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RISKS AND INTERVENTIONS IN COMPARTMENT SYNDROME IN CHILDREN WITH CRITICAL POLYTRAUMA

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ARTIGO DE REVISÃO

RESUMO

A Síndrome Compartimental Aguda (SCA) é uma complicação frequente em pacientes politraumatizados, caracterizada pelo aumento da pressão intracompartimental nos órgãos ou membros acometidos. Quando não identificada e tratada precocemente, pode evoluir para isquemia, necrose tecidual, comprometimento muscular, amputações e até óbito. Essa condição é mais prevalente entre pacientes internados em Unidades de Terapia Intensiva (UTIs). Este estudo teve como objetivo revisar as manifestações clínicas da SCA em crianças, seus principais fatores predisponentes, estratégias terapêuticas utilizadas e sua efetividade, com ênfase em casos de politrauma crítico. A metodologia adotada foi uma revisão integrativa da literatura, com buscas nas bases de dados *SciELO, LILACS e PubMed*. Para a seleção dos materiais, consideraram-se a atualidade das publicações e a relevância temática, incluindo artigos que abordassem a SCA no contexto pediátrico de politraumatismo. Os achados indicaram que os principais agentes causais incluem traumas de alta energia, fraturas, queimaduras extensas e envenenamentos por animais peçonhentos. Em crianças, o diagnóstico precoce é essencial, mas pode ser dificultado pelas limitações na comunicação e pela apresentação clínica atípica. A fasciotomia é considerada o tratamento mais eficaz e tem seus resultados diretamente relacionados à precocidade da intervenção, entretanto, complicações como infecções, lesões nervosas e danos teciduais são frequentes. Conclui-se que o manejo da SCA em pediatria exige uma abordagem multidisciplinar, com ênfase na detecção precoce dos sinais clínicos e resposta ágil da equipe de saúde, a qual deve estar devidamente capacitada. A implementação de capacitações específicas e o uso de biomarcadores podem contribuir para o diagnóstico oportuno e para a melhoria dos desfechos, minimizando o risco de sequelas permanentes e reduzindo a mortalidade.

Palavras-chave: Síndrome Compartimental Aguda, Politrauma Pediátrico, Unidade de Terapia Intensiva, Intervenção Cirúrgica.

RISKS AND INTERVENTIONS IN COMPARTMENT SYNDROME OF CHILDREN WITH CRITICAL POLYTRAUMA IN THE ICU

ABSTRACT

Acute Compartment Syndrome (ACS) is a frequent complication in polytraumatized patients, characterized by increased intracompartmental pressure in affected organs or limbs. When failed to identify and treat early, it may progress to ischemia, tissue necrosis, muscle impairment, limb amputations and even death. This condition is more prevalent among patients admitted to Intensive Care Units (ICUs). This study aimed to review the clinical manifestations of ACS in children, its main predisposing factors, the therapeutic strategies used and their effectiveness, with an emphasis on critical polytrauma cases. An integrative literature review was conducted using SciELO, LILACS, and PubMed databases. For material selection, the recency and thematic relevance of publications was considered, including articles from the last 5 to 10 years addressing ACS in the context of pediatric polytrauma. The findings indicated that the main causative agents include high-energy trauma, fractures, extensive burns and envenomation by poisonous animals. In children, early diagnosis is essential, but may be hindered by limitations in communication and atypical clinical presentation. Fasciotomy is considered the most effective treatment, with outcomes directly related to the timing of the intervention; however, complications such as infections, nerve injuries, and tissue damage are common. It's concluded that the management of pediatric ACS requires a multidisciplinary approach, emphasizing early detection of clinical signs and a prompt response from a well-trained healthcare team. The implementation of specific protocols and the use of biomarkers may significantly contribute to timely diagnosis and improved outcomes, minimizing the risk of permanent sequelae and reducing mortality.

Keywords: Acute Compartment Syndrome, Pediatric Polytrauma, Intensive Care Unit, Surgical Intervention.

