Compartment Syndrome of The Lower Limb : Diagnosis, Anatomy and Treatment

Fuad Iqbal Elka Putra[1], Hanifah Hanum[2]

[1]General Practitioner, Cileungsi Regional Hospital, Bogor, West Java, Indonesia

[2]General Practitioner, Kartika Hospital, East Jakarta, DKI Jakarta, Indonesia

Abstract

Acute compartment syndrome (ACS) is an orthopaedic emergency that can threaten life and limb. A comprehensive understanding of anatomy, along with proper diagnosis and treatment, plays a crucial role in preventing lower limb ischemia. We conducted an updated review of the literature using digital databases such as PubMed, Springer Link, and Science Direct. A clinical diagnosis of compartment syndrome must be followed by surgical decompression. Clinical signs of ACS include the 6 P's: pain, poikilothermia, pallor, paresthesia, pulselessness, and paralysis. This literature review revealed that some studies showed fasciotomy is an emergency surgical procedure performed to decompress a compartment. The most common and validated method to measure limb intracompartment pressure (ICP) is by using the handheld Stryker Intra-Compartmental Pressure (STIC) Monitor System. Lower leg compartment divided into anterior, lateral, superficial posterior and deep posterior compartment, inside of compartment there are muscle, nerve, artery and vein. After diagnosis compartment syndrome we should continue to surgical decompression by fasciotomy in two methode medial incision (deep and superficial posterior compartment) and lateral incision (anterior and lateral compartments). The time limit for fasciotomy is within 8 hours or within one hour for compartment pressure 40mmHg. Early fasciotomy had a lower limb amputation rate comparison with delayed fasciotomy (8.5% vs 24.6%, p>0.001). As a conclusion early recognition and diagnosis of conditions of compartment syndrome are essential in preventing lower limb ischemia.

Keywords: Acute compartment syndrome, intracompartmental pressure, lower extremity

Kompartemen Sindrom Ekstremitas Bawah : Diagnosis, Anatomi dan Tatalaksana

Abstrak

Kompartemen sindrom akut (SKA) merupakan keadaan darurat di bidang ortopedi yang dapat mengancam jiwa dan anggota gerak. Pemahaman yang komprehensif terhadap anatomi, bersama dengan diagnosis dan pengobatan yang tepat, memainkan peran penting dalam mencegah iskemia anggota gerak bawah. Kami melakukan tinjauan literatur terbaru dengan menggunakan basis data digital seperti *PubMed, Springer Link*, dan *Science Direct*. Diagnosis klinis dari sindrom kompartemen harus diikuti dengan dekompresi bedah berupa fasiotomi. Tanda-tanda klinis SKA meliputi 6P: *pain, poikilothermia, pallor, paresthesia, pulselessness, and paralysis*. Tinjauan literatur ini mengungkapkan bahwa beberapa studi menunjukkan bahwa fasiotomi merupakan prosedur bedah darurat yang dilakukan untuk mendekompresi kompartemen. Metode paling umum dan tervalidasi untuk mengukur tekanan intrakompartemenpada anggota gerak adalah dengan menggunakan Sistem Monitor Tekanan Intra-Kompartemen Stryker. Kompartemen kaki bagian bawah dibagi menjadi kompartemen anterior, lateral, *superficial* posterior, dan *deep* posterior. Di dalam kompartemen terdapat otot, saraf, arteri, dan vena. Setelah diagnosis sindrom kompartemen tegak, studi menunjukkan harus segera dilakukan dekompresi bedah melalui fasiotomi dengan dua metode, yaitu insisi medial (kompartemen posterior dalam dan permukaan) dan insisi lateral (kompartemen anterior dan lateral). Batas waktu untuk fasiotomi kurang dari 8 jam, atau dalam waktu 1 jam jika tekanan kompartemen mencapai 40mmHg. Fasiotomi yang dilakukan sejak awal menurunkan angka amputasi anggota gerak jika dibandingkan dengan fasiotomi yang dilakukan terlambat (8.5% vs 24.6%, p>0.001). Sebagai kesimpulan, pengenalan dan diagnosis dini kondisi sindrom kompartemen menjadi hal penting dalam mencegah iskemia anggota gerak bawah.

