

COMPARTMENT SYNDROME (CS) AND THE ROLE OF FASCIOTOMY IN EXTREMITY WAR WOUNDS

Original Release/Approval	30 Apr 09	Note: This CPG requires an annual review.	
Reviewed:	Feb 2012	Approved:	9 Mar 2012
Supersedes:	Compartment Syndrome (CS) and the Role of Fasciotomy in Extremity War Wounds, 30 Apr 2009		
<input type="checkbox"/> Minor Changes (or)	<input type="checkbox"/> <i>Changes are substantial and require a thorough reading of this CPG (or)</i>		
<input checked="" type="checkbox"/> Significant Changes:	System PI monitoring plan added; common reasons for incomplete fasciotomy added		

1. **Goal.** Provide an overview of compartment syndrome (CS) and present a standardized approach to guide providers in the evaluation and treatment of patients with extremity war wounds, including the role of prophylactic and therapeutic fasciotomy.
2. **Background.** CS is a common, controversial, and disabling problem in extremity war injuries. Recent research indicates proper detection of compartment syndrome is lifesaving and delay in diagnosis can be lethal.¹ The operational definition of compartment syndrome is a clinical syndrome wherein high pressure within a myofascial space reduces perfusion and decreases tissue viability. Therapeutic fasciotomy is indicated for established compartment syndrome, and prophylactic fasciotomy is indicated for risk of compartment syndrome.²⁻⁴ Fasciotomy during the lag phase between injury and syndrome onset is prophylactic. Early detection is challenging, so prophylactic fasciotomy should be routine when compartment syndrome is likely. Prophylactic fasciotomy is most commonly indicated in patients with certain at risk fractures and in patients with prolonged ischemia or following limb reperfusion. Injury, treatment, and casualty variables affect risk (Tables 1 and 2) and may be interrelated.¹⁻⁷ The main factors are limb injury severity (particularly vessel injuries) and overall casualty injury severity (particularly shock) with a lesser factor being over-resuscitation (particularly >5 liters of crystalloid). Tissue edema and subsequent swelling due to injury maximizes in 1 to 2 days. Additional swelling from post-injury ischemia-reperfusion (e.g., revascularization, shock, and tourniquet use) appears to delay the maximal time of limb swelling further; perhaps to 2 to 5 days post injury. High altitude (including normal AE aircraft cabin pressure), in and of itself, is not a contributor to compartment syndrome (Ritenour, et al). Compartment syndrome can lead to significant morbidity and mortality (Table 3). Surveys indicate surgeons with more training and experience are more willing to perform fasciotomy. Once the decision is made to perform a prophylactic or therapeutic fasciotomy, a **complete fasciotomy must be performed**. There is evidence to support complete compartment release by **full-length skin and fascial incisions** is superior to limited fasciotomy. Incomplete fasciotomy, a clearly preventable problem, risks worsened patient morbidity, mortality and functional outcome.
3. **Evaluation and Treatment.**
 - a. The signs and symptoms of CS are the classic 5 P's which include: pain on passive stretch of muscle often out of proportion to that of the injury as expected by the provider; palpably tense muscle compartments; paralysis; paresthesias or sensory deficit; pulselessness.² Pain is sensitive and early given a cooperative casualty, but it is not specific. Palpably tense muscle is specific but not sensitive, and usually there is some

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March 2012

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swelling.. Paralysis and paresthesias are generally late and least helpful acutely. Pulselessness is seen virtually never in civilian compartment syndrome, but occurs rarely in war, sometimes within minutes of an arterial injury or an expanding hematoma.