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INTRODUÇÃO

Acute Compartment Syndrome (ACS) is a serious condition that requires attention from healthcare professionals and, when not treated promptly, can cause severe, extensive and irreversible consequences in the affected tissues. This condition occurs when there is an increase in pressure within an anatomical compartment of the body, compromising blood circulation, and consequently reducing oxygenation within the tissue, which can lead to necrosis and serious complications. Therefore, urgent medical intervention is necessary to relieve the pressure and prevent outcomes such as permanent disability, loss of limbs and death, depending on the duration and severity of the condition (Fabien *et al*., 2024).

It is frequently associated with trauma, fractures, and accidents, standing out as an important complication, especially in limb crush injuries in accidents, it is also an orthopedic emergency that results in fractures and subsequent ACS. It is difficult to make an accurate diagnosis because the signs are very subtle in children compared to those seen in adults. Although ACS is documented in orthopedic literature, its occurrence in children is rare, and there is a limited number of cases. In adults, the signs are the '5 Ps' (pain, pallor, paresis, paralysis, and absence of pulse), whereas in pediatrics, the signs are atypical (agitation, anxiety, and increased need for analgesics) (Uquilla-Loaiza *et al*., 2025).

Trauma caused by snake envenomation can mimic ACS, and its treatment should not follow the same trauma guidelines. The focus should be on neutralizing the venom, which causes effects similar to pancreatitis, rather than on surgeries like fasciotomy. Antivenom is essential and unnecessary surgical procedures can be harmful, except in specific cases. Therefore, management should be specific for snake bites and not for traumatic ACS (Cañas, 2024).

Currently, traumatic injuries are classified according to the Abbreviated Injury Scale (AIS), a scale created by the Association for the Advancement of Automotive Medicine. This system represents an overall severity score, assigning levels according to the significance of the injury in relation to the whole. Based on the AIS, two other scores have emerged used in the classification of injuries: the Injury Severity Score (ISS) and the New Injury Severity Score (NISS) (Garcia *et al*., 2024).

One of the most common complications of traumatic fractures is ACS, which usually arises from increased compartmental pressure, compromising blood flow and potentially causing muscle and nerve ischemia, leading to necrosis of the affected areas (Borrelli; Donohue, 2022). Children affected by polytrauma require treatment that is even more specialized than that of adults with the same condition, due to differences in their anatomy and physiology, which makes their treatment even more complex. Furthermore, children have a longer life expectancy, meaning that permanent sequelae, such as paralysis or limb loss, becomes even more devastating and should be avoided at all costs (Morrow, 2021).

The management of ACS in polytrauma contexts requires the involvement of a multidisciplinary team, since different organs and systems may be compromised. Upon identifying ACS, the immediate initiation of treatment is essential to prevent unfavorable and irreversible outcomes, such as loss of function or amputation of the affected limb. In the past, the most commonly used premise followed the principle “life before limb”; however, recognizing the impacts of inadequate treatment, including disabilities and social and economic losses, the current perspective values proper initial care, focusing on achieving the best long-term outcomes (Devendra et al., 2020).

Compartment Syndrome (CS) occurs when there is an increase in pressure within the muscle fascia, compromising microcirculation and progressively compressing veins and arteries. This pressure can result from edema, bleeding, or external compression. The lack of oxygen supply to the muscles leads to tissue necrosis and rhabdomyolysis, with the consequent release of myoglobin into the circulation, which can progress to acute renal failure (Hansen; Pedersen; Lindberg-Larsen, 2021).

This condition mainly affects the legs, followed by the forearm, arm, thigh, foot, gluteal region, hands, and abdomen. The pathophysiology involves an increase in pressure within a muscle compartment, usually caused by trauma, which compromises microcirculation. This progressive increase in pressure reduces local blood flow, resulting in ischemia, muscle necrosis, and nerve dysfunction, with a higher incidence in men than in women (Alamoudi et al., 2025).

Furthermore, in the pediatric population, this diagnosis proves to be particularly challenging due to the communicative limitations inherent to the age group. Many children, especially the younger ones, do not yet have sufficient cognitive and linguistic

development to accurately describe signs and clinical symptoms. The clinical presentation is similar to that of adults; however, there are also behavioral markers that help in recognizing the condition, such as restlessness, anxiety, and the need for increased analgesia (Viegas et al., 2025).

