JOHNS HOPKINS ALL CHILDREN'S HOSPITAL

Compartment Syndrome Clinical Pathway

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Updated: April 2020
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Acute Compartment Syndrome Clinical Pathway

Rationale

This clinical pathway was developed by a consensus group of JHACH orthopaedic surgeons, trauma surgeons, emergency physicians, advance practice providers, hospitalists, intensivists, and nurses to standardize the management of children with a concern for acute compartment syndrome (ACS). The following clinical issues are addressed:

- When to evaluate for acute compartment syndrome
- When to consult orthopedic surgery or trauma surgery for further evaluation and management
- Appropriate admitting locations for children with concern for acute compartment syndrome
- Appropriate inpatient monitoring for acute compartment syndrome

Background

Compartment syndrome is defined as increased pressure within a myofascial space resulting in decreased tissue perfusion to structures within that space. The decreased perfusion may lead to potentially irreversible ischemic damage to the neuromuscular structures. Acute compartment syndrome (ACS) may result in tissue necrosis in eight hours and in some cases even sooner. Therefore, prompt recognition and treatment are critical for successful outcomes.

The challenge in acute compartment syndrome is obtaining an accurate, prompt diagnosis that leads to the appropriate management. The diagnosis is mainly a clinical one and this presents many unique challenges especially in the pediatric patient. A reliable exam is the most important factor in making the diagnosis and this is difficult in patients with unclear symptoms, those who are obtunded or intoxicated, and in those with co-morbidities or other distracting injuries. Children are even more difficult to reliably examine secondary to fear and anxiety or lack of understanding. In addition, acute compartment syndrome is relatively uncommon and may be missed by an inexperienced clinician who has never seen the clinical presentation of a compartment syndrome. Therefore, it is important for all clinicians to understand the risks factors and varying etiologies of acute compartment syndrome so that the appropriate clinic service is promptly consulted.

The most common etiology for ACS in children is trauma either with or without a fracture. However, ACS may develop in many clinical scenarios both traumatic and atraumatic. The most common traumatic etiologies in children are upper and lower long bone fractures, crush injuries, and penetrating injuries such as gunshot or knife wounds. A less common traumatic etiology is venomous snake bites. The most common atraumatic etiology in children is a vascular insult to the limb. This can occur from a wide range of causes such as arterial cannulation, deep vein or

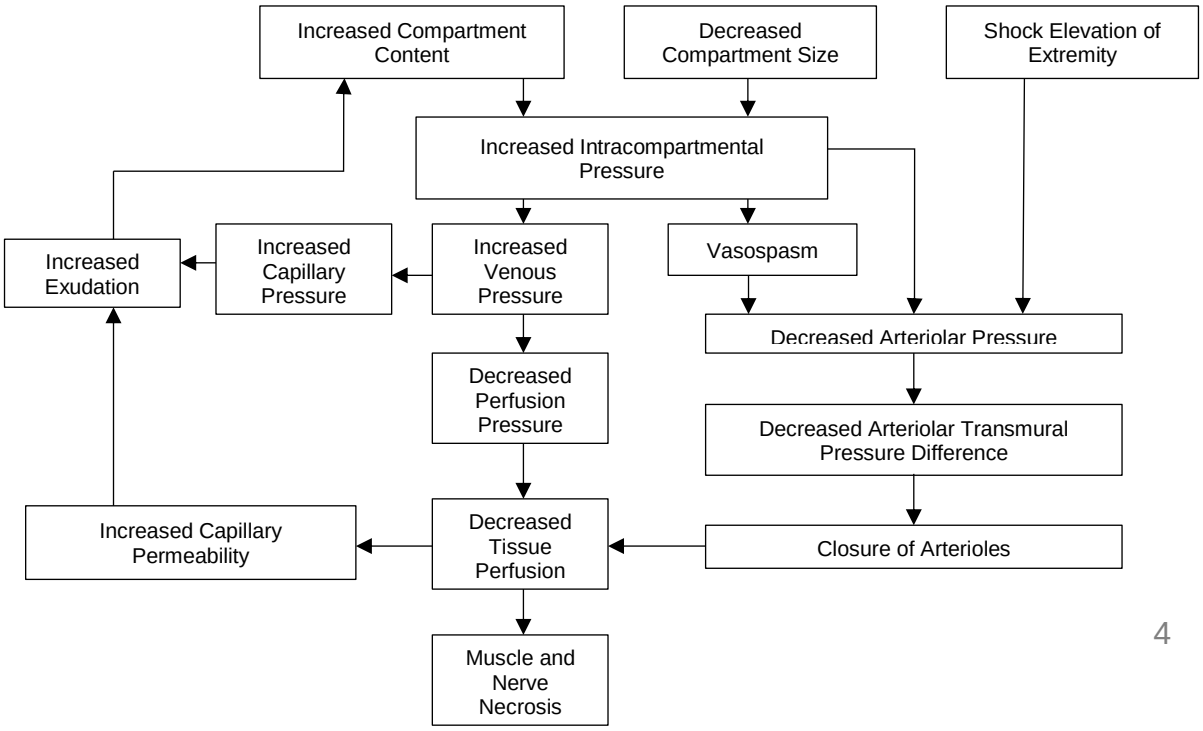
artery thrombosis, intravenous infiltration, extracorporeal membrane oxygenation, and disseminated intravascular coagulation. Reperfusion of an ischemic limb can also result in ACS; and in children this may be seen in prolonged tourniquet times, long cross clamp times for arterial repairs, and improper intraoperative limb positioning. A list of factors associated with compartment syndrome are listed in Table 1.

