater risks of complications (e.g. infection, non-union, chronic pain) and should be advised against salvage. Eg, neuropathic diabetes, peripheral vascular diseases</td>
<td>III-3</td>
</tr>
<tr>
<td>Treatment (amputation or salvage) should be influenced by the patient’s activity level.</td>
<td>Consensus</td>
</tr>
<tr>
<td>Patients with inadequate psychological, socioeconomic, and educational resources may have difficulties managing, adapting to, and coping with salvage surgery, rehabilitation, and significant lifestyle changes. Early amputation may be a treatment for best outcome in such patients.</td>
<td>Consensus</td>
</tr>
</tbody>
</table>
5. How do severity scores contribute to decision making about amputation?

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity scores have low sensitivity and specificity. Severity scores should only be used as a guide in conjunction with the surgeon’s clinical judgement. It should not be the sole basis of decision making.</td>
<td>II</td>
</tr>
</tbody>
</table>

6. How do system risks contribute to decision making about early amputation?

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>In mass casualty situations, preserving a limb is secondary to saving lives. When resources are limited or depleted, patients should be stabilised and only be considered for limb salvage when resources become available.</td>
<td>Consensus</td>
</tr>
</tbody>
</table>

**Recommendations**

It is important for the best outcome for patients in this situation that all steps of the guideline be completed in consultation with the following Units: Orthopaedics; Plastics; Vascular and Trauma. Please be aware that the amputated limb should be considered as a potential donor site for the reconstruction of other coexisting injuries and hence should not be removed and/or discarded to Pathology without consultation with the Plastic Surgery Unit.

**Ongoing Care**

Inpatient multidisciplinary rehabilitation is effective in improving the physical health and vocational prospects of persons undergoing trauma-related amputations. The rehabilitation physician, through pre-operative and follow-up consultations, can advise on functional expectations, patient and carer education/supportive counselling, amputation-level and prosthetic considerations, care for the residuum including oedema control, removable rigid dressing (RRD) application for below knee amputations, pre-prosthetic training, phantom limb pain management and referral to the appropriate inpatient rehabilitation service.
Mangled Lower Limb Guideline

Patient Presents with 'mangled limb'
(Gustilo type III-B & III-C open tibial fracture)

Are there any of the following damage control indications present?
• Temperature <34 degrees Celsius
• pH <7.2
• Serum Lactate > 6mmol/L
• INR> 1.3 (PT>16s and for APPT> 60 secs)
• >10 units blood transfused
• Systolic blood pressure <90mmhg for >60mins

Yes

Are there indications for primary amputation to consider?
• Complete transection of tibial nerve
• Crush injury with warm ischaemic time >6 hours
• Near complete traumatic amputation
• Massive contamination

Yes

Consider primary/early amputation
In consultation with orthopaedics, plastics, vascular and trauma

No

Are there any patient key factors and or clinical characteristics present that may increase the risk or desirability of an early amputation precedent?

Patient Variables
• Age
• Smoking status
• Co-morbidities
• Patient wishes
• Support networks
• Personality
• Pre-morbid function
• Vocation
• Patient goals

Risk Factors
• Soft-tissue injury
• Neurological injury
• Vascular injury
• Mechanism of injury
• Fracture characteristics
• Associated injuries
• Contamination
• Knee preservation
• Prosthetic considerations

Yes

Amputation
Store limb in appropriate manner until review by plastic surgery unit

No

Consider Limb Salvage
Appendix 1

Table 1 Gustilo Classification of Open Fractures

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A fracture with a clean cutaneous wound less than 5cm in length</td>
</tr>
<tr>
<td>II</td>
<td>A fracture with laceration greater than 5cm in length lacking any severe soft-tissue damage</td>
</tr>
<tr>
<td>III</td>
<td>A fracture with extensive soft-tissue damage and:</td>
</tr>
<tr>
<td>III A</td>
<td>Adequate cover of the fracture by soft-tissue despite extensive cutaneous lacerations or flaps. High-energy trauma regardless of wound size.</td>
</tr>
<tr>
<td>III B</td>
<td>More extensive injury to and contamination of the soft tissues, periosteal stripping and soft-tissue gaps are present.</td>
</tr>
<tr>
<td>III C</td>
<td>Any open fracture with arterial injury requiring repair regardless of the extent of soft-tissue injury.</td>
</tr>
</tbody>
</table>

Appendix 2

Appendix 3


Appendix 4

NHMRC Levels of Evidence

<table>
<thead>
<tr>
<th>Level</th>
<th>Evidence obtained from</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I</td>
<td>Evidence obtained from a systematic review of all relevant</td>
</tr>
<tr>
<td></td>
<td>randomised control trials</td>
</tr>
<tr>
<td>Level II</td>
<td>Evidence obtained from at least one properly-designed</td>
</tr>
<tr>
<td></td>
<td>randomised control trial</td>
</tr>
<tr>
<td>Level III-1</td>
<td>Evidence obtained from well-designed pseudo-randomised</td>
</tr>
<tr>
<td></td>
<td>controlled trials (alternate allocation or some other</td>
</tr>
<tr>
<td></td>
<td>method)</td>
</tr>
<tr>
<td>Level III-2</td>
<td>Evidence obtained from comparative studies (including</td>
</tr>
<tr>
<td></td>
<td>systematic reviews of such studies) with concurrent</td>
</tr>
<tr>
<td></td>
<td>controls and allocation not randomised, cohort studies,</td>
</tr>
<tr>
<td></td>
<td>case-control studies, or interrupted time series</td>
</tr>
<tr>
<td></td>
<td>with a control group</td>
</tr>
<tr>
<td>Level III-3</td>
<td>Evidence obtained from comparative studies with</td>
</tr>
<tr>
<td></td>
<td>historical control, two or more single arm studies or</td>
</tr>
<tr>
<td></td>
<td>interrupted time series without a parallel control group</td>
</tr>
<tr>
<td>Level IV</td>
<td>Evidence obtained from a case-series, either post-test or</td>
</tr>
<tr>
<td></td>
<td>pre-test/post-test</td>
</tr>
</tbody>
</table>
References

34. DSTM. *The Definitive Surgical Trauma Care Course Manual*. Parkville; 2004: Pages.