Case Presentation #5: “Pain, Paresthesia, Paresis, and PulseFULness”

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An 18-year-old male arrives in the ED complaining of right forearm pain. He had gone on a drinking binge the previous night. He recalls falling off a bar stool and onto his arm. His next recalls waking up in the back of his friend’s pick-up truck. He is ambulatory and cooperative. He is only minimally able to move his right hand (1).

The PAT is as follows
- **Appearance**: Alert and cooperative.
- **Work of Breathing**: Normal.
- **Circulation to the Skin**: Normal except for his right forearm which is noted to have some areas of hyperemia.

Vital Signs Include
- Heart rate: 70 bpm
- Respiratory rate: 16 breaths/min
- Blood pressure: 120/80 mmHg
- Temperature: 37.0°C
- Weight: 80 kg

Initial Assessment
- A: Normal.
- B: Normal.
- C: Normal. Perfusion of his right hand and fingers is normal. Capillary refill time is 2 seconds. Pulse oximetry in his fingers reveals a normal perfusion waveform.
- D: Not able to move his right hand well. His right forearm is slightly swollen with no angular deformity. He complained of moderately severe pain in his forearm, yet his skin was hypoesthetic. He is able to move his elbow.
- E: His back reveals a geometric shaped bruise approximately 7 cm in diameter.

Focused History
- S: Alcohol binge, fall onto his arm, pain, paresthesia, paresis.
- A: No allergies.
- M: None.
- P: Healthy.
- L: Ate half a sandwich before having his friend drive him to the ED.
- E: No fever. Alcohol binge and a fall.
Detailed Physical Exam
- Skin: No additional findings. Findings are limited to his right forearm and the bruise lesion on his back.
- Head: Normal.
- Chest: Normal.
- Heart: Normal.
- Abdomen: Normal.
- Neurologic examination: Unable to move his right hand well, hypoaesthesia of his hand.

Key Questions
*What is your general impression of this patient?*
Characterize the patient’s condition as one of the following:
- Stable
- Respiratory Distress
- Respiratory Failure
- Shock
- Primary CNS/Metabolic Dysfunction
- Cardiopulmonary Failure/Arrest

Core Knowledge Points – General Impression
He is stable from a cardiopulmonary standpoint. Does he have an emergent condition due to his forearm?

Key Questions
*What are your initial management priorities?*
- Radiographs of his right forearm. These are obtained and are normal.

Critical Actions
- Cellulitis is suspected. He is given IV morphine and IV ceftriaxone.
- Compartment syndrome should be suspected.
- Measurement of the intracompartmental pressure is essential.

Case Development
The diagnosis of compartment syndrome is considered, but the clinicians are skeptical because:
- There is no fracture present.
- The published signs and symptoms of compartment syndrome include the 6 P’s: pain, paresthesia, paresis, pallor, pulselessness, poikilothermia.
- While pain, paresthesia, and paresis are present, there is no pallor, distal circulation is good, and the forearm is warm.
• How is the bruise on his back possibly related to compartment syndrome?

Case Development
Differential Diagnosis:
• Occult fracture, peripheral nerve palsy, compartment syndrome, cellulitis, rhabdomyolysis, vascular injury, deep venous thrombosis, gas gangrene, necrotizing fasciitis
• His intracompartment pressure is measured as 72 mmHg (exceeding the 30 to 45 mmHg critical range).

Key Question
What do these results indicate?
• Compartment syndrome is confirmed.

Core Knowledge Points — Possible Diagnosis
• Although the published signs and symptoms of compartment syndrome include the 6 P’s: pain, paresthesia, paresis, pallor, pulselessness, poikilothermia, the latter three are NOT signs of an early compartment syndrome. It is essential for this diagnosis to be made early if a good outcome is to be achieved.