Table 1: Factors Associated With Compartment Syndrome

Fractures/dislocations	Thromboembolism
Crush injuries	Drug abuse
Reperfusion injury	Tourniquet use
Arterial injury	Constrictive dressings/splints/casts
Venomous bite	Burns
Penetrating injury	Extravasation of fluids
Bleeding disorder	DIC
Post-thrombolytic therapy	ECMO

Regardless of the etiology, the pathophysiology of acute compartment syndrome is consistent. There is a rise in intracompartmental pressure which leads to collapse of the venules as they lack musculature. This results in a decreased hydrostatic gradient, causing decreased local perfusion. Edema develops due to increased capillary permeability causing an even greater increase in intracompartmental pressure and volume and the cycle accelerates (Figure 1). The most susceptible structures to loss of microperfusion are the skeletal muscles and nerves. Studies have shown that ischemia is seen within 4 hours and irreversible tissue necrosis in 8 hours, again highlighting the need for prompt recognition of the condition.

Figure 1: Vicious Cycle of Acute Compartment Syndrome (ACS)



Diagnosis

The diagnosis of ACS is predominately a clinical one and requires consideration of the entire clinical picture including a thorough physical exam. Classically, the hallmark signs and symptoms of compartment syndrome are a swollen/tense compartment associated with the five Ps: pain, paresthesias, paralysis, pallor, and pulselessness. These are all present in late stages of ACS in adults but are not all seen early on and not nearly as reliable in children. The challenge is to diagnosis a developing compartment syndrome prior to the presence of all five Ps. In children, an additional set of findings designated the “Three As” has been proposed as more appropriate. The “Three As” are increasing anxiety, agitation, and analgesic requirements.

Clinical Suspicion
First and foremost, clinical suspicion for a compartment syndrome is critical as many of the signs and symptoms of ACS are routinely seen in the setting of pediatric trauma. It is easy to attribute swelling, pain, and paresthesias as routine findings following a significant trauma and this may lead to a missed or late diagnosis of ACS.

Physical Exam
The most consistent finding in ACS is a markedly swollen and tense muscle compartment. In some cases, this may be obvious but in many it is quite difficult for several reasons. Often, the involved compartment is covered either in dressings, a splint, or a cast making direct examination of the compartment impossible. Second, some of the compartments are anatomically deep and hidden from examination by the subcutaneous tissues. Therefore, the other signs and symptoms become even more critical to evaluate.

Pain
Pain is the first symptom of a compartment syndrome in most cases and there are specific characteristics that need to be evaluated. In general, pain out of proportion to the injury is worrisome. In children, this may be manifested by uncontrolled pain, pain requiring a significant increase in analgesics, marked anxiety or agitation. Specifically, pain with passive stretch of the muscles within the suspected muscle compartment is concerning for a compartment syndrome. These symptoms may be masked in children with a regional block, those that are obtunded, or in late presentations when nerve injury occurs resulting in paresthesias or complete numbness. While pain is typically seen in virtually all etiologies of ACS, the pain should not worse with treatment of the underlying condition. It is also important to point out that in vascular related ACS substantial pain was NOT present in the majority of cases. Neurovascular symptoms were the prevailing clinical findings.