The assessment of early signs of ACS in sedated or unconscious children in the ICU presents significant challenges due to the difficulty in patient communication and the variability in clinical presentation depending on the trauma area. In abdominal cases, signs include inflammation, edema, distension, and organ dysfunction (Jacobs et al., 2022). In trauma to the upper limbs, such as snake bites, severe pain, edema, and necrosis appear. These manifestations reinforce the need for early diagnosis based on objective observations, as verbalization of symptoms, as occurs in adults, may be difficult (D' Oliveira et al., 2022).

In pediatric patients, abdominal compartment syndrome (ACS) is a serious clinical condition associated with significantly high morbidity and mortality rates when in a critical state (Silveira et al., 2021). Another compartment syndrome that affects these patients is osteofascial, which is one of the high-severity emergencies in pediatric orthopedics (Yuan et al., 2020). Compartment syndrome due to extravasation is also related to pediatric patients, as studies have shown that up to 11% of hospitalized children were affected by this condition, due to an increased risk for this syndrome because of communication difficulties. The etiology of this syndrome is characterized as iatrogenic, leading to outcomes linked to medico-legal processes by affecting families harmed by functional, aesthetic, and psychological sequelae, such as painful syndromes, Volkmann ischemic contracture, and secondary amputations caused by the syndrome (Rueda-Mojica et al., 2021).

Immediate surgical decompression via fasciotomy is the gold-standard treatment for ACS in both adult and pediatric patients; however, although the procedure prevents severe complications, the risks associated with this surgical intervention include surgical site infections, which can affect up to 30% of patients undergoing this procedure. Injury to the fibular nerve, the saphenous nerve and vein, incomplete release of pressure in the affected compartment, and complications in wound closure and skin grafts represent other risks associated with fasciotomy (Hobbs et al., 2024).

Due to the compromise of microcirculation, ACS requires intervention as early as

possible. The treatment consists of performing a fasciotomy, which is a surgical opening of the compartments to relieve internal pressure, restore tissue perfusion, and result in an open surgical wound that requires proper care to minimize the risk of infection or other complications. This procedure is indicated when the compartment's internal pressure is greater than 30mmHg in a normotensive patient. If it is not possible to measure this intracompartmental pressure, the decision should be based on the clinical presentation, with fasciotomy performed early, with a maximum tolerance of 6 hours (Takano, 2023).

In this scenario, surgical treatment is the first choice, even though it presents higher chances of infection, long recovery periods, and the risk of causing nerve and vascular injuries. To minimize these risks, other surgical techniques have been proposed, such as endoscopic fasciotomy, which has shown a low complication rate and allowed faster patient recovery. Various clinical strategies for treating this condition have also been studied, such as the combined use of phenylephrine and dobutamine or the use of compressive bandaging, but they still do not show clear evidence of effectiveness when compared to surgical treatment (Costa et al., 2019).

For the proper management of ACS, it is important to have the technical knowledge that allows for rapid diagnosis and early interventions. Taking ACS as an example and following the guidelines of the World Society of the Abdominal Compartment Syndrome (WSACS), the clinical examination can raise suspicion of the presence of ACS by indicating the possibility of increased intra-abdominal pressure (IAP) through signs such as abdominal distension, tachycardia, hypotension, respiratory dysfunction, decreased or absent bowel sounds, tachypnea, and signs of organ compromise such as renal or hepatic failure (KIRKPATRICK et al., 2013). Risk factors that may help in this suspicion include severe abdominopelvic trauma, significant abdominal distension, abdominal surgery, and extensive burns. However, the clinical examination is imprecise for the detection of ACS, making it necessary to measure IAP via the transvesical technique when this condition is suspected. A sustained IAP > 20 mmHg confirms the diagnosis (Borrelli; Donohue, 2022).