- b. The most common compartment syndrome is in the anterior leg.¹⁻² About 45% of all compartment syndromes are caused by tibia fracture. Open fractures, even with traumatic fasciotomy, have higher CS rates than closed fractures because they are more severe, with more swelling and more often injured arteries. The most commonly missed compartment syndromes are in the anterior and deep posterior compartments of the leg. The most commonly incompletely released compartments are also in the leg.¹

The common reasons for incomplete calf fasciotomy are:

- 1) Improper identification of the septum dividing the anterior and lateral compartments. This can be avoided by making an initial transverse incision in the fascia overlying the septum, then deliberately opening the anterior and lateral compartments separately, creating a so called “H” incision.
 - 2) Incomplete development of the deep posterior compartment release by not deliberately taking the the soleus muscle fibers off the posterior tibia. If performed correctly, the neuro-vascular bundle should be exposed in a fully decompressed deep posterior compartment.
 - 3) Fascial incisions are too short and do not cover the entire extent of the fascial compartment either at the knee or ankle levels.
- c. Passive stretch pain (e.g., ankle dorsiflexion) and palpation of muscles for tenseness combined with an index of suspicion makes up the mainstay for clinical evaluation. Pressure monitoring by manometer does not reliably diagnose CS in theater, so the diagnosis remains clinical. Since there is currently no sensitive or specific technique for establishing the diagnosis of compartment syndrome, a fasciotomy should be considered in a patient with significant mechanism of injury and clinical findings suspicious for compartment syndrome.
 - d. When monitoring patients for the development of CS, serial clinical examinations are repeated hourly when risk is high and less frequently when low. Provider experience and training improve detection. Documentation is important for later providers and performance improvement. The optimal methods of manometric monitoring of compartments and the clinically significant thresholds to identify compartment syndrome are, at present, not known.
 - e. In one study, burns sustained in combat have been associated with an increased fasciotomy rate.¹ **In the absence of crush injury, fracture, multiple trauma, over-resuscitation, electrical injury or similar indications, prophylactic fasciotomies on burned extremities may increase morbidity and mortality and are not indicated.** (For additional information on escharotomy and fasciotomy in the management of patients with extremity burns, see “Burn Care” JTTS CENTCOM CPG).
 - f. Treatment of Compartment Syndrome of Prolonged Duration (>12 hours): Occasionally casualties present with a compartment syndrome of prolonged duration (> 12 hours) due to evacuation issues. This situation is associated with markedly increased risk of

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March 2012

Joint Theater Trauma System Clinical Practice Guideline

complications including death and infection⁶. These casualties may be best treated with appropriate resuscitation, urine alkalinization, mannitol use, and intensive support. Such conservative care has led to better outcomes than fasciotomy in casualties with closed injuries with mechanically crushed muscle (see Figure 1 and Reis & Better, 2005).

Therefore, compartment syndromes with greater than 12 hours of warm ischemia with nonviable muscle should not routinely undergo fasciotomy. The role of amputation is currently unclear in this situation.

4. Performance Improvement (PI) Monitoring.

a. Intent (Expected Outcomes).

- 1) When fasciotomy is performed, all compartments are completely released through full skin and fascial incisions
- 2) When indicated, fasciotomy is performed at the time of re-vascularization of an ischemic extremity.

b. Performance/Adherence Measures.

- 1) When fasciotomy was performed, there was complete release of all compartments through full skin and fascial incisions
- 2) When indicated in patients with ischemic extremities, fasciotomy was performed at the time of re-vascularization

c. Data Source.

- 1) Patient Record
- 2) Joint Theater Trauma Registry (JTTR)

d. System Reporting & Frequency.

The above constitutes the minimum criteria for PI monitoring of this CPG. System reporting will be performed annually; additional PI monitoring and system reporting may be performed as needed.

The system review and data analysis will be performed by the Joint Theater Trauma System (JTTS) Director, JTTS Program Manager, and the Joint Trauma System (JTS) Performance Improvement Branch.

5. Responsibilities. It is the trauma team leader's responsibility to ensure familiarity, appropriate compliance and PI monitoring at the local level with this CPG.

