Trauma Service Guidelines
Title: **Mangled Lower Limb Guideline**
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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[1]. 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 [2, 3].

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 hospitalizations; lower hospital costs; faster return to work and lower perceived disability[4-12] with Prosthetic ambulation more successful for the below versus above knee amputees[13].

In this guideline the mangled limb is defined as a Gustilo type III-B & III-C open tibial fracture (Append x 1)[14].

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[15]. Consequently, blunt injuries are approximately five time more common than penetrating injuries[16].

Blunt mechanisms of injury are associated with higher risks of amputation[17-24]. 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[25-28]. 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[21, 22, 24] . Crush injuries have the worst prognosis, with 82% of crush/avulsion injuries leading to amputation[29].

Anatomy

The leg is divided into four fascial compartments. These are bounded by the crural fascia and separated by the tibia, 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)[30].

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[31].
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 [32].

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

2. What are the indications for primary amputation?	
Guideline	**Level of Evidence**
Complete anatomical disruption of the tibial nerve [7, 29, 35-40] (except in isolated stab injuries)	IV
Massive crush injuries to: Proximal # of tibia with ischemia >6 hours[18]	IV
Near complete traumatic amputations involving devascularisation or loss of muscles in all four crural compartments	Consensus
Massive contamination where debridement would: result in removal of structures critical to limb salvage (eg tibial nerve); put the patient's life at risk;	Consensus
Associated mangled ipsilateral foot	Consensus

3. *How does clinical assessment contribute to the decision for early amputation?*		
Guideline		**Level of Evidence**
Mechanism of injury:	Prognosis	III-3 to II
Explosive	Worst [41]	
Crush	Very poor [29, 36, 38-41]	
Blunt high energy	Poor [17-22]	
Penetrating high energy	Poor-fair [17-24]	
Blunt low energy	Fair-good [17-24]	
Penetrating low energy	Good [17-24]	
* NB Prognosis in the absence of absolute indications for amputation		

Fracture Characteristics: Gustilo type III-B and III-C fractures have the poorest prognosis [14, 18, 35, 37]	III-3
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]	II
Adequate soft tissue coverage must be available for salvage to be considered	Consensus
Vascular Injury: Warm ischemia time >6hrs significantly increases the risk of poor outcome if salvage is attempted [12, 21, 36, 38-40, 43]	III-3
Number of vessels injured correlate with risk of amputation [44]	III-3
More distal vascular injuries increase risk of amputation [4, 11, 12, 16, 17]	III-3
Failed revascularisation should warrant early amputation	Consensus
Nerve Injury Plantar sensation cannot be used to predict posterior tibial nerve integrity[5]	II
Limb salvage in patients with incomplete disruption of the posterior tibial nerve have poor outcomes[5, 11, 18, 29, 45]	III-3
Posterior tibial nerve integrity must be visually inspected before making a decision	Consensus

4. *How do patients characteristics contribute to decision making about early amputation?*	
Guideline	**Level of Evidence**
Smoking increases complications (time to union, non-union, infection) associated with limb salvage[84-95]	II
Patients over the age of 50 generally have poorer outcomes after salvage[6,10,16,18,41,53,69,73,96,97]	III-3
Patients with pre-existing cardiovascular and neurological co-morbidities have greater risks of complications[98,99] (eg infection, non-union, chronic pain) and should be advised against salvage. Eg. neuropathic diabetes[98,99], peripheral vascular diseases	III-3
Treatment (amputation or salvage) should be influenced by the patient's activity level.	Consensus
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.	Consensus

5. How do severity scores contribute to decision making about amputation?	
Guideline	**Level of Evidence**
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	II

6. How do system risks contribute to decision making about early amputation?	
Guideline	**Level of Evidence**
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.	Consensus

