RQ [1]: In open fractures, is compartment pressure monitoring essential in uninvolved compartment?

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Section 1: Background (<300 words):

Acute Compartment Syndrome (ACS) occurs when the interstitial pressure exceeds the perfusion pressure, resulting in hypoxia and necrosis of structures within the compartment. Following injuries and fractures of the limbs, ACS is commonly seen in the legs and forearm due to their distinct closed compartments. If ACS goes unrecognized or treatment is delayed, irreversible necrosis of muscles and nerves occurs, leading to contracture and permanent nerve palsy. Early diagnosis is therefore critical for urgent intervention.

Excruciating pain out of proportion to the injury is the earliest and most valuable sign, but it can be overlooked or missed in patients receiving regional analgesia, or those who are intubated, comatose, polytraumatized, or in children. Other early findings include tense, “timber-like” swelling of the limb, paraesthesia, and pain on passive stretch. Pulselessness and paralysis are very late findings and indicate poor prognosis.

A common misconception is that ACS does not occur in open fractures. In reality, open fractures are severe injuries, and the open wound may not adequately decompress all compartments. Continuous Compartment Pressure Monitoring (CCPM) helps in the early detection of rising interstitial pressure and contributes to timely management of ACS.

With this background, the question arises: **Is clinical diagnosis sufficient, or is CCPM required in all cases of open fractures of the leg? Furthermore, is monitoring necessary for all four compartments of the leg?** To address this, relevant literature was reviewed and analysed.

Section 2: Data extraction table

S.no	Author, year of	Evidence level, Study	Sample Size (add	Study population (Inclusion and	Intervention / Groups compared	Results and Outcomes

	publication, Country	Design	individually for each group if multiple groups compared)	exclusion criteria)	Follow up duration	
1	Janzing HMJ. Et al [1], 2001, Belgium	Prospective study	100 patients (104 limbs)	Inclusion: All patients with tibia fractures including polytrauma and children treated between 1996-97	ICP monitored in 95 patients 97 fractures) Follow up at least 1 year (average 393 days) Monitored for clinical symptoms and ICP in anterior compartment using portable pressure monitor	An optimal threshold pressure with both good sensitivity and specificity could not be identified. Routine monitoring can result in overtreatment. CCPM needs to be used in combination with clinical symptoms or with serial measurement
2	Harris IA et al [2], 2006, Liverpool	Level I, Randomized Control study	Randomized 200 consecutive acute extra-articular tibia fractures into monitored and nonmonitored groups.	Inclusion: 200 consecutive acute extra-articular tibia fractures	The monitored group received continuous compartment pressure for 36 hours and the nonmonitored group received usual postoperative observations. Follow up 6 months	There were five cases of compartment syndrome in the nonmonitored group and none in the monitored group. In the monitored group, there were 18 patients with DP less than 30 mm Hg, none of whom developed compartment syndrome or late sequelae. CPPM is not indicated in alert patients who are adequately observed.

3	Al-Dadah et al [3], 2008, UK	Level III Retrospective cohort study	109 consecutive patients who underwent CCPM (MG) compared to immediate previous 109 patients who were clinically monitored (NMG)	Inclusion: patients diagnosed with tibial fractures.	Compartment pressure monitored using Stryker monitor. Compared Monitored group vs Non-monitored group	Fasciotomy rate: 15.6% in MG and 14.7% in NMG. Mean time to fasciotomy was 22h in MG and 23h in the NMG. CCPM did not increase the rate of unnecessary fasciotomies.
4	McQueen et al [4], 2013, Edinburg	Level II, Prospective cohort study	1184 consecutive patients Monitored group – 979 Non monitored group - 205	Inclusion: patients twelve years of age or older with a fracture of the tibial diaphysis admitted between 1998 and 2007. Exclusion: 129 patients (13.2%) excluded in MG due to loss of follow up and early amputation.	Acute compartment syndrome in Monitored group (n=850) vs Non-monitored group. Mean follow-up time of 59 weeks	Fasciotomy rate: 17.9% in MG and 7.3% in NMG CCPM – sensitivity 94%, specificity 98%, positive predictive value 93% and Negative predictive value 99%. CCPM should be considered for patients at risk for acute compartment syndrome.
5	Ho, K. L. K et al [5], 2017,	Prospective study	13 patients	Closed tibia fractures	Intraoperative Compartment pressure	Routine measurement results in overdiagnosis.