Kata kunci: Ekstremitas bawah, kompartemen sindrom akut, tekanan intrakompartemen

Korespondensi : Fuad Iqbal Elka Putra, alamat Jl. Masjid Al-Umar no 77, Lubang Buaya, Cipayung, Bandar Lampung, email : fuadiqbal91@gmail.com

Introduction

Acute compartment syndrome (ACS) is a surgical emergency that can threaten life and limb. Additionally, lower extremity compartment syndrome often occurs in cases involving high-energy mechanisms of injury. However, it's crucial to maintain a high index of suspicion even in situations involving low-energy or penetrating trauma, vascular or crush injuries, and prolonged periods of immobility.[1] In cases where a comprehensive physical examination is not feasible, intramuscular compartment pressure measurements can serve as a valuable additional diagnostic tool, although serial physical examinations conducted by an experienced

provider are still considered the gold standard for accurate diagnosis[2]. Unlike many musculoskeletal conditions, compartment syndrome presents a greater challenge in terms of accurate diagnosis rather than treatment. Prompt performance of fasciotomies, releasing all affected muscular compartments, is crucial in preventing life- and limb-threatening consequences associated with a missed compartment syndrome.[1,2]

Compartment syndrome arises when the pressure within a specific compartment surpasses a critical threshold, leading to a reduction in perfusion pressure within that compartment. In general, longer durations of compartment syndrome and tissue ischemia are associated with poorer outcomes. Ischemia lasting only 1 hour can result in reversible neuropraxia, while ischemia lasting 4 hours can lead to irreversible axonotmesis. Ischemia lasting up to 6 hours is associated with irreversible necrosis and a higher likelihood of causing functional impairment.[2]

The anterior compartment contains the tibialis anterior, extensor hallucis longus, extensor digitorum longus, innervated by the deep peroneal nerve and supplied by the anterior tibial artery. The anterior compartment muscles function as the primary extensors of the ankle (dorsiflexion) and extensors of the toes.[3] The Lateral compartment contains Peroneus Longus and Peroneus Brevis, innervated by Superficial peroneal nerve and supplied by peroneal artery.[4]

The posterior compartment of the leg (often referred to as the "calf") further divides into superficial and deep compartments by the transverse intermuscular septum. The larger, superficial compartment of the lower leg contains the gastrocnemius, soleus (GS) and plantaris muscles. The deep layer of the leg's posterior compartment contains the popliteus, flexor digitorum longus (FDL), flexor hallucis longus (FHL), and tibialis posterior (TP) muscles. [5] A missed diagnosis of compartment syndrome is important because of direct morbidity to the patient and because it creates a high-risk medical-legal environment for the provider.[5] This review article aims to know the definition, diagnosis anatomy, and treatment of lower leg posterior compartment syndrome.

Results

Compartment syndrome occurs when the pressure within a defined compartmental space increases past a critical pressure threshold, thereby decreasing the perfusion pressure to that compartment. The commonest cause of all ACSs are tibial shaft fractures with a range from 2-9%. After the leg, the next commonest location is in the forearm, but almost any compartment can be affected: arm, thigh, foot, buttock, hand, and abdomen.[6] Any internal or external etiology can increase intra-compartmental pressure cause acute compartment syndrome. Trauma is the most likely precipitating facator, with fracture leading the greatest number of cases of compartment syndrome. Some of the etiology are : fracture, crush injury, injection injury, penetrating trauma, constrictive dressings, casting, burns, infection, bleeding disorders, arterial onjury, reperfusion and extravasation of drugs.[6,7]

Acute compartment syndrome is a clinical diagnosis, the most important determinant of ouctome is early recognition and emergency surgical intervention. Classically the signs of acute compartment syndrome include the 6 ‘P’s’ : pain, parasthesia, poikilothermia, pallor, paralysis, and pulselessness. Pain is the most common and the initial complaint and should trigger the workoup of diagnosis of acute compartment syndrome.[7] A clinical diagnosis of compartment syndrome must be followed by surgical decompression, however the diagnosis is often unclear; and pressure monitoring is commonly required. Due to its subjective nature, the absence of pain, although unlikely, does not eliminate the possibility of compartment syndrome. Several case have documented where patients with acute compartement syndrome did not experience pain.[8]

All characteristics of the six P's may not be present in every individual. Furthermore, presentation of these symptoms will vary depending on time that has lapsed since the initial pressure began to rise, the rate of ICP increase, blood pressure, and damage within the compartment. Pain [8,9] As acute compartment syndrome (ACS) advances, the affected extremity undergoes edema and becomes tense. This leads to increased pressure on nerve fibers and injured structures within the compartment.