Core Knowledge Points — Compartment Syndrome (1)
• Compartment syndrome (CS) is the result of increased pressure within a closed anatomical space. As such, any area of the body which contains a compartment can be affected, namely the hand, forearm, upper arm, entire lower extremity, abdomen, and buttocks. As the intracompartmental pressures increase and exceed the perfusion pressure, tissues become ischemic and may become necrotic without timely intervention. Compartment Syndrome (CS) is a thus a limb- and even life-threatening condition. Patient prognosis depends upon the timeliness of diagnosis and intervention. Therefore, time is critical. It is generally accepted that 6 hours is the upper limit of tissue viability (2). Traditionally, the "6 Ps" (pain, paresthesia, paresis, pallor, pulselessness, poikilothermia) were used to clinically diagnose CS; however pulselessness and pallor are usually NOT present in a compartment syndrome (3). Additionally, poikilothermia is not a term which is commonly used. Thus, only 3 Ps remain. Learn the three important Ps of pain, paresthesia and paresis and do not rely on the other three.
• In the pathophysiology of CS, venous outflow resistance is increased, ultimately leading to a cessation in blood flow. CS is really a venous obstruction rather than an arterial infarction. Venous outflow is impeded when the compartment pressure exceeds about 30 mmHg. As the compartment pressure rises, all the veins are compressed and venous outflow is blocked. Since venous outflow is blocked, perfusion of the tissues within the compartment ceases. There may still be arterial
pulsation of the larger arteries within the compartment and distal to the compartment because the systolic pressure still exceeds the compartment pressure. In addition, arterial blood may continue to flow through arteriolo-arteriolar shunts, thus distal pulses may still be present (2, 4, 5). Pulsation within larger arteries, however, will not result in any capillary circulation (i.e., no cellular perfusion is present), because venous outflow is blocked. Avoid this pitfall: pulselessness is NOT present in early cases of compartment syndrome. Do not use the presence of pulses to rule out a compartment syndrome, because this will cause the diagnosis to be delayed beyond the point of salvage.

- Consider a more extreme example. If the two iliac arteries are ligated, there is obviously no flow through the iliac arteries. Yet, a finger placed on the iliac arteries (proximal to the ligation) would still yield pulsation. Again, the presence of pulsation does not necessarily equate to blood flow.

- Similarly, pallor may not be evident in a compartment syndrome. The skin outside the compartment may be normally perfused since only intracompartmental perfusion may be affected. Even if the venous outflow of the skin is impeded, the appearance of the skin would be that of venous congestion and NOT pallor.

- Pain, however, is a reliable indicator of compartment syndrome. CS should be suspected if the patient complains of severe pain following any injury to an extremity. Often, the pain is more severe than one would expect from the injury. Severe pain after splinting or casting should raise the possibility of CS. The pain may occur at rest or with certain movements, such as passive stretching of the muscles or active flexion/extension. The pain can be described as a burning sensation, and it is not usually relieved by pain medication or splinting.

- Paresthesia will ultimately develop as nerve conduction slows in hypoxic/ischemic conditions. A later finding in CS, paresis or paralysis may set in as motor neurons start to dysfunction. The extremity may also feel tense or hard (2, 5).

- The anterior distal lower extremity is cited as the most common site of compartment syndrome. The reason for this location is probably due to its high frequency of injury. The usual cause of CS is a fracture. However, the incidence of CS following a fracture is actually very small. In the setting of a fracture, compartment syndrome is therefore a diagnosis of low probability but high morbidity. It is also estimated that 30% of limbs will develop CS following vascular injury (2).

- There are two main pathways to increasing intracompartmental pressure:
  - Increasing the fluid content within the compartment, either by hemorrhage or from edema
  - Decreasing the compartment size, either by tissue constricture or by external compression (2, 6)
Osseofascial compartments are relatively nondistensible and have a fixed volume. Thus, the introduction of fluid into or external compression of the compartment will undoubtedly raise the intracompartmental pressure. There are several theories which attempt to explain the exact mechanism of the resulting decrease in tissue perfusion. One popular theory states that the increase in intracompartmental pressure leads to a compression of the venous system. As the pressure in the venous system rises, the arteriovenous pressure gradient decreases. Hence, blood has a decreased tendency to flow into the capillaries. The body's compensatory mechanisms to increase perfusion pressure are eventually overwhelmed by increasing intracompartmental pressures. The increased venous outflow resistance ultimately causes a retrograde blood stasis. Blood ceases to perfuse the cells and the tissues become ischemic (4).

