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The Analysis Study of Surgical Management of Acute Compartment Syndrome - An Orthopaedic Comprehensive Systematic Review

[1,2] Aulia Wiratama Putra, [2] Yoga Putra Herlambang, [3] Fahmi Fauzi Sugandi, [1,2] Savira Felicia, [4] Ezra Randa, [5] Fakhri Abdurrahman, [6] Balqis Al Khansa

[1] Sayang Regional General Hospital - Type B Teaching Hospital
, Cianjur Regency, West Java, Indonesia
[2] Faculty of Medicine, Trisakti University, Special Region of Jakarta, Indonesia
[3] Kesehatan Kerja Regional General Hospital, Bandung Regency, West Java, Indonesia
[4] Abdoel Wahab Sjahranie Regional General Hospital, Samarinda City, East Kalimantan, Indonesia
[5] Faculty of Medicine, University of Sriwijaya, Palembang City, South Sumatera, Indonesia
[6] Pandanaran Primary Health Care, Semarang City, Central Java, Indonesia

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ABSTRACT

Introduction: Acute compartment syndrome (ACS), first described in 1881 by Richard von Volkmann, remains a critical orthopedic emergency requiring timely diagnosis and intervention. Despite advancements, ACS poses significant clinical and economic challenges. It is commonly diagnosed through surrogate indicators like fasciotomy rates. The 2018 clinical practice guideline (CPG) by the American Academy of Orthopaedic Surgeons (AAOS) emphasized evidence-based practices for diagnosis and management. This systematic review synthesizes historical, current, and emerging evidence on ACS surgical management to improve clinical outcomes.

Method: This systematic review adheres to PRISMA 2020 guidelines, focusing on studies published between 2014–2024. Databases such as PubMed, ScienceDirect, Embase, and Cochrane Library were searched using terms like "Acute Compartment Syndrome," "Fasciotomy," and "Surgical Decompression." Inclusion criteria involved human studies on ACS surgical management, while reviews, non-peer-reviewed articles, and animal studies were excluded. Data extraction focused on intervention techniques, timing, outcomes, and complications. Quality assessment ensured robust methodological inclusion.

Results: Eight studies met the eligibility criteria. Findings revealed the importance of early fasciotomy (preferably within 6–12 hours) in preventing severe complications like ischemic contracture, infection, and amputation. Variations in surgical techniques, including single-incision vs. two-incision fasciotomy, were reported, showing flexibility in management approaches. Studies emphasized multidisciplinary care and tailored surgical approaches to optimize patient outcomes.

Discussion: ACS is characterized by a pathological rise in intracompartmental pressure leading to reduced tissue perfusion, ischemia, and potentially irreversible damage. Early intervention is crucial, with clinical symptoms such as severe pain being key diagnostic markers. Surgical decompression remains the cornerstone of treatment, supported by advances in wound management, such as negative pressure systems and skin grafting. Complications, including nerve damage and chronic functional deficits, underscore the need for timely diagnosis and intervention. Variability in study methodologies and healthcare settings highlights challenges in standardizing ACS management, warranting further research.

Conclusion: This review underscores the critical importance of early diagnosis, tailored surgical techniques, and multidisciplinary collaboration in managing ACS. Future research should address gaps in standardizing care, enhancing early detection, and reducing long-term complications.

Keywords: acute compartment syndrome, ACS, fasciotomy, surgical decompression, trauma, ischemia

INTRODUCTION

Acute compartment syndrome (ACS), first described by Richard von Volkmann in 1881, remains a critical orthopaedic emergency requiring prompt diagnosis and intervention.[1,2] Volkmann observed that paralysis and contracture occurred as a consequence of impaired blood supply to the affected muscles. Subsequently, in 1924, Paul Jepson demonstrated experimentally that timely surgical decompression could prevent ischaemic contractures, further emphasizing the importance of early intervention in ACS management.[3,4]

Despite advancements, ACS continues to pose significant clinical and economic challenges. The true incidence of ACS is difficult to determine, as fasciotomy often serves as a surrogate indicator of its diagnosis. Patients with ACS frequently experience extended hospital stays, elevated healthcare costs, and persistently impaired function and quality of life. Moreover, medicolegal implications surrounding the diagnosis and treatment of ACS impact patients, healthcare providers, and systems alike.[1,5,6]

Recognizing these challenges, the American Academy of Orthopaedic Surgeons (AAOS), in collaboration with several organizations, including the Orthopaedic Trauma Association and the U.S. Department of Defense, developed a clinical practice guideline (CPG) for the management of ACS. Published in 2018, the CPG emphasizes evidence-based approaches for diagnosis and treatment, incorporating insights from an exhaustive review of over 3,600 abstracts and 480 full-text articles. This effort culminated in 15 recommendations, including consensus statements and graded guidelines, aimed at improving patient outcomes and advancing research in ACS management.[7,8]

This systematic review aims to provide a comprehensive analysis of the surgical management of ACS, exploring its historical evolution, current evidence-based practices, and areas requiring further investigation. By synthesizing existing literature, this review seeks to guide clinicians in optimizing care for patients with this critical condition.