Even with this information, there is still a lack of awareness among healthcare professionals regarding the diagnosis of ACS. In many cases, diagnoses were missed due to a lack of knowledge of the clinical aspects involved in ACS and the measurement of

IAP, highlighting the importance of training healthcare professionals on the subject. Furthermore, the indication for measuring IAP is the responsibility of the physician, but its insertion and measurement fall exclusively under the nurse's responsibility, which demonstrates the importance of the multidisciplinary team in the management of ACS (Reyad; Mahmoud; Eldriny, 2022).

METODOLOGY

An integrative review with a qualitative research approach was conducted, which allows the combination of scientific evidence to build a comprehensive analysis on a specific topic.

The search was carried out in the main databases: Latin American and Caribbean Health Sciences Literature (LILACS), Medical Literature Analysis and Retrieval System Online (MEDLINE/PubMed®), and Scientific Electronic Library Online (SciELO).

The descriptors used in the search strategy were according to the keywords: Acute Compartment Syndrome, Pediatric Polytrauma, Intensive Care Unit, Surgical Intervention, while the search strategy followed the criteria of the Boolean operator "AND", combining the terms.

The inclusion criteria were articles with systematic or integrative literature review methodology and full texts. The results were presented through a sample sampling frame.

RESULTADOS E DISCUSSÃO

Eight studies were selected to make up the research results. The criteria used for selection included relevance, quality, and timeliness, with the aim of ensuring solid evidence on the topic.

Table 1: Summary of the main results organized by author/year, database, title, and key findings.

Autor/Ano	Título	Achados Importantes
Livingston; Glotzbecker; Shore, 2017	Pediatric Acute Compartment Syndrome	The outcomes after fasciotomy in children tend to be excellent; however, delays in diagnosis

		due to unfamiliar clinical scenarios can lead to muscle necrosis and subsequent poor outcomes.
Canales-Zamora *et al*., 2020	Complicaciones de fracturas supracondíleas humerales en niños	It was found that compartment syndrome can arise in cases of high-energy trauma, occurring in 0.1% to 0.3% of cases. Vascular injuries and primary inflammatory processes can trigger the development of the syndrome within a period of 12 to 24 hours. If not treated promptly, it can lead to ischemia.
Yuan *et al*., 2020	Fasciotomy through multiple small skin incisions for the treatment of early acute osteofascial compartment syndrome in children	Most cases of compartment syndrome involved car accidents (32), followed by falls of heavy objects (10), falls from heights involving children (11), and sports injuries (3). A predominance of multiple traumas was observed in men. As for symptoms, the most common were pain on passive stretching in 66.1% of patients, tension blisters in 44.6%, weak arterial pulse in 19.6%, cold extremities in 32.1%, and numbness in 28.6%.
Rueda-Mojica *et al*., 2021	Compartment syndrome due to liquid extravasation in a pediatric patient. Case report and bibliographic review	Extravasation Compartment Syndrome (ECS) has an overall incidence ranging from 0.01% to 6.5%, while in the pediatric population this rate is higher, ranging from 1.8% to 11%, highlighting the greater vulnerability of children to the condition. The progression of the syndrome can result in functional and aesthetic sequelae, including Volkmann's contracture (2.3%) and, in severe cases, the need for

		amputation (2.3%). The patient described in the study underwent surgical decompression of the right forearm and hand, presenting only mild sequelae.
Shi *et al.,* 2022	Case Report: Tachycardia, Hypoxemia and Shock in a Severely Burned Pediatric Patient	Among pediatric patients with extensive burns, 10% to 30% may develop Acute Compartment Syndrome (ACS), with a mortality rate of 40% to 100%. The condition is worsened by visceral edema and the effects of administered fluids, and it is common in burned children.
Rezeni; Thabet, 2022	Awareness and management of intra-abdominal hypertension and abdominal compartment syndrome by paediatric intensive care physicians: a national survey	It was identified that, among pediatric patients undergoing surgery, cases of trauma or intra-abdominal bleeding were the most recurrent, accounting for 82% of the situations requiring monitoring for Abdominal Compartment Syndrome or hypertension. To treat this condition, decompressive laparotomy was considered in cases where there was worsening oliguria, increased ventilatory and oxygen demands, worsening acidosis, and abdominal distension.