Recommendations

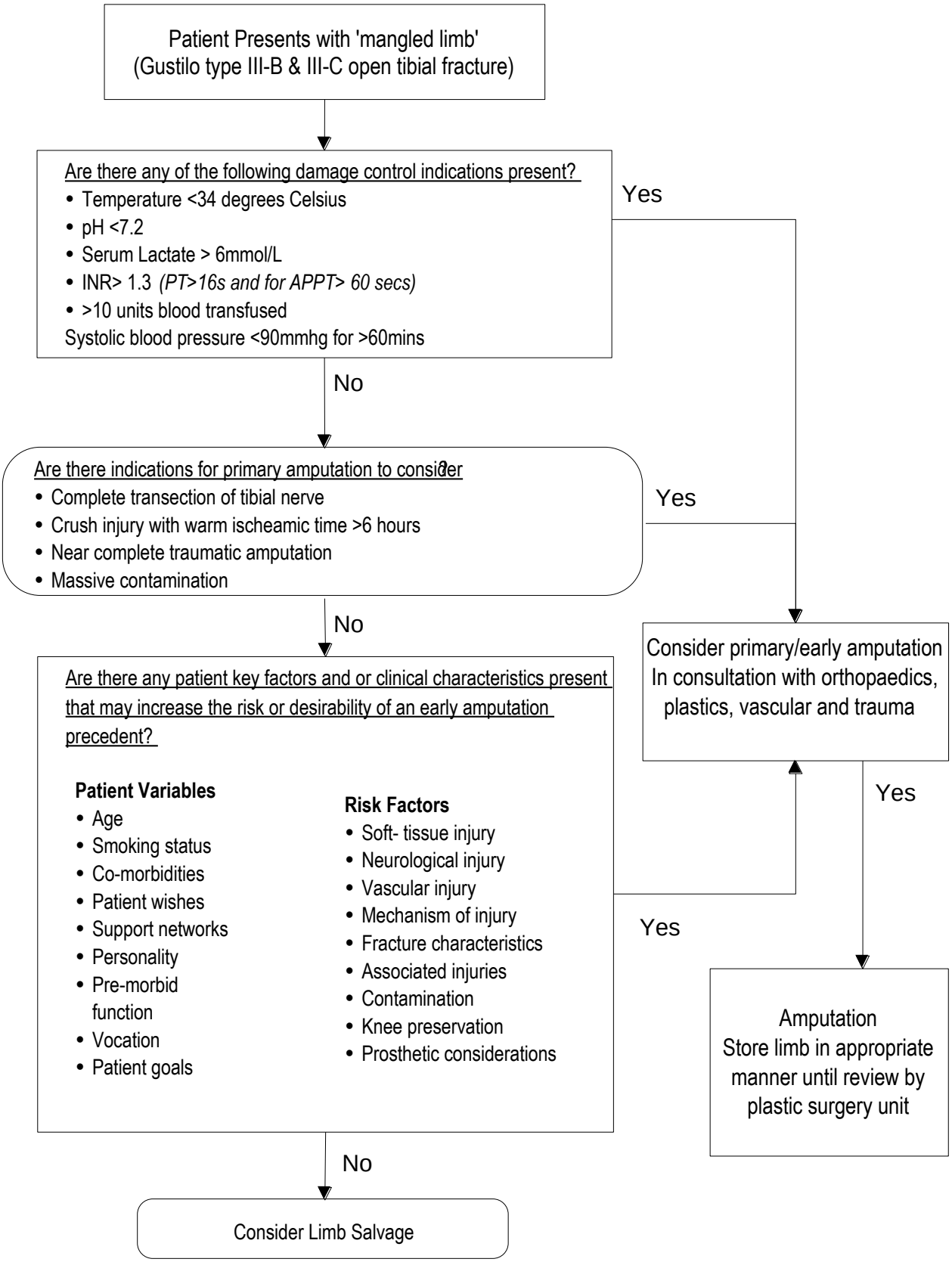
It is important for the best outcome for patients in this situation that all steps of the guideline be completed in consultation with the following Units: Orthopaedics; Plastics; Vascular and Trauma.

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[46]. 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