METHOD

Protocol

This systematic review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency, consistency, and reproducibility of the findings. The protocol is designed to systematically review and analyze the surgical management strategies and outcomes of acute compartment syndrome (ACS) in orthopedic and traumatology settings.

Criteria for Eligibility

This review will focus on studies published in the last two decades that investigate the diagnosis, surgical intervention, and outcomes associated with acute compartment syndrome. Research studies published in English between 2014 and 2024 will be considered if they involve patients diagnosed with ACS due to trauma or ischemia and discuss the effectiveness of fasciotomy or other surgical treatments. Eligible studies will include clinical trials, cohort studies, case-control studies, and observational studies that provide data on surgical techniques, timing of intervention, patient outcomes, and complications. Studies will be excluded if they are review articles, expert opinions, conference abstracts, non-peer-reviewed articles, animal studies, in vitro experiments, or if they lack detailed methodology relevant to surgical management. The primary focus will be on human subjects undergoing surgical intervention for ACS in orthopedic and trauma cases.

Search Strategy

A comprehensive search will be conducted using databases such as PubMed, ScienceDirect, Embase, Cochrane Library, and Web of Science. The search will focus on key terms related to acute compartment syndrome, surgical management, and fasciotomy outcomes. The primary search terms will include "Acute Compartment Syndrome," "ACS," "Fasciotomy," "Surgical Decompression," and "Orthopedic Surgery." Secondary terms such as "Trauma," "Ischemia," "Compartment Pressure," and "Patient Outcomes" will also be utilized. Boolean operators (AND, OR) will be used to ensure a comprehensive retrieval of relevant literature. Example search strings include: ("Acute Compartment Syndrome" OR "ACS") AND ("Fasciotomy" OR "Surgical Decompression") AND ("Trauma" OR "Ischemia") AND ("Orthopedic Surgery" OR "Outcomes").

Data Retrieval

The review process will involve an initial screening of titles and abstracts to assess their relevance to the study of surgical management and outcomes in acute compartment syndrome. Full-text articles that meet the inclusion criteria will be reviewed, and data extraction will focus on study characteristics, diagnostic criteria for ACS, surgical interventions performed, timing and techniques of fasciotomy, and patient outcomes, including complications and long-term recovery. Studies not meeting these criteria will be excluded.

Quality Assessment and Data Synthesis

Two independent reviewers will assess each selected article for methodological quality based on study design, sample size, control of confounding variables, and reliability of outcome measures. Any disagreements between the reviewers will be resolved through discussion or with the involvement of a third reviewer. Only studies with robust methodological quality will be included in the final synthesis.

A qualitative analysis will summarize the findings related to the surgical management of acute compartment syndrome, focusing on the timing of intervention, techniques used, and patient outcomes, including rates of muscle necrosis, limb salvage, and functional recovery. If sufficient homogeneous data are available, a meta-analysis may be conducted to quantify the effectiveness of different surgical approaches. Subgroup analyses will explore the impact of variables such as patient age, injury severity, time to intervention, and specific surgical techniques employed.

Table 1. Search Strategy and Results

Database	Search Strategy	Hits
PubMed	("Acute Compartment Syndrome" OR "ACS") AND ("Fasciotomy" OR "Surgical Decompression") AND ("Trauma" OR "Ischemia") AND ("Orthopedic Surgery" OR "Outcomes")	227
ScienceDirect	"Acute Compartment Syndrome" AND "Fasciotomy" AND "Surgical Decompression" AND "Trauma" AND "Outcomes"	203
Embase	'Acute Compartment Syndrome' OR 'ACS' AND 'Fasciotomy' OR 'Surgical Decompression' AND 'Trauma' OR 'Ischemia'	181
Cochrane Library	"Acute Compartment Syndrome" AND "Fasciotomy" AND "Orthopedic Surgery" AND "Outcomes"	176
Web of Science	"Acute Compartment Syndrome" AND "Fasciotomy" AND "Surgical Management"	198

Database	Search Strategy	Hits
	AND "Trauma" AND "Patient Outcomes"	

This systematic review follows a structured approach to identify, evaluate, and synthesize the current evidence on the surgical management of acute compartment syndrome, aiming to provide insights into best practices and improve clinical outcomes in orthopedic and trauma care.