Parasthesias & Paralysis
Similar to pain, paresthesias are a common finding in pediatric trauma irrespective of compartment syndrome. However, these are typically seen at presentation and should not worsen following treatment. Development of paresthesias or paralysis following treatment in a child who was neurologically intact upon presentation is worrisome for a developing compartment syndrome. This is complicated by the fact that young children often give an

unreliable neurologic exam secondary to fear or lack of understanding. Repeated examinations are sometimes helpful in this regard. Again, in the setting of a vascular related ACS paresthesias and paralysis is noted more frequently than excessive pain.

Pallor & Pulselessness
In trauma related ACS, pallor along with poor capillary refill and true pulselessness are fairly late findings in compartment syndrome. In these cases, permanent muscle and nerve necrosis has already likely begun. However, in vascular related ACS these may be the presenting findings. In either case, these findings are very worrisome for a compartment syndrome or vascular injury, both of which require prompt evaluation and intervention.

Diagnostic Tests
In most cases of ACS, the diagnosis is made strictly on the basis of the clinical exam findings combined with the index of suspicion given the clinical scenario. No further diagnostic testing is needed and the patient is treated with an emergent fasciotomy and any associated vascular procedures if indicated. In some cases, such as in neonatal cases, obtunded children, those with a regional anesthetic, or very young children with an unreliable exam, the clinical exam does not provide enough information and compartment pressures may be measured.

Compartment pressures should be measured by a member of the orthopaedic team using the Stryker pressure monitor. There is no consensus as to which value of compartment pressure constitutes a compartment syndrome. Some studies advocate the use of a compartment pressure measurement greater than 30 mmHg while others suggest a ΔP value of less than 20 mmHg from the patient's diastolic pressure or less than 30 mmHg from the patient's mean arterial pressure. These guidelines were all established in adults and have not yet been verified in children. In particular, there is no evidence-based studies in neonates who have far different resting pressures. Some studies also suggest that in a vascular associated ACS a ΔP of less than 40 mmHg may be more appropriate. Compartment pressure measurements have also been shown to be highly variable even in experienced hands so serial measurements may play a role in some scenarios.

Emergency Center Management

Early Recognition
As previously mentioned, the first priority in treating potential acute compartment syndromes is to recognize the injuries and clinical scenarios that predispose a child to the development of ACS. In children considered at risk the appropriate orthopaedic and trauma services should be notified and the child promptly evaluated.

Preventative Measures
Preventive measures include maintaining normal blood pressure and avoiding excessive pressure or tight circumferential dressings on the anatomic compartment of concern. Traction and elevation of the involved limb should be avoided whenever possible. For those children being evaluated in the emergency center both the orthopaedic and trauma services should be

consulted and the treatment algorithm that is recommended is provided below. For those with an obvious orthopaedic injury and no vascular concern, the orthopaedic service would be the admitting and treating service. In those scenarios where there is concern for a vascular etiology, the trauma service will be the admitting and treating service.

Confirmed ACS

For those children with a confirmed diagnosis of ACS, the treating service should notify the operating room that an emergent fasciotomy is indicated and this should be scheduled as a Level 1 case. Every effort should be made to minimize delay in operative treatment. While the surgical treatment for ACS is a complete fasciotomy of all compartments in the affected limb, it is important to remember that additional procedures may be required such as fracture stabilization or vascular repair. In most cases of ACS, the wound is left open to allow for further swelling. Wound vacs are often utilized to aid in delayed closure.

Admission of "High Risk" Patients

For those patients who are not felt to have an acute compartment syndrome but are deemed at high risk for future development of one, they should be admitted to a designated floor or ICU that is appropriately staffed to be able to provide hourly neurovascular checks. The admitting service should be physically present to give report to the admitting nurse/attending. There should be a review of the concerns for compartment syndrome and a baseline exam should be done together so there is complete agreement on the examination findings. Ideally, the subsequent neurologic exams should be done by the same individual on the admitting service as well as the same floor/icu nurse. In all changes of shift, the incoming and outgoing nurses should perform an examination together to confirm the exam findings and concerns in the presence of the admitting service if possible. All serial examinations should be fully documented by both the bedside nurse and the admitting service. The admitting service should be immediately notified of any change in the exam in between scheduled examinations. This includes any observed increased anxiety, agitation or analgesic requirements. The duration and interval of serial examinations will be determined by the admitting service and will be individualized for each clinical scenario.