Appendix 1

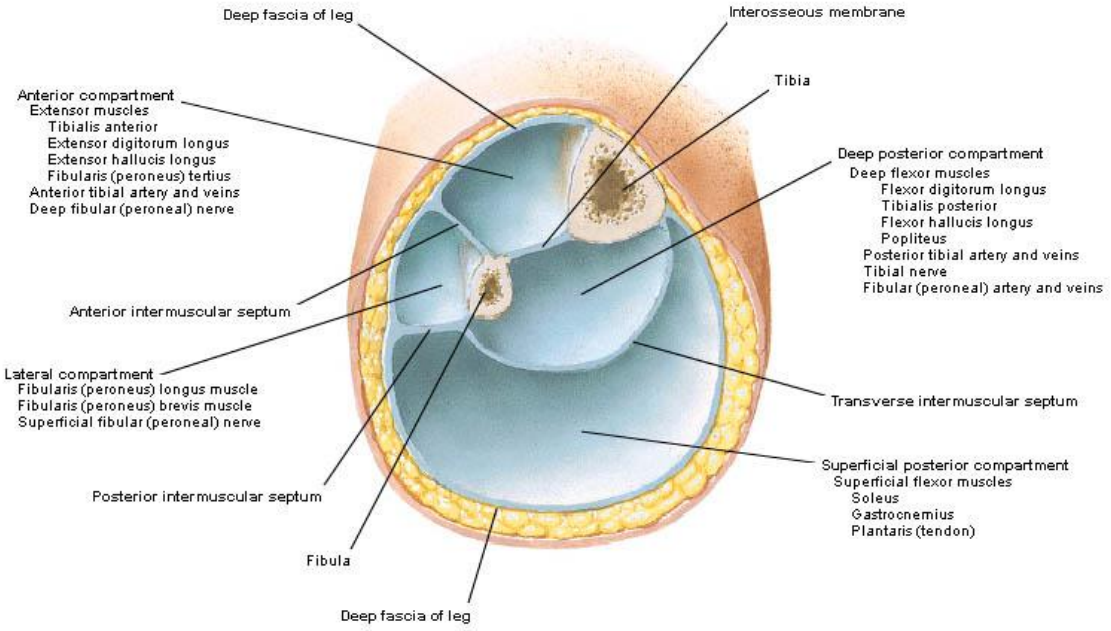
Table 1 Gustilo Classification of Open Fractures

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

Appendix 2

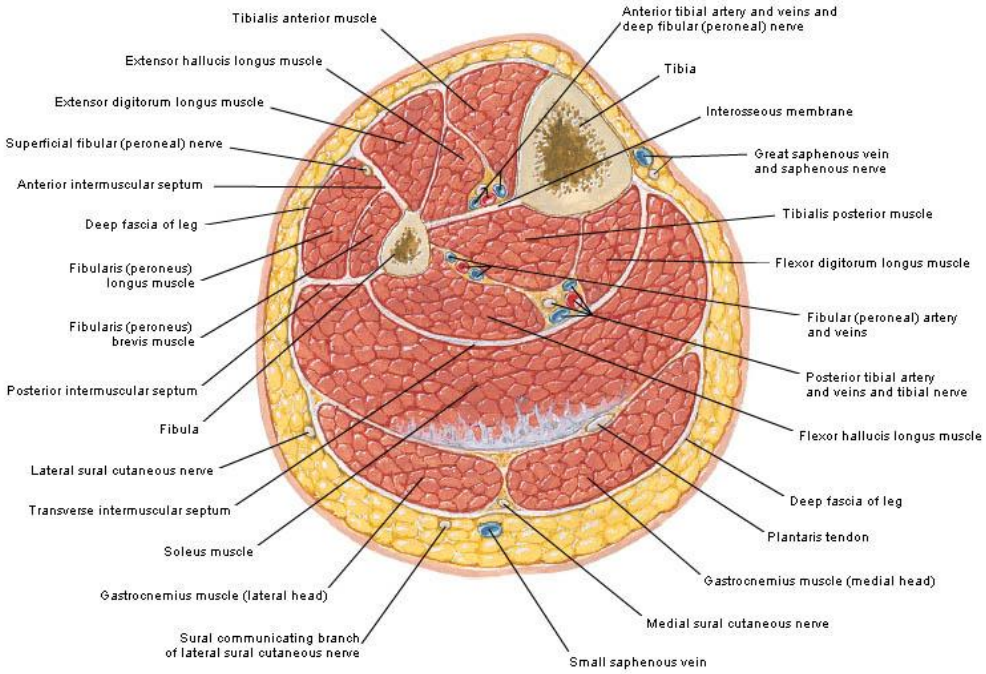
Cross section of the leg showing the four fascial compartments. From: Netter FH.

Atlas of human anatomy. Summit, New Jersey: Ciba-Geigy Corporation, 2003.



Appendix 3

Cross section just above middle of leg showing the contents of the four fascial compartments. From: **Netter FH**. *Atlas of human anatomy*. Summit, New Jersey: Ciba-Geigy Corporation, 2003.



Appendix 4

NHMRC Levels of Evidence

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

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