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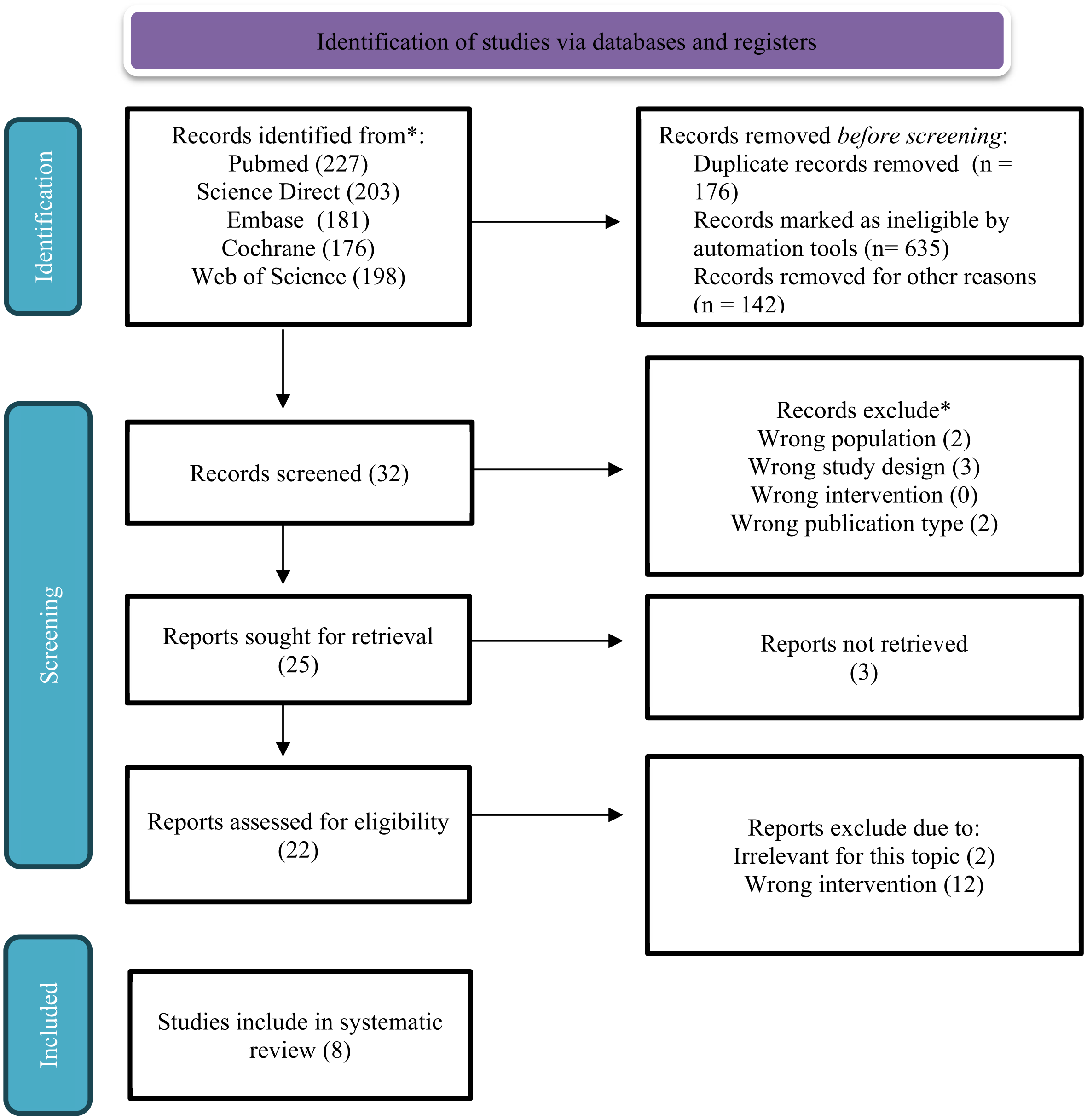

Figure 1. PRISMA Flowchart for Study Selection

RESULT

Our research team first gathered publications from reputable sources such as Science Direct, PubMed, and SagePub. After a thorough three-level screening procedure, only eight papers were determined to be directly relevant to our ongoing systematic evaluation. Following that, these sections were picked for additional research and a close reading of the entire manuscript. The material that was evaluated for this analysis is compiled in Table 2 for ease of viewing.

Table 2. The literature included in this study

Author	Origin	Method	Sample Size	Result
de Bruijn J et al., 2021.[9]	India	Randomized controlled trial.	Included in the study were 50 patients (66% female; median age, 22 years [range, 18-65 years]).	No differences between the devices were found in terms of perioperative complications (both had none), minor postoperative complications including hematoma and superficial wound infection (overall complication rate: FascioMax, 8% vs Due, 6%), or reduction of CECS-associated symptoms at rest and during exercise. At long-term follow-up (>1 year), 82% of the patients were able to regain their desired type of sport, and 67% (33/49) were able to exercise at a level that was comparable with or higher than before their CECS-associated symptoms started.
Barkay et al., 2021.[10]	Israel	A Retrospective Cohort Study	25 patients.	Fasciotomies were performed for compartment syndrome caused by fracture in 11 patients (44%), and due to insults other than frac- tures in 14 patients (56%). The average time to fasciotomy in patients without a fracture was 10.21 hours and 16.55 hours with a fracture. Fasciotomy performed more than 24 hours from the initial insult was not found to significantly affect long- term sequelae compared to fasciotomy performed earlier than 24 hours from the initial insult. The non-fracture group had more long-term sequelae than the fracture group (13/15 pa- tients and 5/11 patients, respectively).
Pallister et al., 2016.[11]	UK	A non-invasive study normal active volunteers was conducted.	Fourteen healthy active volunteers underwent hand-held ultrasound to identify the antero- lateral inter-muscular septum in the left lower limb, which	Hand held ultrasound was successful in identifying the position of the inter-muscular septum in healthy volunteers, as confirmed on MRI scanning. The position and number of peroneal and anterior perforators proved very variable. Direct decompression of the anterior compartment would result in the loss of all anterior perforators in all subjects. Decompression with the skin incision over the intermuscular septum would not jeopardise any peroneal muscular perforators.