A further complication is that hypoxic cells will release vasoactive substances such as histamine and serotonin which serve to increase capillary permeability. As protein leaks into the interstitial space, water is pulled along with it. Thus, the intracompartmental pressures continue to rise.

Prolonged ischemia (over 6 hours) will result in rhabdomyolysis and potential loss of limb. Rhabdomyolysis may lead to acute renal failure and eventual death. CPK and serum myoglobin levels may be elevated, indicating rhabdomyolysis. Dipstick urinalysis may be positive for blood, but on microscopic review be negative for RBCs, indicating the presence of myoglobin in the urine (2).

Radiographs of the extremity may show the presence of an underlying fracture, but the absence of a fracture does not rule out a compartment syndrome since there are other etiologies for compartment syndrome. A CT scan may reveal areas of muscle necrosis. A CT scan, however, should not delay the treatment of a compartment syndrome. Once it is suspected, it should be acted upon immediately to maximize the patient's chance of recovery.

A measurement of the compartment pressure should be obtained as soon as a diagnosis of CS is suspected. Commercial pressure measurement devices are available. If none is available, three generic procedures for measuring the intracompartmental pressure are suggested at the end of this case.

The level of intracompartmental pressure which serves as the cutoff point for diagnosing CS is under debate. Some cite 30 mmHg as indicative of CS, whereas others claim that 45 mmHg is an appropriate cut-off (2).

The threshold for developing CS is directly affected by the amount of blood flow to that area. As such, hypotensive patients may develop CS at lower intracompartmental pressures. Thus, some advocate the use of perfusion pressure, rather than just intracompartmental pressure, in determining CS. Perfusion pressure = Diastolic BP minus the intracompartmental pressure (7,8). McQueen used perfusion pressure measurements of less than 30 mmHg as diagnostic of CS and an indication for fasciotomy (2).
Management: Since the pathophysiology of CS involves an ischemic event, it may be helpful to give the patient oxygen to increase pO2. The patient should be hydrated intravenously to prevent acute renal failure secondary to rhabdomyolysis (2, 6). The involved extremity should be kept at body level so that arterial blood flow is not compromised and venous drainage is unhindered (5). The definitive therapy for CS is fasciotomy to relieve the intracompartmental pressure. The emergency physician should seek immediate surgical consultation.

Core Knowledge Points — Intracompartmental Pressure Measurement Methods
- The Stryker Stic device (registered trademark, Stryker, Kalamazoo, MI) is a commercially available product made specifically for measuring intracompartmental pressures. It is fast and accurate, but it is modestly expensive and it is possible that your hospital does not have it. Prep the skin with povidone-iodine solution. Administer local anesthesia, if necessary, being careful not to inject within the compartment.
- If you don't have access to a Stryker Stic device, there are three generic alternatives, two of which will probably work with equipment that is available in most hospitals.
  - The IV infusion pump method (probably the best alternative to the Stryker Stic)
  - Electronic pressure transducer method
  - Mercury column Manometer method (difficult and sometimes not reliable) (9)

IV Infusion Pump Method
- This method is very simple, but it requires an IV infusion pump with a built-in pressure readout. Most modern IV infusion pumps have this feature, which is most commonly used to permit nurses to set limits on IV infusion pressure so that the pump with alarm if a high pressure condition is encountered, usually due to an infiltrated IV or a malpositioned IV catheter. These sophisticated pumps reduce the likelihood of an undetected infiltrated or obstructed IV catheter. Uppal et al, described the use of the IVAC infusion pump to measure the intracompartmental pressure (10). The accuracy of this method has been confirmed by others (9):
  - Prime the IV infusion pump with saline and remove all air bubbles.
  - Attach an 18-gauge needle to the end of the IV tubing. Infuse saline so that saline is primed through the entire needle.
  - Set the IV infusion pump to 25 cc/hr.
  - Set the pump to read pressure in mmHg (rather than cm H2O).
  - Adjust the height of the IV infusion pump to be roughly level to the patient's extremity that is about to be measured.
  - Turn the pump on to begin infusion, then insert the 18-gauge needle with saline flowing through it at 25 cc/hr into the desired compartment.
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- Immediately read the infusion pressure on the pump when the needle is inserted. Some pumps have a feature to display the pressure continuously. The pressure should have gone from a value near zero to a higher value reflecting the pressure within the compartment. The pressure must be read immediately to prevent fluid from infusing into the compartment and elevating the pressure further.
- Remove the needle from the compartment.