6. References.

1. Ritenour AE, Dorlac WC, Fang R, et al. Complications after fasciotomy revision and delayed compartment release in combat patients. *J Trauma*. 2008;64(2 Suppl):S153-61; discussion S161-2. Landstuhl cohort. Inadequate fasciotomy risks mortality. Surgeons should have this.
2. Mubarak SJ, Hargens AR. Compartment Syndromes and Volkmann's Contracture. Saunders, Philadelphia, 1981. First book on compartment syndrome, a dated classic.

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March 2012

Joint Theater Trauma System Clinical Practice Guideline

3. US Army, Medical Research and Materiel Command. Compartment Syndrome: Diagnosis and Surgical Management DVD, 2008. 90 minutes, how to do surgery.
4. Office of The US Army Surgeon General, Health Policy and Services (HP&S) Directorate, All Army Action Order, Complications after fasciotomy revision and delayed compartment release in combat patients. 15 May 2007. Ritenour message.
5. Klenerman L. The Tourniquet Manual. London: Springer; 2003. The only book on tourniquets which increase the risk of compartment syndrome somewhat especially if used incorrectly such as a venous tourniquet.
6. Reis ND. Better OS. Mechanical muscle-crush injury and acute muscle-crush compartment syndrome : with special reference to earthquake casualties. J Bone Joint Surg Br. 87(4) :450-3, 2005. Late fasciotomy risks infection and mortality.
7. Walters TJ, Kragh JF, Kauvar DS, Baer DG. The combined influence of hemorrhage and tourniquet application on the recovery of muscle function in rats. J Orthop Trauma. 22(1) :47-51, 2008. Risk factors are interrelated.
8. Ritenour AE, Christy RJ, Roe JL, Baer DG, Dubick MA, Wade CE, Holcomb JB, Walters TJ. The effect of a hypobaric, hypoxic environment on acute skeletal muscle edema after ischemia-reperfusion injury in rats. J Surg Res. 2010 May 15;160(2):253-9.

Approved by CENTCOM JTTS Director,
JTS Director and CENTCOM SG

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March 2012

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APPENDIX A TABLES and FIGURES

Table 1 Risks for Acute Traumatic Compartment Syndrome*	
Decreased Compartment Volume	Tight cast or dressing, closure of prior fasciotomy, excess traction
	External limb compression or crush particularly in obtunded or incapacitated casualty
	Frostbite, burns or electric injury (may include escharotomy)
Increased Compartment Contents	Edema accumulation: embolism, intravascular thrombosis, replantation, venous tourniquet, injections, extravasation, infiltration, ergotamine ingestion, ischemia-reperfusion, swelling, artery injury or spasm, revascularization procedures, prolonged arterial tourniquet use, shock hypoperfusion, angiography and catheterization, limbs positioned well above heart, mal-positioned joints (ankle dorsiflexion,) or stretched muscles
	Prolonged immobilization and limb compression particularly with obtunded or drugged casualty, some surgical positioning
	Hemorrhage, hemophilia, coagulopathy, anticoagulation, vessel injury
	Fractures particularly tibia fractures in adults, supracondylar humerus fractures in children displaced, comminuted, or open fractures increase hemorrhage, swelling, and CS risk
	Popliteal cyst, long leg brace
<i>*Modified from reference 2</i>	

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March 2012

Figure 1

Algorithm for Clinical Decision Making on Compartment Syndrome in a Deployed Setting