			was then marked using cod liver oil capsules	
Du et al., 2019. [12]	China	Prospective study.	46 patients with acute compartment syndrome were enrolled, including 8 cases with serious complications.	All patients had necrotic muscles and nerves, damaged vascular, and severe foot deformities. In the early stage, each patient received systemic support and wound debridement to promote wound healing. For patients with serious complications, a number of medical measures, including installation of Ilizarov external frames, arthrodesis, osteotomy fusion, arthroplasty, or tendon lengthening surgery, were performed to achieve satisfactory clinical outcomes. All the patients resumed weight-bearing walking and daily exercises.
Chang G et al., 2020. [13]	China	This retrospective study included all patients treated for ACS by a single surgeon during a 3-year period.	Eleven patients were included in the study.	A protocol was used including a single-incision technique followed by vacuum-assisted wound-closure dressing, periodic return to the operating room at 48- to 72-hour intervals, and sequential wound closure with vertical mattress sutures. Complications associated with this protocol were analyzed. Eleven patients were included in the study. Average length of follow-up was 12 months (range, 2-35 months). There were no instances of malunion, deep or superficial infection, intraoperative neurovascular injury, or progressive neurologic deficits-indicating adequate release of all 4 compartments through a single incision. All patients were closed primarily without need for skin grafting. Average time to primary closure was 4.5 days. One patient had a tibial fracture nonunion and 1 had distal wound breakdown, which healed by secondary intention.
Neal, et al., 2016. [14]	US	Experimental study.	8-paired, fresh-frozen human cadaver legs by infusing normal saline into all 4 compartments.	Sustainable pressures greater than 60 mm Hg were established in all 4 compartments of each specimen. Postfasciotomy pressures were all reduced to less than 30 mm Hg using both single-incision and 2-incision techniques. There were no statistically significant differences in postrelease pressures between the 2 techniques in any compartment. The

				average postrelease pressure in the deep posterior compartment was 4.6 mm Hg (range 0-10 mm Hg) with the single-incision technique and 5.6 mm Hg (range 1-10 mm Hg) with the 2-incision technique (P = 0.44). After complete fasciotomies, it was not possible to recreate the elevated pressures of acute compartment syndrome in the deep posterior compartment of any specimen.
MacKenzie et al., 2020.[15]	US	A retrospective review.	There were 206 patients (21 ACS) with long-term outcome data at a mean of 5 years (1–9).	There was no significant difference between ACS and non-ACS groups in the overall rate of infection (17% vs. 9.2%, respectively; P = 0.14), deep infection (4.9% vs. 3.8%; P = 0.67), or nonunion (4.9% vs. 7.0%; P = 1.00). There were 206 patients (21 ACS) with long-term outcome data at a mean of 5 years (1–9). There was no significant difference between groups about the EQ-5D (P = 0.81), the Oxford Knee Score (P = 0.24), or the Manchester–Oxford Foot Questionnaire (P = 0.63). Patient satisfaction was reduced in patients who developed ACS (77 vs. 88; P = 0.039).
Yuan et al., 2020. [16]	China	Retrospective study	56 pediatric patients with early osteofascial compartment syndrome	The osteofascial compartment syndrome was diagnosed at 7.4 ± 2.1 h after injury, and then fasciotomy was performed at 1.4 ± 0.4 h later. The average procedure time of fasciotomy was 12.7 ± 4.8 min. No postoperative incision infections or neurovascular injuries were observed in all the patients. The incisions completely healed in 7-10 days with an average healing time of 8 days without secondary suture. The patients were followed up for an average of 5.1 years. No Volkmann's contractures in the injured limbs were found. The appearance, electromyography, and nerve conduction velocity of the affected limbs were not significantly different from that of the contralateral limbs. All the patients were free of symptoms and were fully recovered of sensation and function, being an "excellent" outcome at the latest follow-up.
Lollo et al., 2016.[17]	US	Retrospective chart analysis.	One hundred twenty-four	One hundred and eight patients were assessed at 12 months. Eighty-one percent were male.

			patients were enrolled in this study.	Motorized vehicles caused 51% of injuries in males. Forty-one percent of injuries were tibia fractures. Acute kidney injury occurred in 2.4%. Mean peak serum creatine kinase levels were 58,600 units/ml. Gauze dressing was used in 78.9% of nonfracture patients and negative pressure wound vacuum therapy in 78.2% of fracture patients. About 21.6% of patients with CS had prior surgery. Nearly 12.9% of patients required leg amputation. Around 81.8% of amputees were male. Sixty-seven percent of amputees had associated vascular injuries. Foot numbness occurred in 20.5% of patients and drop foot palsy in 18.2%. Osteomyelitis developed in 10.2% of patients and fracture nonunion in 6.8%. About 14.7% of patients underwent further orthopedic surgery. At long-term follow-up, 10.2% of patients reported moderate lower extremity pain and 69.2% had returned to work.