"Low Risk" Patients

For those patients who are not felt to have an ACS and require admission for observation or ongoing treatment but are deemed at low risk for compartment syndrome, they may be admitted routinely to the admitting service. The clinical presentation of ACS should be reviewed with the admitting nurse/attending and the serial examinations should be performed by the bedside nurse as directed in the admitting orders. The duration and interval of the serial examinations will be determined by the admitting service and will be individualized for each clinical scenario. Any change in the exam should be documented by the bedside nurse and the admitting service should be notified. For low risk patients not requiring admission, they may be discharged home after the orthopaedic or trauma team has reviewed the signs and symptoms of ACS with the family.

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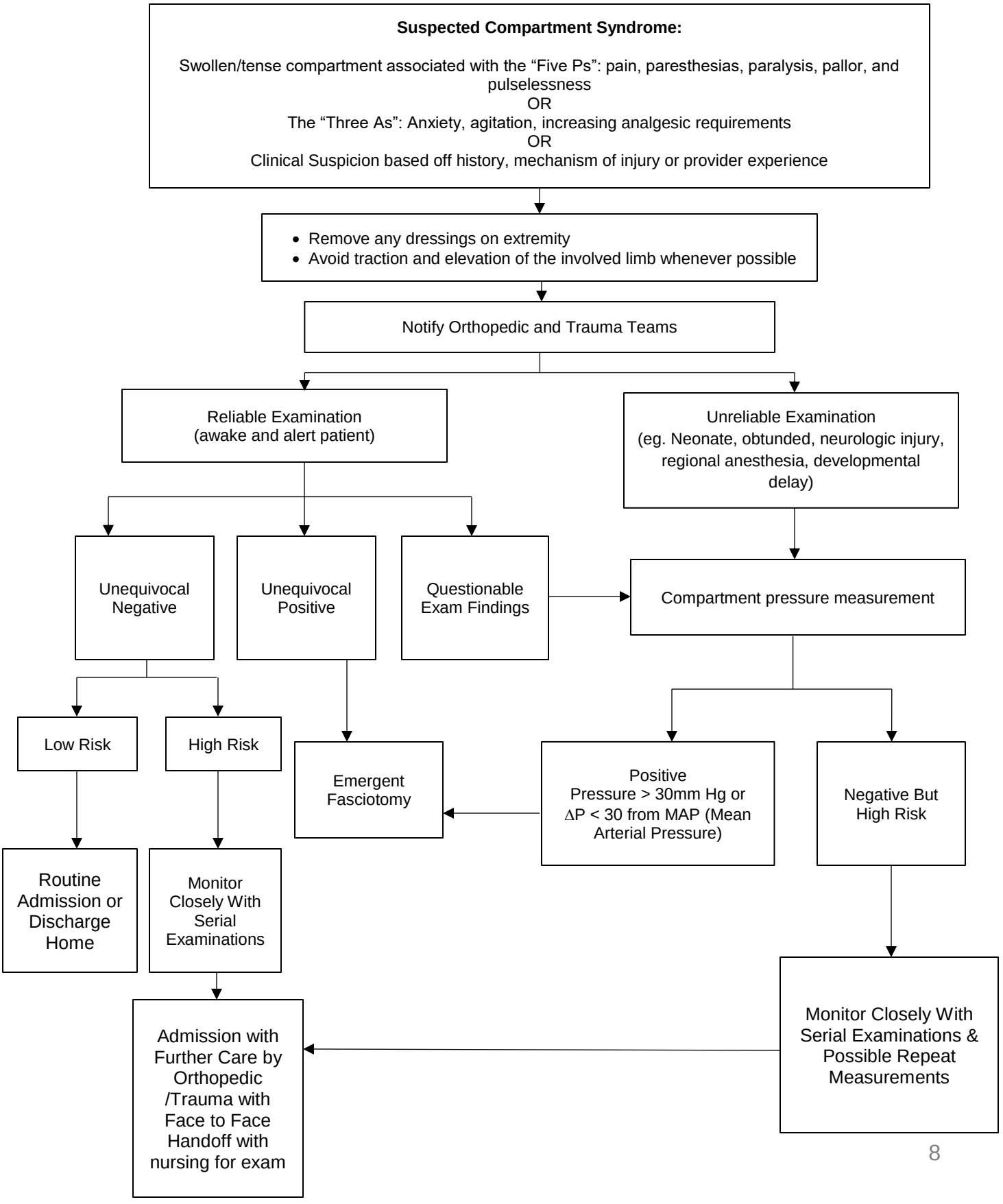