	Singapore				monitored in all 4 compartments using Stryker pressure monitor	ACS needs to be considered with clinical diagnosis.
6	Powell-Bowns et al [6], 2021, United Kingdom	Level III Retrospective cohort study	287 patients 171 in monitored group (MG) and 116 in non-monitored group (NMG). Open fractures: 33 in MG and 22 in NMG	Inclusion: patients with an acute tibial diaphyseal fractures and aged over 13 yrs. Exclusion: patients with fracture of the tibial plateau or the tibial plafond Study period 2012-2013	Continuous compartment pressure monitoring (CCPM) of the leg slit catheter technique. Compared MG vs NMG group for acute compartment syndrome (ACS). Follow up: average 9 (3-26 months)	21 patients developed ACS and underwent fasciotomy. Comparable rates in both groups (n=13 in the MG *vs* n=8 in NMG; p=0.82). 33% ACS in open fractures (4 in MG and 3 in NMG) Average time to fasciotomy 19.8hrs (range, 6.5-40 hrs) in the MG and 25.8hrs (range, 10-44) in the NMG (p=0.301) Continuous compartment pressure monitoring safe with no increase in the rate of fasciotomies performed. There was a trend towards reduced time to fasciotomy with CCPM.
7	Leighton, R et al.[7], 2025, Canada	Prospective study Multicentre trial	100 patients	Inclusion: Acute long bone fractures	Intra-compartmental pressure (ICP) was continuously measured pre op and for up to 18 hours post op	Immediate post-operative ICP can be higher acceptable, but usually dropped rapidly. Compartment pressure in upward trend or persistently above the perfusion pressure and even more when associated with excruciating pain needs fasciotomy. Trend of the curve in continuous pressure monitoring appears to be more significant than absolute

						pressure

Section 3: Results summary write-up (upto 500 words)

Many clinical studies have highlighted the importance of CCPM in open fractures of tibia.

McQueen et al.[4] (2013, JBJS) In a 10-year prospective database of 1184 tibial fractures, CCPM demonstrated sensitivity 94% and specificity 98%, with PPV 93% and NPV 99%. They concluded CCPM should be considered for all at-risk patients, as it markedly reduced missed diagnoses.

Powell-Bowns et al.[6] (2021, Injury) In a multicenter cohort of 287 tibial shaft fractures, 171 underwent CCPM and 116 were clinically monitored. ACS occurred in 7% overall, with no difference in complication rates between groups. However, CCPM showed a trend toward earlier fasciotomy (mean 19.8 vs 25.8 hrs) and lower need for split-skin grafting (15% vs 50%). They concluded CCPM is safe, does not increase unnecessary fasciotomies, and may improve wound outcomes.

Al-Dadah et al.[3] (2008, Injury) Compared 109 monitored vs 109 clinically assessed patients. Fasciotomy rates were similar (15.6% vs 14.7%), with no significant difference in outcomes or time to fasciotomy (22 vs 23 hrs). They concluded CCPM did not increase unnecessary fasciotomies but offered no clear benefit over vigilant clinical monitoring.

Harris et al.[2] (2006, J Trauma) A randomized trial of 200 tibial fractures found five ACS cases in the non-monitored group and none in the monitored group. Yet complication rates at 6 months were similar, and 18 monitored patients had $\Delta P < 30$ mmHg without developing ACS. Authors concluded CCPM is not indicated in alert patients under close observation, but may be useful in unconscious patients.

Concerns reported about CCPM include False Positives and Overtreatment

Ho et al.[5] (2017) prospectively measured ICP in 13 tibial fractures without clinical suspicion of ACS. Using thresholds of ICP > 30 mmHg or $\Delta P < 30$ mmHg, 62% and 23% of patients respectively would have been incorrectly diagnosed, risking unnecessary

fasciotomy. They concluded: “Diagnosis based on pressure measurements alone may result in unnecessary fasciotomies in a sizeable number of patients. Compartment syndrome remains a clinical diagnosis.”.

Janzing & Broos [1] (2001) found no optimal threshold combining sensitivity and specificity. Routine monitoring led to high fasciotomy rates, many potentially unnecessary. They cautioned against indiscriminate use, recommending ICP measurement only in symptomatic or difficult-to-assess patients.