Figure 1. The Stryker Intra-Compartmental Pressure (STIC) Monitor System.[2,6,7]

Pain is typically described as disproportionate to the injury, especially during passive stretching.

Pulselessness and pallor [8,9] are observed as late findings in acute compartment syndrome (ACS). Pulselessness is not a reliable indicator of ACS, while pallor is less frequently observed. In the early stages of ACS, arterial insufficiency is atypical, and both the dorsalis pedis and posterior tibial pulses can be palpated. Capillary refill is rapid, and the affected extremity usually appears pink. However, as the intracompartmental pressure (ICP) continues to rise, the loss of limb pulses and the development of pallor indicate compression of arterial perfusion.

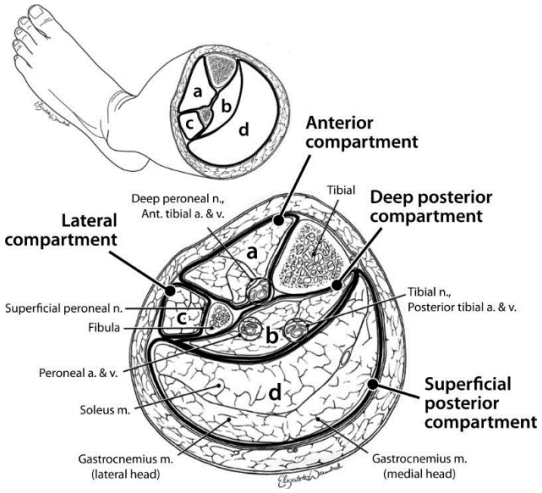

Figure 2. Cross-section of the lower leg depicting the 4 compartments and select key structures.[7]

Paresthesia and paralysis [8,9] are observed as ICP (intracompartmental pressure) increases. The rise in ICP leads to ischemia of neuronal tissues, resulting in nerve dysfunction and the development of paresthesia, followed by paresis and ultimately paralysis. Paresthesia may manifest within 30 minutes after nerve injury, while motor function deterioration can occur within four hours of muscle tissue ischemia. Functional losses, once ischemia persists for eight to 24 hours, may become irreversible. In cases of increased pressure on the deep peroneal nerve, the loss of light touch sensation often precedes limb weakness. Light touch assessment can be performed using two-point discrimination or pin prick testing. Poikilothermia refers to a change in temperature or the presence of coolness in the affected extremity. Williams et al. found a rate of infection of 28% when fasciotomy was delayed more than twelve hours[6].

Normal resting limb ICP is 0-4 mmHg.[6] With exertion, typical limb ICP may increase up to10 mmHg.[6] With ACS, an ICP of 30 mmHg or above is considered critical and treatment with emergent surgical decompression should be considered. The most common and validated method to measure limb ICP is by using the handheld Stryker Intra-Compartmental Pressure (STIC) Monitor System. [8] (Figure 1; Stryker Instruments, Kalamazoo, MI)[2,6,7].

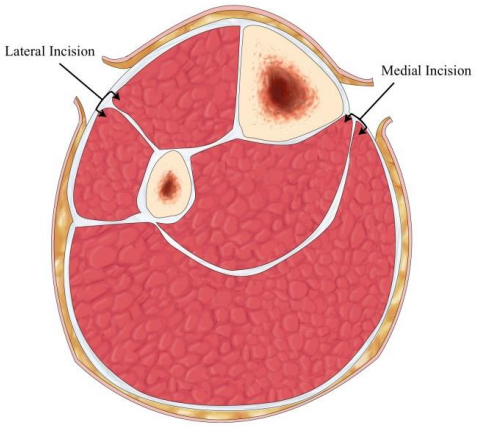

Figure 3. Four-compartment fasciotomy of the right leg through two incisions. The lateral incision decompresses the anterior and lateral compartments, and the medial incision decompresses the superficial and deep posterior compartment.[2]

The lower leg divides into 4 compartments : Anterior, Lateral, Superficial Posterior and Deep Posterior compartments (figure 2). Each compartment contains specific nerves, arteries

and veins, muscles, and bony structures that with injury contribute to the unique clinical presentations in ACS. Knowledge about the most important structures (table 1) within these compartments is critical to efficiently assess and diagnose physiologic changes in ACS that contribute to pathologic development.[7]

Table 1. Key structures within the lower leg compartments[7].