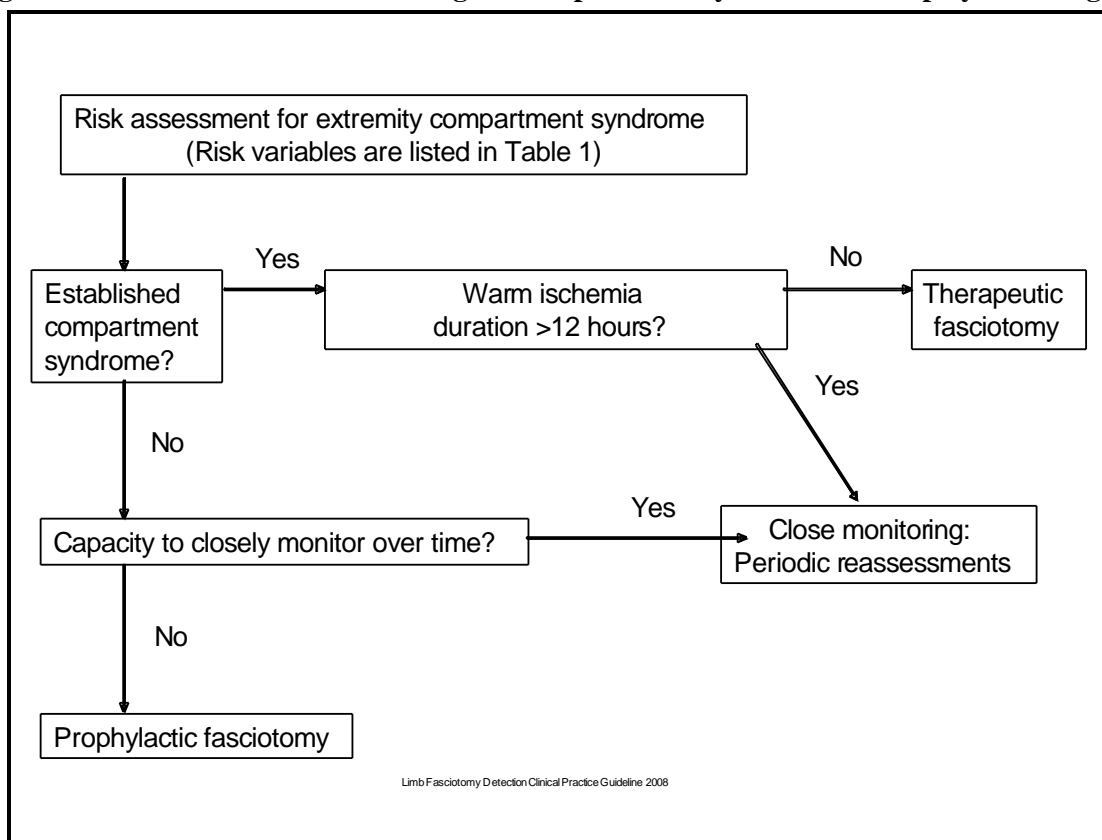


Table 2

Healthcare Record Data in the Setting of Compartment Syndrome During War

Was the fasciotomy prophylactic (compartment syndrome absent) or therapeutic (compartment syndrome present)?
When was the fasciotomy indicated and when was the injury?
When was the procedure (to determine treatment lag)?
Was the casualty able to be followed closely? If so, what was the clinical course? Was the casualty alert, intubated, or head injured?
Was there a nerve injury or nerve block/regional anesthetic?
What was the injury or risk factors, e.g., ischemia-reperfusion, that indicated the procedure?
What are the sources of ischemia-reperfusion in the injury and care of this case? Associated injuries altering risk of compartment syndrome: shock, occult hypoperfusion, hypoxia, nerve dysfunction, impaired, obtunded, or uncooperative casualty, arterial injury or ischemia, fractures with soft tissue injury, over-resuscitation syndrome, coagulopathies (including hemophilia, etc.), hematoma formation, crush injury, capillary leak syndrome, and prolonged compression.