Table 2. Critical appraisal of Study

Parameters	de Bruijn et al., 2021	Barkay et al., 2021	Pallister et al., 2016	Du et al., 2019	Chang et al., 2020	Neal et al., 2016	MacKenzie et al., 2020
1. Bias related to temporal precedence							
Is it clear in the study what is the "cause" and what is the "effect" (ie, there is no confusion about which variable comes first)?	Clear cause-effect relationship.	Clear temporal relationship.	Temporal relationship was clear.	Cause-effect relationship described.	Temporal relationship clearly stated.	Clear cause-effect established.	Cause-effec established over lon term follov up.
2. Bias related to selection and allocation							
Was there a control group?	Randomized controlled trial with control group.	Retrospective, no control group.	No control group.	No explicit control group.	No control group.	No control group.	Retrospectiv with contr group (AC vs. no ACS).
3. Bias related to confounding factors							
Were participants included in any	Participants	Confounding	Homogeneous	Limited	Differences	Comparisons	Groups n

comparisons similar?	well-matched.	factors addressed (fracture vs. non-fracture).	participants (healthy volunteers).	adjustment for confounding factors.	between groups clearly described.	based on notstandardized models.	fully matched; differences analyzed.
4. Bias related to administration of intervention/exposure							
Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Consistent interventions.	Treatment protocols varied.	Consistent intervention.	Standardized interventions described.	Consistent protocol.	Intervention consistently applied.	Treatment protocols consistent.
5. Bias related to assessment, detection, and measurement of the outcome							
Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	Consistent, reliable pre- and post-intervention measurement.	Long-term outcomes assessed consistently.	Single measurement; MRI confirmation reliable.	Reliable, consistent outcome measurement.	Reliable and consistent measurements.	Reliable post-intervention outcome measurements.	Consistent, reliable too for measuremen
Were the outcomes of participants included in any comparisons measured in the same way?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were outcomes measured in a reliable way?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6. Bias related to participant retention							
Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Follow-up complete (>1 year).	Follow-up differences not analyzed in detail.	Not applicable (volunteer-based).	Long-term follow-up reported; limited details.	Follow-up described adequately.	Not applicable (cadaver study).	Long-term follow-up described b differences not analyze
7. Statistical conclusion validity							

Was appropriate statistical analysis used?	Appropriate statistical analysis.	Statistical analysis performed appropriately.	Limited but appropriate statistical analysis.	Appropriate statistical analysis.	Statistical tests appropriate.	Descriptive statistics; limited inferential testing.	Appropriate statistical tests used.

DISCUSSION

Acute compartment syndrome (ACS) is defined as a critical increase in pressure within a confined compartmental space, leading to a significant reduction in tissue perfusion pressure within that compartment. This condition can arise from any elevation in interstitial pressure within an osseo-fascial compartment, compromising tissue viability.[18] Tissue perfusion is directly proportional to the difference between capillary perfusion pressure (CPP) and interstitial fluid pressure. When fluid, such as blood from bleeding, enters a compartment with fixed volume, the resulting increase in tissue and venous pressures may exceed CPP, causing capillary collapse. This leads to muscle and nerve ischemia. Similarly, external compression that reduces the compartment's size can increase intracompartmental pressure and lower CPP, exacerbating ischemic conditions.[19,20]