Inpatient Management

Suspected ACS

The first priority in treating potential acute compartment syndromes is to recognize the injuries and clinical scenarios that predispose a child to the development of ACS. In children considered at risk the appropriate orthopaedic and/or trauma services should be notified and the child promptly evaluated. Preventive measures include maintaining normal blood pressure and avoiding excessive pressure or tight circumferential dressings on the anatomic compartment of concern. Traction and elevation of the involved limb should be avoided whenever possible. For those with an obvious orthopaedic injury and no vascular concern, the orthopaedic service should be stat consulted. In those scenarios where there is concern for a vascular etiology, the trauma service should be stat consulted. If etiology is unclear both services should be consulted. In the rare circumstance where the primary consulted service is not readily available, the other service should be consulted as well. Prompt evaluation by a clinician with experience recognizing acute compartment syndrome is paramount. The treatment algorithm is provided below.

Confirmed ACS

For those children with a confirmed diagnosis of ACS, the consulting service should notify the operating room that an emergent fasciotomy is indicated and this should be scheduled as a Level 1 case. Every effort should be made to minimize delay in operative treatment. While the surgical treatment for ACS is a complete fasciotomy of all compartments in the affected limb, it is important to remember that additional procedures may be required such as fracture stabilization or vascular repair. In most cases of ACS, the wound is left open to allow for further swelling. Wound vacs are often utilized to aid in delayed closure.

Monitoring of "High Risk" Patients

For those patients who are not felt to have an acute compartment syndrome but are deemed at high risk for future development of one, they should be transferred to a designated floor or ICU that is appropriately staffed to be able to provide hourly neurovascular checks. The consulting service should be physically present to give report to the admitting nurse/attending. There should be a review of the concerns for compartment syndrome and a baseline exam should be done together so there is complete agreement on the examination findings. Ideally, the subsequent neurologic exams should be done by the same individual on the consulting service as well as the same floor/icu nurse. In all changes of shift, the incoming and outgoing nurses should perform an examination together to confirm the exam findings and concerns in the presence of the consulting service if possible. All serial examinations should be fully documented by both the bedside nurse and the consulting service. The consulting service should be immediately notified of any change in the exam in between serial examinations. This includes any observed increased anxiety, agitation or analgesic requirements. The duration and interval of serial examinations will be determined by the consulting service and will be individualized for each clinical scenario. Once the patient is no longer considered high risk, the patient may be transferred back to the most appropriate floor/ICU.

“Low Risk” Patients

For those patients who are not felt to have an ACS and are deemed at low risk for compartment syndrome, they may remain in their current location. The clinical presentation of ACS should be reviewed with the bedside nurse/attending and the serial examinations should be performed by the nurse as directed by the consulting service. The duration and interval of the serial examinations will be determined by the consulting service and will be individualized for each clinical scenario. Any change in the exam should be documented by the bedside nurse and the consulting service should be immediately notified.

Special Circumstances

As mentioned throughout the pathway, acute compartment syndrome is a clinical diagnosis and as such, relies heavily on a reliable physical exam. Unfortunately, there are many scenarios in pediatric patients that prohibit or significantly compromise the reliability of the physical exam. Some examples are evaluation of a neonate, an obtunded or developmentally delayed child, a child who has suffered a neurologic injury or one who has been given a regional anesthetic. In any scenario when a reliable examination cannot be performed, then compartment pressure measurements may be indicated. Compartment pressure measurements are often difficult to perform and interpret. The test is prone to technical errors and the even when done correctly the measurement may be difficult to interpret as there is no consensus of accepted norms for young children. Therefore, these should only be done by a member the orthopaedic or trauma service that has experience in performing the procedure. Again, it is important to remember that a single compartment pressure measurement may not be diagnostic and serial measurements may need to be performed to assess progression. In all cases, the measurements should be used as an additional tool for determining the likelihood of an ACS and when in doubt a fasciotomy should be performed.