Brinkemper *et al.,* 2024	Analysis of compartment syndromes in lower extremity pediatric and adolescent trauma - are there predictors of a late onset?	The study revealed that adolescents between 13 and 17 years old were the most affected by compartment syndrome (CS), with the majority being male (73.2%) and female (26.8%). Among the cases, 64.3% occurred after traffic accidents and 23.2% due to sports-related accidents. The feet, legs, and thighs were the most affected areas. The main causes of trauma included motorcycle accidents (34.3%) and collisions or run-overs involving pedestrians/cyclists and cars (26.9%).
Alvarez López; Valdebenito-Aceitón; Soto-Carrasco, 2024	Complicaciones vasculares agudas en pacientes pediátricos con fracturas supracondíleas del húmero	The incidence of compartment syndrome in pediatric patients with supracondylar humerus fractures ranges from 0.1% to 0.5%. In cases of compartment syndrome, 90% of patients who undergo fasciotomy within 30 hours of diagnosis have a good prognosis.

Sources: The authors, 2026.

According to Rueda-Mojica (2021), among the factors that influence the prognosis, early diagnosis is extremely important in order to reduce the incidence of complications, as Rezeni; Thabet (2022) highlights the fragility of the pediatric population, whose clinical manifestations may be less specific and difficult to diagnose.

Therefore, early detection can be optimized with the use of biochemical markers, such as plasma P-myoglobin and P-creatine phosphokinase (P-CK), both associated with muscle injuries and indicative of compartmental involvement in traumatic tibial fractures, for example. Despite this, the interpretation of these tests in pediatrics requires caution due to individual variations in metabolic and inflammatory response (Nilsson et al., 2022).

Conversely, late diagnoses directly impact morbidity and mortality rates, especially when muscle necrosis progresses. Pediatric patients with ACS without

fractures have a higher risk of necrosis, and this risk is even more significant in children with Cushing's syndrome, since cortisol suppresses the immune and inflammatory response, delaying healing (Wang et al., 2023). Furthermore, in other types of pediatric trauma, such as burns, the incidence of ACS varies between 10% and 30%, and mortality can reach 100% in severe cases. The condition is aggravated by visceral edema and fluid administration, and is more common in children with extensive burns. (Shi *et al*., 2022).

Regarding epidemiological aspects, in Brinkemper's study (2024), the most common contexts in which ACS occurred were: high-energy trauma (generally in polytrauma patients), such as car accidents (64.3%) and sports accidents (23.2%), in the 13 to 17 age group, with 73.2% in males and 26.8% in females, highlighting the prevalence among male adolescents. In burn trauma, Shi (2022) discusses that 30% of pediatric patients with more than 20% of their total body surface area compromised tend to present with various organ dysfunctions and develop ACS as a secondary effect.

From another point of view, Canales-Zamora (2020), in his study of complications related to supracondylar fractures of the humerus in the pediatric population, recorded that the incidence of ACS as a complication is relatively low, ranging from 0.1% to 0.5% in traumas in this population. However, the outcomes can be serious if there is no early intervention. Thus, the urgency of early diagnosis of this condition is evident in order to avoid the development of the aforementioned complications.

With regard to therapeutic approaches, the literature mostly indicates surgical fasciotomy as the gold standard in the case of traumas that mainly involve the feet, hands, upper limbs and lower limbs (Livingston; Glotzbecker; Shore, 2017) and decompressive laparotomy for Abdominal Compartment Syndrome (ACS) (Rezeni; Thabet, 2022). Furthermore, minimally invasive techniques, such as small multiple incisions, have shown promise in reducing complications (Yuan et al., 2020).

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CONSIDERAÇÕES FINAIS

Based on the research conducted, it is concluded that effective management essentially depends on early identification and immediate surgical intervention to avoid irreversible sequelae such as tissue necrosis, amputation, and death. Children, especially newborns and victims of extensive burns, constitute a vulnerable population, demanding differentiated clinical attention, as the signs are atypical. Considering the nonspecific clinical manifestations in this age group and the limited therapeutic window, it is essential that healthcare professionals are trained to recognize early signs of the syndrome, ensuring effective interventions and reducing associated complications, with emergency fasciotomy being a gold standard treatment.

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