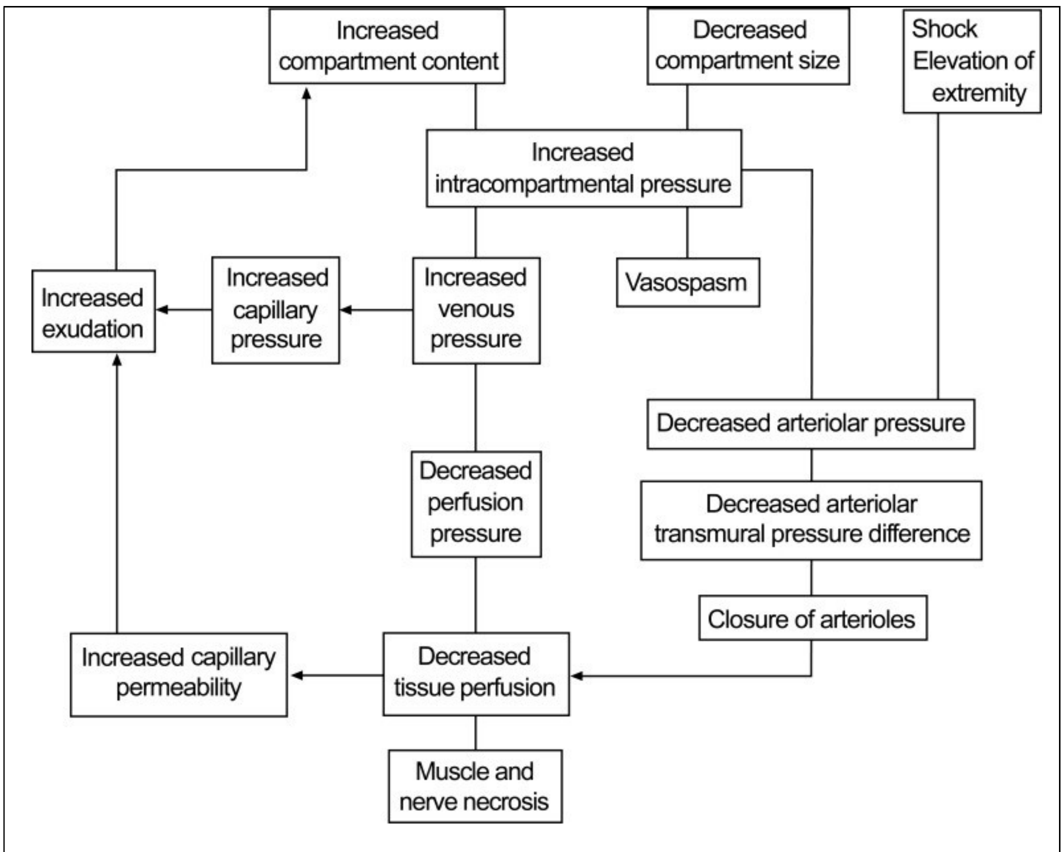

Figure 2. Illustrates The Cascade Of Events That Culminate In ACS.[21]

Compartment syndromes can develop in any part of the body where tissue expansion capacity is minimal or absent. Tibial shaft fractures, occurring in 2-9% of cases, are the most common cause of ACS. The forearm is the second most frequently affected location, but ACS can occur in the arm, thigh, foot, buttock, hand, abdomen, and other areas. Prolonged poor positioning of unconscious patients can also precipitate ACS. Essentially, any internal or external factor that increases intracompartmental pressure can induce compartment syndrome. Table

1 provides a comprehensive list of common causes. Epidemiological data suggest an incidence of 3.1 per 100,000 population, with males being ten times more likely to be affected than females.[19,22]

Table 3. Common causes of ACS.

- Fracture
- Crush injury
- Injection injury
- Penetrating trauma
- Constrictive dressings
- Casts
- Burns Infection
- Bleeding disorders
- Arterial injury
- Reperfusion
- Extravasation of drugs

The prognosis of ACS is influenced by multiple factors, including the severity of the injury, duration of ischemia, pre-existing health status, and most critically, the time elapsed before fasciotomy. Prompt surgical intervention is vital. Rorabeck reported almost complete limb function recovery if fasciotomy was performed within six hours. Delays up to twelve hours resulted in 68% recovery of normal function, whereas delays beyond twelve hours saw a dramatic decline to only 8% recovery. Late diagnosis can result in irreversible ischemia, leading to severe complications such as neurological deficits, muscle necrosis, ischemic contracture, infection, chronic pain, delayed fracture union, rhabdomyolysis, amputation, and even death.[22]

The diagnosis of ACS is predominantly clinical, with early recognition and urgent surgical intervention being paramount. The classic symptoms of ACS are encapsulated in the "five Ps": pain, pallor, pulselessness, paralysis, and paresthesia. Among these, pain—described as out of proportion to the injury and exacerbated by passive stretching of the affected muscles—is the earliest and most reliable indicator. However, pain assessment can be challenging in unconscious patients or those with severe trauma. Pulselessness and paralysis are late signs and typically indicate significant arterial injury or prolonged ischemia. Subtle physical signs, such as a firm, wooden feeling on deep palpation and reduced two-point discrimination or vibration sense, may be present in early stages. If ACS is suspected, urgent surgical fasciotomy is required. In cases of diagnostic uncertainty, intracompartmental pressure measurements can provide confirmation. A pressure difference (delta pressure) of ≤30 mmHg between diastolic blood pressure and intracompartmental pressure is a reliable threshold for decompression. Continuous pressure monitoring in high-risk patients may enable earlier detection of ACS, potentially reducing time to fasciotomy and subsequent complications.[23]

The immediate management of ACS involves the removal of external compressive forces, such as tight casts or dressings, and lowering the limb to the level of the heart to optimize arterial flow. Fluid resuscitation and correction of metabolic abnormalities are essential to prevent renal failure and other systemic complications. Definitive treatment involves fasciotomy, which requires input from orthopedic, vascular, and plastic surgeons to address associated injuries. In cases of delayed diagnosis or severe limb trauma, primary amputation may be necessary.[23]