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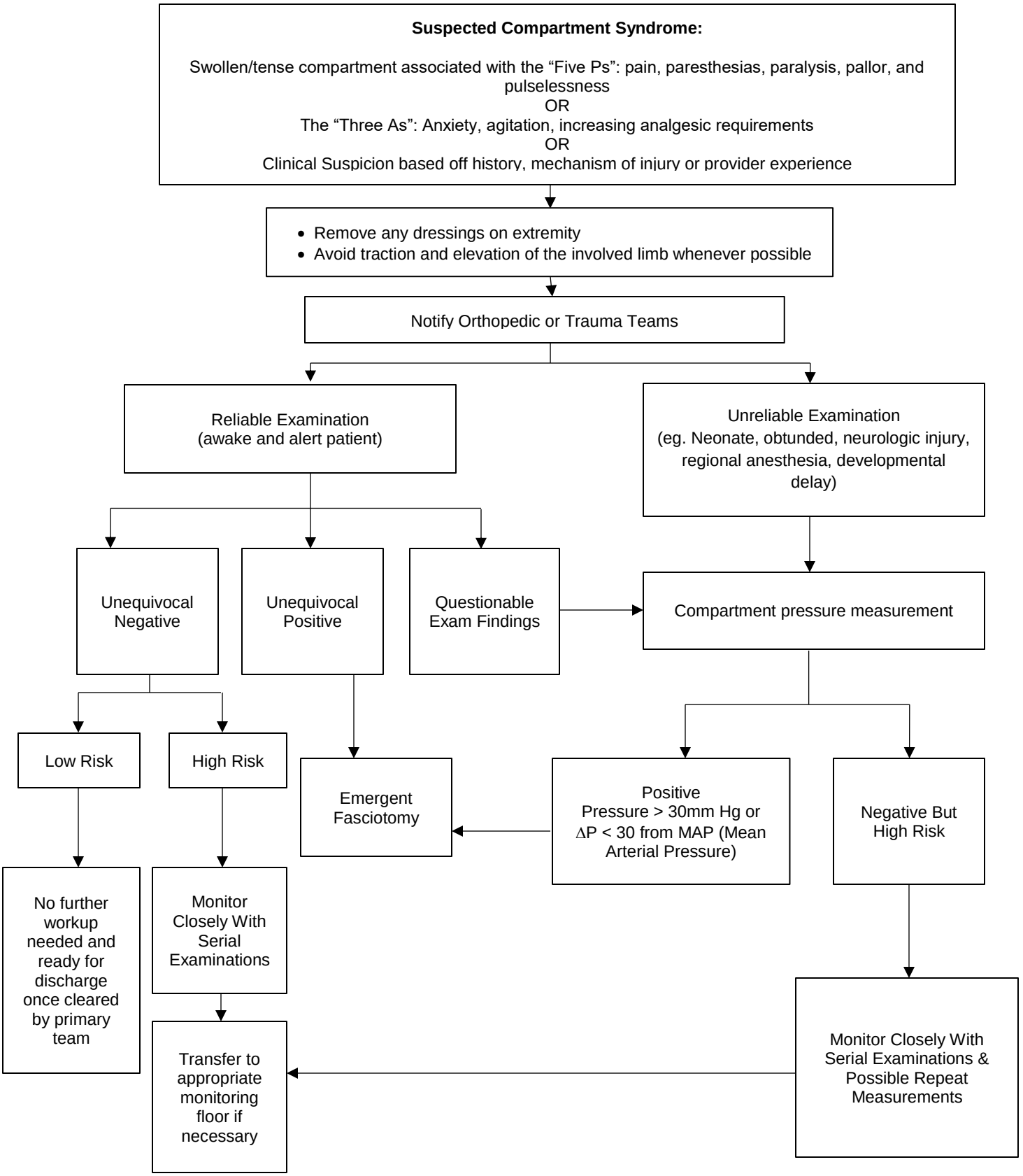
Inpatient Acute Compartment Syndrome Clinical Pathway



Documentation Reminders

Documentation Suggestions:

- Timeline is important, document a clear clinical picture with timestamps
- It is important to document the specific location and laterality, if applicable (i.e. abdomen, left hip, right thigh, etc.)
- It is important to document if it is associated with a post-procedural complication
- It is important to document if it is related to trauma
- It is important to document any medical co-morbidities the patient has
- It is important to document any complications the patient is experiencing, such as the specific electrolyte derangements (hypokalemia), ischemic muscle infarction, reperfusion syndrome, acute kidney injury/failure, etc.

Patient Status Suggestion:

- Low risk patients being observed for serial exams with anticipated length of stay less than 24 hours should be placed in OBSERVATION status
- All patients that are high risk and/or are taken to the OR should be placed in INPATIENT status

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Upstate University Hospital GoLisano Children's Hospital
www.upstate.edu/surgery/pdf/healthcare/trauma/trauma_guideline_manual.pdf

Outcomes

- Number of cases of irreversible muscle damage by 100% chart review
- Time from confirmed compartment syndrome booking to the operating room

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Date Approved by JHACH Clinical Practice Council:

Date Available on Webpage:

Last Revised: April 2020

Disclaimer

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