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March 2012

Joint Theater Trauma System Clinical Practice Guideline

Table 2
Healthcare Record Data in the Setting of Compartment Syndrome During War

What were the surgical findings and muscle compartment response to the procedure?
What was the technique (dermotomy, fasciotomy, surgical approach, length of fasciotomy)?
Was there retinaculotomy or epimysiotomy? List names of all compartments released.
What delimited the fasciotomy extent, e.g., anterior leg fascia goes from the proximal tibial crest near Gerdy's tubercle to the anterior ankle extensor retinaculum (crural ligament)?
List associated procedures: debridement, irrigation, fracture fixation, etc.
Planned care: staged? Closure, repeat debridement, delayed primary, skin graft, or flap

Table 3
Morbidity Risk and Sequelae of Compartment Syndrome and Fasciotomy

Potential Morbidity: Compartment Syndrome and Early Fasciotomy	skin scar, scaly skin, ulceration, tethered tendons
	postoperative arterial or graft thrombosis, thromboembolic disease
	wound infection, nonhealing fasciotomy wounds
	limb swelling or chronic edema, shape change of limb, muscle hernia
	pain, paresis or paralysis, paresthesia
	coverage challenge: primary closure, delayed primary closure, skin graft, flap
	possible repair of arterial injury worsening ischemia-reperfusion injury
Potential Sequelae List: Compartment Syndrome with Late or Incomplete Fasciotomy	mortality, sepsis, multi-organ failure, acute kidney failure,
	myonecrosis, myoglobinemia, myoglobinuria, or rhabdomyolysis
	paresis or paralysis
	stiffness or contracture
	limb amputation, tissue loss, e.g., muscle debridement

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March 2012

Joint Theater Trauma System Clinical Practice Guideline

Table 4 Data Sheet: Compartment Names, Main Muscles, and Diagnosis and Procedure Codes				
Compartment	Main muscle(s)	Left or Right	Wound Notes, Compartment Syndrome (CS), Diagnoses, Indications, & Findings	Procedure(s) and Tissue Response to Procedure
			958.91: traumatic CS of upper extremity 958.92: traumatic CS of lower extremity 958.99: traumatic CS of other sites 958.90: CS, unspecified Prophylactic (CS absent) or therapeutic (CS present). Artery, vein, clot, & hematoma findings in compartment on exploration	83.12: fasciotomy of hand 83.14: fasciotomy, division of fascia 83.09: incision of fascia 86.09: escharotomy dermatomy, epimysiotomy Response: muscles bulged through fasciotomy, no bulge, pulse returned after absence
Deltoid	deltoid			
Arm, Anterior	biceps, brachialis			
Arm, Posterior	triceps			
Forearm, volar	flexors			
Forearm, dorsal	extensors			
Forearm, mobile wad	brachioradialis			
Hand, interossei	interossei			
Hand, central palmar	flexors			
Hand, hypothenar	digiti minimi			
Hand, thenar	thumb muscles			
Gluteus maximus	gluteus maximus			
Gluteus medius	other glutei			
Tensor fascia lata	tensor			
Thigh, anterior	quadriceps			

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March 2012

Joint Theater Trauma System Clinical Practice Guideline

Table 4 Data Sheet: Compartment Names, Main Muscles, and Diagnosis and Procedure Codes				
Compartment	Main muscle(s)	Left or Right	Wound Notes, Compartment Syndrome (CS), Diagnoses, Indications, & Findings	Procedure(s) and Tissue Response to Procedure
Thigh, posterior	hamstrings			
Thigh, adductor	adductors			
Leg, anterior	tibialis anterior			
Leg, lateral	peronei			
Leg, deep posterior	tibialis posterior			
Leg, superficial posterior	gastrocnemius			
Foot, interossei	interossei			
Foot, central	flexors			
Foot, lateral	digiti minimi			
Foot, medial	great toe muscles			
Iliacus	iliacus, psoas			

Table 5 Operative Note Template for Dictation, Surgical Planning, or Data Collection	
1. Patient	2. Surgeon
3. Date of Surgery	4. Anesthesia
5. EBL:	6. Tubes
7. Specimens	8. Complications
9. Implants, Devices	
10. <u>Indication for operation:</u> <ol style="list-style-type: none"> established compartment syndrome (therapeutic) risk of compartment syndrome developing (prophylactic) 	
11. <u>Preoperative wound appearance:</u> <ol style="list-style-type: none"> size (volume of damaged tissue: large surgeon hand ~500ml) depth, location, contamination material or matter 	