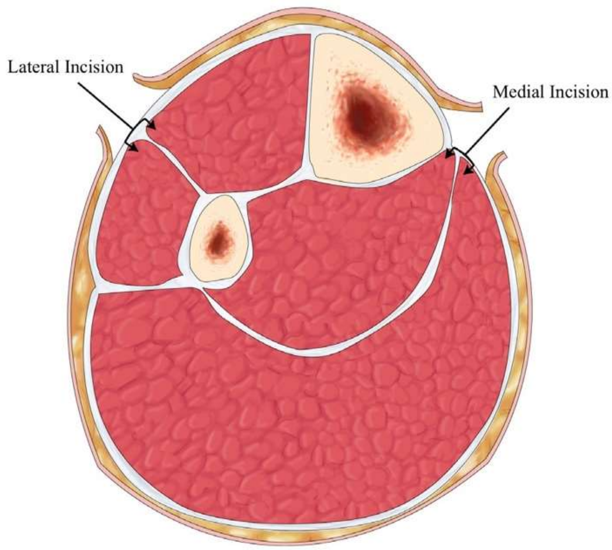

Figure 3. Four-compartment fasciotomy of the right leg through two incisions. The lateral incision decompresses the anterior and lateral compartments, and the medial incision decompresses the superficial and deep posterior compartments.

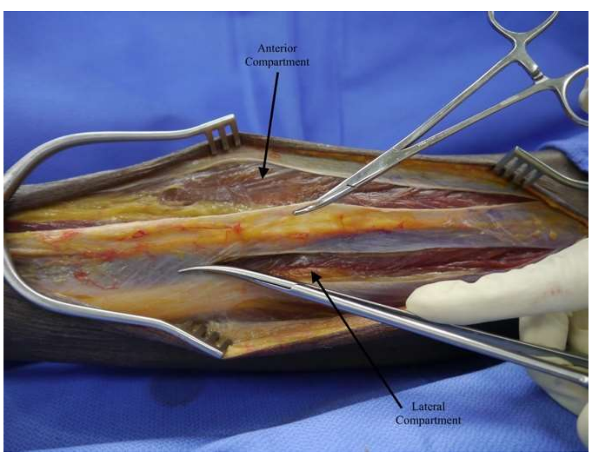

Figure 4. Identification of the septum, which separates the anterior and lateral compartments. The lateral compartment is decompressed with long scissors.50

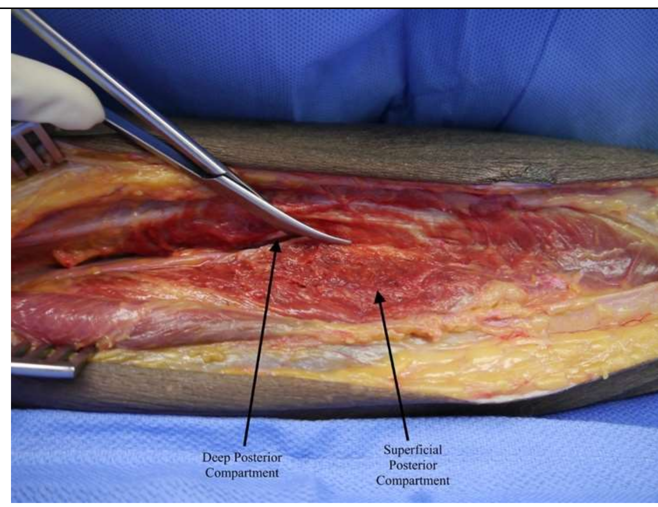

Figure 5. Left leg fasciotomy, medial incision. The superficial compartment is decompressed with a fascial incision, made about two fingerbreadths posterior to the tibia. The deep posterior compartment is decompressed through a fascial incision just behind the edge of the tibia.50

The principles of fasciotomy include extensile incisions for adequate compartment decompression, preservation of vital structures, thorough debridement, and delayed wound closure or grafting once swelling subsides. For the leg, a two-incision technique is recommended to release the anterior, lateral, and posterior compartments effectively. Similarly, specific approaches exist for the thigh, forearm, hand, and foot to decompress their respective compartments. Delayed fasciotomy, particularly beyond eight hours, is controversial due to the risk of irreversible tissue damage and complications such as infection and multi-organ failure. Wound management after fasciotomy often involves delayed primary closure or skin grafting within 7-10 days, with interim coverage using absorbent dressings or negative pressure systems. [24]

Complications from fasciotomy are not uncommon and include altered sensation, pruritus, discoloration, chronic venous insufficiency, and tethered scars, among others. In patients with underlying bleeding disorders, such as hemophilia, the diagnosis and management of ACS pose additional challenges. Initial treatment focuses on correcting clotting deficiencies and achieving hemostasis. Fasciotomy is reserved for cases where conservative measures fail, given the higher risks of amputation and other adverse outcomes. [23,25]

In summary, ACS is a medical emergency that requires early recognition and prompt intervention to prevent devastating outcomes. Effective management hinges on timely surgical decompression, meticulous postoperative care, and addressing systemic complications to optimize patient recovery and functional outcomes.

The included studies provide a comprehensive overview of various aspects of acute compartment syndrome (ACS) management, encompassing surgical techniques, outcomes, and complications. Collectively, they highlight the importance of early diagnosis, individualized surgical approaches, and multidisciplinary care in achieving favorable outcomes. However, variations in study methodologies, patient populations, and healthcare settings reveal the complexities and challenges in standardizing ACS management.