Section 4: Discussion (<1000 words)

Acute compartment syndrome (ACS) is a limb-threatening emergency characterized by increased pressure within a closed osseofascial compartment, leading to compromised tissue perfusion and ischemia. If untreated, irreversible muscle and nerve necrosis occurs within 6–8 hours, resulting in contractures, chronic pain, neurological deficits, or even amputation. Tibial fractures, particularly diaphyseal and high-energy injuries, are the most common precipitating events. The challenge lies in timely diagnosis: clinical signs are often subtle, unreliable, or masked in sedated, polytrauma, or pediatric patients.

ACS occurs when intracompartmental pressure (ICP) rises above perfusion pressure, reducing capillary blood flow. The earliest and most reliable symptom is pain out of proportion to injury, often exacerbated by passive stretch. Other early signs include tense swelling, paraesthesia, and pain with passive movement. Pulselessness and paralysis are late findings, usually indicating irreversible damage.

Gamulin et al [8] emphasized that open tibial fractures do not protect against ACS, contradicting the traditional belief that skin lacerations decompress compartments. Their retrospective cohort of 711 patients found ACS in 9.2% overall, with higher rates in Gustilo II–III open fractures of proximal tibia (13.3%). They concluded: “Clinicians should not be wrongly reassured by an open fracture, assuming that the wound would relieve the pressure inside the muscle compartments”.

Reliance on clinical diagnosis alone is problematic. Ulmer’s systematic review [9] showed clinical signs have sensitivity as low as 13–19%, meaning most cases would be missed if only clinical criteria were used. Specificity was high (~97%), but by the time multiple signs appear, irreversible damage is likely. Consequently, the role of continuous compartment pressure monitoring (CCPM) has been debated for early diagnosis.

Continuous Compartment Pressure Monitoring (CCPM) provides objective, real-time data on ICP. The most accepted diagnostic threshold is ΔP < 30 mmHg (diastolic blood pressure minus ICP) sustained for >2 hours. This criterion, advocated by McQueen and Court-Brown, balances sensitivity and specificity better than absolute ICP thresholds.

CCPM requires specialized equipment, training, and hourly documentation. False readings may occur due to catheter malposition, clotting, or low diastolic pressures (especially in adolescents). Monitoring only the anterior compartment risks missing isolated posterior ACS.

The consensus across studies is that neither clinical assessment nor CCPM alone is sufficient. Instead, a combined approach is recommended: Clinical vigilance remains paramount, especially for pain out of proportion, stretch pain, and tense swelling. CCPM is most valuable in: Sedated, intubated, or obtunded patients, Polytrauma cases with distracting injuries, Pediatric or uncooperative patients and Equivocal clinical findings.

Clinical signs alone are unreliable—low sensitivity risks missed diagnoses (Ulmer, Powell-Bowns). CCPM improves diagnostic accuracy—high sensitivity/specificity (McQueen et al.), earlier fasciotomy (Powell-Bowns), and potentially better wound outcomes. But CCPM may overdiagnose—false positives common if thresholds applied rigidly (Ho et al., Janzing).

Acute compartment syndrome remains one of the most feared complications of tibial fractures. Early diagnosis is critical, yet challenging. Clinical signs, though specific, are insensitive and often delayed. Continuous compartment pressure monitoring offers objective data with high sensitivity and specificity, but risks overtreatment if used indiscriminately. Evidence suggests CCPM is safe, does not increase unnecessary fasciotomies, and may facilitate earlier intervention and improved wound closure. However, routine monitoring of all tibial fractures is not universally supported; selective use in high-risk or unassessable patients is most appropriate.

Section 5: Risk of bias of included studies

MODERATE: As Clinical Diagnosis is subjective and the Objective CPPM is not standardised.

Section 5: Response/Recommendation (1-2 lines as a conclusion and recommendation statement for the question)

Compartment syndrome may occur even in open fractures of the leg and can involve any of the four compartments. Early recognition is paramount and can be achieved through vigilant clinical monitoring in alert and cooperative patients. In contrast, in patients who are at high-risk and clinically unassessable, or have equivocal findings; continuous compartment pressure monitoring (CCPM) of all four compartments is recommended to minimize the risk of missed or delayed diagnosis.

Section 6: Level/ strength of Evidence:

MODERATE

Evidence was collected from seven studies (one RCT, five Prospective and two Retrospective cohort studies) with moderate risk of bias

References

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