Compartment Syndrome: Diagnosis and Treatment

Marcus Coe, MD
Ann Van Heest, MD
Paul Dougherty MD

Problem Identification and Needs Assessment

Identification of targeted learners
Orthopedic surgery junior level residents

Identification of need or problem for targeted learners
To identify the patient at risk for compartment syndrome.
To diagnose compartment syndrome by physical examination and compartment pressure measurement.
To treat compartment syndrome by fasciotomy.

Current educational approach to address need or problem
Currently most orthopedic surgery residency programs are teaching diagnosis and treatment of compartment syndrome by didactic lectures and on clinical cases.

Ideal educational approach to address need or problem
Ideally, junior level orthopedic residents would demonstrate adequate medical knowledge and patient care skills for diagnosis and treatment in a simulated setting prior to addressing compartment syndrome in the clinical setting, so that learning and preparedness occurs prior to patient care.

Goals and Objectives

Specific educational goals
By the end of the module learners should:

- Demonstrate knowledge of the patient population at risk for developing compartment syndrome
- Demonstrate knowledge of the signs and symptoms of compartment syndrome and their reliability
- Demonstrate knowledge of the anatomy of the areas most commonly at risk for developing compartment syndrome: the forearm and the leg
- Demonstrate knowledge of when the measurement of compartment pressure is warranted
- Describe indications for operative fasciotomy.

Specific cognitive, affective, psychomotor task objectives
By the end of the module learners should:

- Demonstrate the ability to correctly place a needle in different areas of a model that contains numerous compartments
- Demonstrate the ability to correctly use a handheld intra-compartmental pressure monitor and/or arterial line to accurately measure the pressure in a model compartment
- Demonstrate the ability to successfully perform a fascial release of the lower leg and the forearm/hand on a cadaver (if available)

Syllabus Development

Assumptions
It is assumed that residents will have knowledge of basic history taking and physical exam skills. It is assumed that residents will have knowledge of sterile technique and manipulation of basic surgical tools.
Suggested readings

- Schmidt, Andrew: “Acute Compartment Syndrome” in Evidence-Based Orthopaedics edited by Mohit Bhandari, 2011. Pages 627-635

Description of laboratory module

The module will begin with a 20 minute review of the patient population at risk for developing compartment syndrome, the signs and symptoms of compartment syndrome, the reliability of these clinical signs and symptoms in isolation and aggregate, the anatomy of the forearm and lower leg, the indications for use of compartment pressure measurement, and the indications for surgical fasciotomy.

The next 1.5 hours will be devoted to dividing the learners into three different groups to perform tasks at three stations. Station #1 will be dedicated to accurately placing a needle into each of the four compartments of a lower leg model. Station #2 will be devoted to demonstrating the ability to accurately record the pressure in a pressurized compartment model using a handheld intra-compartmental pressure monitor and/or an arterial line. If a cadaver is available, Station #3 will be devoted to demonstrating proper technique for a two incision lower leg fasciotomy and a two incision forearm fasciotomy. The groups will rotate every 30 minutes.

The last ten minutes will be devoted to answering questions that have arisen during the module.

Description of techniques and procedures

At station #1, learners will steriley prep and drape a lower leg model that has the ability to localize the tip of the needle. A model has been developed in conjunction with Sawbones that uses an electrical circuit and a screen to localize the tip of the needle. Learners will prep a small area medially and laterally on the leg. Learners will then open sterile gloves and handle the model’s needle as if the tip were sterile. Learners will then place the needle into the lateral and anterior compartments through a lateral approach. Learners will demonstrate the correct placement of their needle with the feedback screen on the model. Learners will similarly place the needle into the deep and superficial posterior compartments through a medial approach and demonstrate the correct placement of their needle.

In station #2 an overseer will use a sphygmomanometer to pressurize a 500cc bag of normal saline. The pressure of the sphygmomanometer will be blinded to the learner. The learner will then assemble the handheld intra-compartmental pressure monitor, keeping the non-dominant hand and the separately packaged needle sterile. The learner will compress the plunger on the syringe until liquid comes out of the end of the needle and there are no air bubbles in the system. The learner will hold the needle at a consistent angle perpendicular to the access port of the fluid bag. The system should be zeroed at this point, then inserted into the fluid bag maintaining the previous angle of approach. After inserting the needle into the fluid bag, a small amount of fluid (<3/10 cc) should be injected from the syringe. The learner will announce the pressure she believes to be accurate and this will be compared against the sphygmomanometer pressure reading. Using the access port allows the bag of fluid to be reused.

Additionally the learner can use an arterial line to measure the pressure in the pressurized bag of fluid. An arterial line of at least 16 gauge or larger should be used. The catheter should be flushed with saline, inserted into the access port, the needle withdrawn and the catheter left in place, and then the catheter should be connected to the arterial line transducer. The transducer should be at the same level as the compartment being measured.

In station #3 a two incision fasciotomy will be performed on a cadaveric lower leg or forearm. This exercise can be done as a group so that
perform through longitudinal incisions with one digitorum communis. 

An incision should be made from the lateral epicondyle of the elbow to the midline of wrist. An incision should be made in the fascia between the extensor carpi radialis brevis and the extensor digitorum communis. Hand fasciotomies can be performed through longitudinal incisions with one the radial border of the first metacarpal for release of the thenar muscles; two parallel longitudinal incisions on the dorsal aspect of the hand for release of the interossei; and one longitudinal incision on the ulnar border of the fifth metacarpal for release of the hypothenar muscles.

Common errors and prevention strategies

Error 1

The most common cognitive error in treatment of compartment syndrome is failure to diagnose compartment syndrome in a timely manner.