**Electronic Transducer Method**

- Prime a standard arterial line electronic pressure transducer module with normal saline. There should be at least two IV connections. One connects to an IV pump, which should be set at a very low rate such as 10 ml/hr. The distal port should be connected to an 18-gauge needle. The pressure transducer module cable should be connected to a blood pressure module/amplifier on the patient’s monitor system.
- Infuse IV fluid until the 18-gauge needle is filled with saline, and then stop the IV infusion.
- Place the tip of the needle at the level of the patient’s extremity to be tested, and then “zero” the monitor at this level.
- Insert the needle into the designated muscle compartment.
- Start the IV infusion. The monitor should show the pressure rising. When it reaches a plateau, this reflects the intracompartmental pressure. Stop the IV infusion.

**Potential Complications**

- Prognosis ultimately depends upon the speed of diagnosis and treatment. However, even with timely intervention, the patient may still suffer some permanent neuromuscular dysfunction.
- Volkmann's ischemic contracture
- Rhabdomyolysis will occur after approximately 6 hours of warm ischemia and may escalate into a bacterial gangrene infection, loss of limb, and sepsis. Acute renal failure may result from rhabdomyolysis, and if left untreated, will lead to death (7).
- Following a fasciotomy, there is a risk of infection. The procedure will also leave some cosmetic deformity (2).

**Core Knowledge Points**

- CS can occur without any trauma. Prolonged external compression of an extremity can occur in the setting of drug/alcohol overdose and lead to CS.
- Prognosis depends upon the speed of diagnosis and treatment.
- Severe pain (especially with passive stretching of the muscles) followed by increasing neuromuscular deficits are the key clinical manifestations of CS.
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- The traditional sign of pulselessness is not a definitive criteria of CS. Pulses may still be palpable in CS due to arteriolo-arteriolar shunts. Do not be fooled by palpable pulses.
  - CS is mainly a clinical diagnosis, but can be confirmed by measuring intracompartmental pressures.
  - Critically-ill patients may present with a myriad of complicating factors.
    - Shock: Hence, a lower intracompartmental pressure is needed to overcome a lower perfusion pressure. Additionally, patients who require large volume resuscitation are at risk for developing interstitial edema and subsequent CS (7).
    - Altered mental/neurological status: Thus, the patient may not complain of pain and/or paresthesia. Examples include patients with CNS injury or patients on narcotics.
    - Hypoxia and/or Anemia: In which case ischemia will occur more quickly following smaller compromises in capillary perfusion pressure (8).
  - Treatment of rhabdomyolysis involves aggressive IV hydration to prevent acute renal failure.
  - Fasciotomy is the definitive treatment for compartment syndrome.

Case Development

- An orthopedic surgeon performs a fasciotomy of his forearm.
- Large areas of muscle necrosis are noted.
- He also develops renal insufficiency secondary to severe rhabdomyolysis.
- After multiple debridement procedures, he is able to regain some forearm, wrist, and hand function, but it is apparent that he has suffered permanent neuromuscular deficits.
- Upon questioning one of the patient's friends, it was revealed that the patient had taken 20 or 30 shots of liquor the previous night. After falling off the bar stool, his friends carried him into the back of a pick-up truck where he slept until he awoke the next day. His compartment syndrome was due to him sleeping on his arm in an intoxicated state and compressing it for an extended period of time. Because of his alcohol intoxication, the normal body protective reflexes that stimulate the body to move and roll while sleeping were blunted.
- In retrospect, it was believed that the bruised lesion on his back was probably due to pressure necrosis resulting from something (in the back of the pick-up truck) pressing upon his flank while he was unconscious.
References


Additional Reading