De Bruijn et al. (2021) conducted a randomized controlled trial comparing two devices for treating chronic exertional compartment syndrome (CECS), finding no significant differences in complications or symptom relief. Notably, long-term outcomes showed 82% of patients resuming desired sports activities, highlighting the potential for functional recovery with effective intervention. This study underscores the necessity of long-term follow-up in assessing the success of ACS interventions.[9]

Barkay et al. (2021) addressed the timing of fasciotomy in fracture versus non-fracture-related ACS. Their retrospective cohort study revealed that delayed fasciotomy (>24 hours) did not significantly worsen long-term outcomes, though non-fracture cases exhibited more sequelae. These findings emphasize the need for careful patient selection and suggest that prompt intervention remains critical in minimizing complications, especially in non-fracture ACS. [10]

Pallister et al. (2016) explored anatomical variability in healthy volunteers using handheld ultrasound and MRI. Their findings highlighted significant variability in the position of peroneal and anterior perforators, suggesting that tailored surgical approaches could avoid unnecessary damage to critical structures during decompression. This insight is particularly relevant in optimizing outcomes while minimizing risks during surgery. [11]

Du et al. (2019) reported on severe ACS cases requiring extensive interventions, such as Ilizarov frames and arthrodesis. Despite the severity of initial deformities, all patients achieved functional recovery, demonstrating that aggressive and multidisciplinary management can yield satisfactory outcomes even in the most challenging cases.[12] Chang et al. (2020) evaluated a single-incision fasciotomy protocol incorporating vacuum-assisted wound closure. The protocol showed efficient timelines for wound closure with minimal complications, highlighting a promising approach for streamlining ACS care while ensuring safety and effectiveness.[13]

Neal et al. (2016) compared single-incision and two-incision fasciotomy techniques in cadaveric models, finding both methods effectively reduced compartment pressures without significant differences. This evidence supports the flexibility in surgical techniques, allowing clinicians to choose the approach best suited to individual patient anatomy and surgical expertise. [14]

MacKenzie et al. (2020) compared long-term outcomes in ACS and non-ACS patients, finding no significant differences in infection rates, union rates, or functional scores. However, patient satisfaction was lower in the ACS group, underscoring the psychological and functional burden of ACS despite adequate physical recovery. [15]

Yuan et al. (2020) focused on pediatric ACS, demonstrating that early diagnosis and timely fasciotomy resulted in excellent outcomes with no long-term impairments. Their findings emphasize the critical importance of prompt intervention in children to prevent complications such as Volkmann's contractures and ensure full functional recovery.[16] Lollo et al. (2016) provided a detailed analysis of ACS complications, reporting outcomes such as amputation, osteomyelitis, and drop foot palsy. Their findings highlight the severe morbidity associated with delayed or inadequate ACS management, especially in cases involving vascular injury.[17]

This systematic review has several limitations that should be acknowledged. Firstly, the heterogeneity in study designs, sample sizes, and populations makes direct comparisons challenging. Randomized controlled trials (e.g., de Bruijn et al., 2021) provide high-quality evidence, but their limited scope may not capture the full spectrum of ACS presentations seen in broader clinical practice. Conversely, retrospective studies (e.g., Barkay et al., 2021; Chang et al., 2020) may be subject to biases such as incomplete data and confounding variables. Secondly, variations in healthcare settings and resource availability across studies influence the applicability of findings. For instance, advanced surgical protocols (e.g., vacuum-assisted wound closure) may not be accessible in resource-limited settings, potentially limiting the generalizability of those results. Additionally, many studies reported outcomes over relatively short follow-up periods, which may not capture late complications or long-term functional impairments. Studies with longer follow-up durations (e.g., MacKenzie et al., 2020; Yuan et al., 2020) provide valuable insights but remain sparse. Finally, pediatric and adult populations were analyzed together, despite potentially differing pathophysiology and treatment responses. The inclusion of diverse etiologies, such as fracture and non-fracture ACS, adds another layer of complexity to the synthesis of findings.

CONCLUSION

This systematic review highlights the critical role of fasciotomy as the primary treatment for compartment syndrome, with evidence showing favorable long-term outcomes and low complication rates when performed promptly and using appropriate techniques. Early diagnosis and intervention are pivotal in preventing irreversible damage, while delays can lead to significant long-term sequelae, such as functional impairments and deformities. Advances in diagnostic modalities, such as ultrasound and MRI, combined with improved surgical techniques, have enhanced the precision of diagnosis and treatment, contributing to better patient outcomes. However, the review also reveals certain limitations in the existing literature, including small sample sizes, retrospective designs, and variability in study methodologies, which underscore the need for further research.

Future studies should focus on establishing standardized diagnostic criteria, comparing surgical approaches, and evaluating long-term functional and quality-of-life outcomes. Additionally, the incorporation of advanced wound care protocols and postoperative rehabilitation may further improve recovery and reduce complications. Addressing these gaps will provide stronger evidence for optimizing the management of compartment syndrome and ensuring consistent, high-quality patient care.

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