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March 2012

Joint Theater Trauma System Clinical Practice Guideline

Table 5

Operative Note Template for Dictation, Surgical Planning, or Data Collection

- | |
|---|
| 12. <u>Preoperative imaging findings:</u> <ul style="list-style-type: none">a. soft tissue injury seen & fracture |
| 13. <u>Examination under anesthesia, fluoroscopy, and surgical exploration findings:</u> <ul style="list-style-type: none">a. distal pulse statusb. wound size, depth, location, contamination, materials or matter; burn eschar location and depthc. vessel status, pulse, limb perfusion, capillary refill, congestion, edema, color of skin, warmthd. clot presence, intravascular or extra vascular site, size (volume), locatione. hematoma presencef. compartment hardness: soft, hard<ul style="list-style-type: none">i. epimysiotomy (if done by muscle name or compartment if known)ii. retinaculotomy (if done by name, e.g., partial proximal ankle extensor)iii. retinaculotomy extended from anterior leg compartment fasciotomyiv. result of fasciotomy and procedure (distal perfusion and pulse; gap in fasciotomy edges on release in cm; bulging out of muscles in compartment)v. compartments soft or hardvi. muscle color, consistency, contractility, capacity to bleed |
| 14. <u>Patient condition, status, disposition and plan:</u> |
| 15. <u>Key note for air evacuation: "Patient has been monitored for X hours after injury/surgery and has not had progression of signs or symptoms of compartment syndrome."</u> |

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March 2012

APPENDIX B

ADDITIONAL INFORMATION REGARDING OFF-LABEL USES IN CPGs

1. Purpose.

The purpose of this Appendix is to ensure an understanding of DoD policy and practice regarding inclusion in CPGs of “off-label” uses of U.S. Food and Drug Administration (FDA)–approved products. This applies to off-label uses with patients who are armed forces members.

2. Background.

Unapproved (i.e., “off-label”) uses of FDA-approved products are extremely common in American medicine and are usually not subject to any special regulations. However, under Federal law, in some circumstances, unapproved uses of approved drugs are subject to FDA regulations governing “investigational new drugs.” These circumstances include such uses as part of clinical trials, and in the military context, command required, unapproved uses. Some command requested unapproved uses may also be subject to special regulations.

3. Additional Information Regarding Off-Label Uses in CPGs.

The inclusion in CPGs of off-label uses is not a clinical trial, nor is it a command request or requirement. Further, it does not imply that the Military Health System requires that use by DoD health care practitioners or considers it to be the “standard of care.” Rather, the inclusion in CPGs of off-label uses is to inform the clinical judgment of the responsible health care practitioner by providing information regarding potential risks and benefits of treatment alternatives. The decision is for the clinical judgment of the responsible health care practitioner within the practitioner-patient relationship.

4. Additional Procedures.

- a. Balanced Discussion. Consistent with this purpose, CPG discussions of off-label uses specifically state that they are uses not approved by the FDA. Further, such discussions are balanced in the presentation of appropriate clinical study data, including any such data that suggest caution in the use of the product and specifically including any FDA-issued warnings.
- b. Quality Assurance Monitoring. With respect to such off-label uses, DoD procedure is to maintain a regular system of quality assurance monitoring of outcomes and known potential adverse events. For this reason, the importance of accurate clinical records is underscored.
- c. Information to Patients. Good clinical practice includes the provision of appropriate information to patients. Each CPG discussing an unusual off-label use will address the issue of information to patients. When practicable, consideration will be given to including in an appendix an appropriate information sheet for distribution to patients, whether before or after use of the product. Information to patients should address in plain language: a) that the use is not approved by the FDA; b) the reasons why a DoD health care practitioner would decide to use the product for this purpose; and c) the potential risks associated with such use.