Compartment	Muscle	Artery/Vein	Nerve
Anterior	Extensor Muscle : • Tibialis Anterior • Extensor Hallucis Longus (EHL) • Extensor Digitorum Longus (EDL)	Anterior tibial	Deep Peroneal
Lateral	• Fibularis Longus • Fibularis Brevis	Peroneal	Superficial Peroneal
Superficial Posterior	Superficial Flexor : • Soleus • Gastrocnemius • Plantaris	Posterior Tibial	Tibial
Deep Posterior	Deep Flexor: • Tibialis Posterior • Flexor Hallucis Longus (FHL) • Flexor Digitorum Longus (FDL)	Posterior tibial and Peroneal	Tibial

Treatment

Immediate management of acute compartment syndrome involves identifying and removing any external compressive forces. Additionally, casts or dressings should be released down to the skin to relieve pressure. It is important not to elevate the limb, but rather keep it at the level of the heart. Elevating the limb further can potentially decrease arterial flow and exacerbate the condition.[2,7] Acute compartment syndrome need emergency surgical decompression, the time limit for fasciotomy is within 8 hours from the diagnosis of acute compartment syndrome. If the clinical symptoms obviously appeared and the measurement of compartment pressure higher than 40mmHg, surgical decompression should be done within an hour. The author suggest non-operative management for a late case presentation or missed diagnosis of acute compartment syndrome, because it asscociated with higher risk of infection. But, in these situations, case by case evaluation is mandatory.

The conventional treatment for lower extremity compartment syndrome involves a two-incision, four-compartment fasciotomy, which has been extensively documented in the literature. The lateral incision is performed to decompress the anterior and lateral compartments, while the medial incision is made to decompress the superficial and deep posterior compartments (refer to figure 3).[2] It is crucial to perform a complete fasciotomy to ensure optimal outcomes.[2] Incomplete fasciotomies do not sufficiently release the affected muscular compartment, contribute to ongoing compartment syndrome, and result in poorer outcomes.[10] A retrospective analysis of 612 patients who faced early and delayed surgical decompression (<8 hours or >8 hours) fasciotomy showed a patient with early fasciotomy had a lower limb rate amputation (8.5% vs 24.6% P>0.001). The author suggest to perform fasciotomy at the time vascular repair. The other author found patient who faced delayed fasciotomy resulted in higher amputations rate within 30 days (50% vs 5.9%, p=0.002).[11]

The lateral incision is made from the tibial tuberosity to just above the lateral malleolus. The incision is continued through the subcutaneous tissue, and a fasciotomy is performed to enter the anterior compartment. The medial incision is made two fingerbreadths posterior to the tibia from just distal to the knee to just proximal to the medial malleolus. Again, the incision is carried through the subcutaneous tissue, without injuring the saphenous vein. The superficial posterior compartment is opened first. The deep posterior

compartment is entered by taking the soleus muscle off of the posterior edge of the tibia.[12]

If the clinical manifestations of acute compartment syndrome (ACS) do not improve with initial interventions, immediate surgical fasciotomy becomes necessary. Depending on the specific circumstances, orthopedic, vascular, and plastic surgery consultations may also be required to address any associated injuries.

In cases where the diagnosis is delayed, there is a lack of muscle function, and significant trauma has occurred to the limb, primary amputation may be considered. [6] The key principles of fasciotomy are as follows: Adequate and extensile incision (1). Complete release of all involved compartment (2). Preservation of vital structure (3). Thorough debridement (4). Skin coverage at a later date (7-10 days) (5). Post-operative pain is a prominent characteristic of acute compartment syndrome (ACS), and it is crucial to provide appropriate analgesia on a regular schedule. Close monitoring of the patient is necessary to promptly detect and manage potential complications, especially rhabdomyolysis and acute renal failure. It is important to maintain an adequate urine output of more than 0.5 mL/kg by administering additional intravenous fluids.[6]

Ideally, wound closure following fasciotomy should be accomplished within a timeframe of one to five days. If closure cannot be achieved within this period, skin grafting may be necessary, requiring a longer duration of more than seven days.[13] Following wound closure, additional surgical procedures, such as tendon transfers and stabilization, may be warranted.[12]

Post-fasciotomy patients may also benefit from aggressive physical and occupational therapy to regain various functions. This may include learning to bear weight with the assistance of devices like crutches, followed by a comprehensive rehabilitation program involving exercises for range of motion (ROM), muscle flexibility, and adjacent joint mobility. [12,13]

Conclusion

Acute compartment syndrome is a serious orthopedic surgical emergency that, although rare, requires prompt attention. Diagnosing ACS conducting a comprehensive neurovascular assessment using the "six P's" (pain, paresthesia, paralysis, pallor, pulselessness, and poikilothermia), along with maintaining a high clinical suspicion. Fasciotomy should be performed less than 8 hours and within an hour for compartment pressure 40mmHg to lower limb amputation rate.

References

1. Tillinghast CM, Gary JL. Compartment Syndrome Of The Lower Extremity [Internet]. Houston. Department of Orthopaedic Surgery, 2019 [cited 2023 July 4]. Available from : https://www.ncbi.nlm.nih.gov/books/NBK553915/
2. Cone J, Inaba K. Lower extremity compartment syndrome. Trauma Surg Acute Care Open. 2017 Sep 14;2(1)
3. Lezak B, Summers S. Anatomy, Bony Pelvis and Lower Limb: Leg Anterior Compartment. 2022 Aug 8. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan–. PMID: 30969547.
4. Khan IA, Mahabadi N, D'Abarno A, Varacallo M. Anatomy, Bony Pelvis and Lower Limb: Leg Lateral Compartment. 2022 Aug 8. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan–. PMID: 30137811.
5. Mostafa E, Graefe SB, Varacallo M. Anatomy, Bony Pelvis and Lower Limb: Leg Posterior Compartment. 2023 May 23. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan–. PMID: 30726025.
6. Donaldson J, Haddad B, and Khan WS. The Pathophysiology, Diagnosis And Current Management Of Acute Compartment Syndrome. The Open Orthopaedics Journal 2014;8(1), 185–193
7. Pechar J, Lyons MM. Acute Compartment Syndrome of the Lower Leg: A Review. The Journal for Nurse Practitioners 2016;12(4), 265–270.
8. Aleisawi H, Alsager G, Pasha A, Alyousif H, Alsarhan H, Surur S. Is It Compartment Syndrome? Two Case Reports and Literature Review. Cureus. 2021 Oct 27;13(10)
9. Raza H, Mahapatra A. Acute compartment syndrome in orthopedics: causes, diagnosis, and management. Adv Orthop. 2015
10. Sonawane K, Dhamotharan P, Dixit H, Gurumoorthi P. Coping With the Fear of Compartment Syndrome Without

Compromising Analgesia: A Narrative Review. Cureus. 2022 Oct 27;14(10)

11. Coccolini, F., Improta, M., Picetti, E. *et al.* Timing of surgical intervention for compartment syndrome in different body region: systematic review of the literature. *World J Emerg Surg* **15**, 60 (2020). https://doi.org/10.1186/s13017-020-00339-8
12. Owen C, Cavalcanti A, Molina V, Honoré C. Decompressive fasciotomy for acute compartment syndrome of the leg. J Visc Surg 2016;153:293–6.
13. Collinge CA, Attum B, Lebus GF, Tornetta P 3rd, Obremskey W, Ahn J, Mirick G, Schmidt A, Spitler C, Coles C, Krause P; Orthopaedic Trauma Association's Evidence-based Quality and Value Committee. Acute Compartment Syndrome: An Expert Survey of Orthopaedic Trauma Association Members. J Orthop Trauma. 2018 May;32(5):e181-e184.