Recognizing at risk patients such as pediatric patients, intubated patients, patients with multiple reductions, patients with long standing unreduced fractures, and patients sustaining fractures with high risk mechanisms (such as crush injuries) are important factors in determining who needs compartment pressure measurement procedures.

Error 2

Failing to insert the pressure monitoring needle into the correct compartment or failing to check all compartments in the limb in question.

Preventing this error requires knowledge of the anatomy of the limb in question. It also requires the ability to feel the change in resistance when the handheld intra-compartmental pressure monitor pierces through a fascial layer, which should feel like a distinct “pop.” Identical pressure readings thought to be from two different compartments should be repeated in a different location with a different needle entry site.

Error 3

Injecting too much fluid into through the handheld intra-compartmental pressure monitor and obtaining spuriously high pressure readings.

Prevention of this error requires a delicate touch on the plunger and knowledge that <3/10 cc of fluid should be injected once the needle is in the compartment to be monitored. The handheld intra-compartmental pressure monitor can be finicky. The goal of the device is to create a continuous column of fluid from the compartment to the monitor so that pressure is directly transmitted to the sensor. Light taps on the plunger are sufficient to pressurize the column of fluid.

Adapted from *Skeletal Trauma, Fourth Edition* edited by Bruce Browner, 2008:

For the lower leg fasciotomy, an anterolateral incision is made from the knee to the ankle centered halfway between the fibula and the anterior crest of the tibia. Care should be taken to identify the superficial peroneal nerve and protect it. The fascia separating the anterior and lateral compartment should be identified. The fascia of the anterior compartment and the lateral compartment should be released along the full length of the compartment using 2 separate fascial incisions. A posterior medial incision should be made from the knee to the ankle 2 cm posterior to the posterior cortex of the tibia. Care should be taken to identify and protect the saphenous vein and nerve. The fascia overlying the gastrocnemius soleus complex should be incised, releasing the superficial posterior compartment. Proximally, some of the fibers from the origin of the soleus must be released off of the back of the tibia. The fascia overlying the flexor digitorum longus underneath should then be incised, releasing the deep posterior compartment.

For the forearm fasciotomy, the approach should begin with a volar Henry approach to release both the superficial and deep flexor compartments. The incision should begin lateral to the biceps tendon and be carried distally to the ulnar-distal side of the forearm. The incision should be extended into a carpal tunnel release, traversing the wrist crease and extending into the palm in line with the radial border of the ring finger. The fascia overlying the superficial fascia should be incised along the length of the incision and the transverse carpal ligament should be released. The radial artery and median nerve should be identified, released, and protected; then the fascia overlying the flexor digitorum profundus, the flexor pollicis longus, and the pronator quadratus should be released. A dorsal fasciotomy is not always needed, but can now be performed. An incision should be made from the lateral epicondyle of the elbow to the midline of wrist. An incision should be made in the fascia between the extensor carpi radialis brevis and the extensor digitorum communis. Hand fasciotomies can be performed through longitudinal incisions with one separate cadavers are not needed for each individual. In lieu of practicing formal releases on cadavers, instructional videos demonstrating leg and forearm compartment releases are included for learners to view.
Error 4
Technical difficulties with automated compartment pressure monitor.

Technical difficulties sometimes arise with the handheld intra-compartmental pressure monitor. Always remember that a clinical diagnosis trumps a malfunctioning pressure monitor of any sort. To avoid mistakes with the handheld intra-compartmental pressure monitor, make sure that you use the side bore needle that comes in the kit; this cannot be substituted with an end bore needle as this will just give a punch biopsy of local muscle tissue. Make sure the limb is at the level of the heart when taking your recording. Try fully withdrawing and flushing the needle then repeating measurements if the measurements are awry. Compressing the adjacent tissue within the compartment being measured or passively stretching the muscle should increase the pressure reading; this can be done to verify that the compartment pressure monitor is recording accurately.

Error 5
Insufficient release of compartments.

Prevention of this error requires long skin and facial incisions, complete visualization of the anatomy in question, and, more specifically, sufficient release of the superficial posterior compartment to access the deep posterior compartment in the leg. The entire length of each compartment should be released. The skin should not be closed over fasciotomies.

Demonstrate expert performance

The technique for the above stations is demonstrated in the included videos.

Recommendations for motor skills practice

Learners should practice:

- Injecting <1/10 cc at a time out of the handheld intra-compartmental pressure monitor needle with one hand

Supplies and station setup

As reviewed on the video:

1) Lower leg compartment pressure model, such as: http://www.sawbones.com/products/product.aspx?2775
2) Sphygmomanometer (handheld, stand or wall mounted)
3) 500 cc bags of fluid
4) Handheld pressure monitor, such as: http://www.stryker.com/en-us/products/OREquipmentConnectivity/GeneralMultiSpecialtyEquipment/PressureMonitors/IntraCompartmentalPressureMonitor/index.htm
5) Arterial line catheters and tubing/wiring
6) Cadaver limbs and dissection equipment

Suggested duration for completion of module

Two hours.

Estimated budget

1) Lower leg compartment model: ~$800 (available for multiple uses)
2) Sphygmomanometer: available in-house at most institutions
3) 500 cc bags of fluid: available in-house at most institutions
4) Handheld pressure monitor, disposable kits and arterial line set-ups: available in-house at most institutions
5) Cadaver limbs and dissection equipment: per institution

Learner Evaluation and Feedback

Methods of performance assessment

At station #1, performance will be assessed on the ability to accurately place the needle in different compartments.

At station #2, performance will be assessed on the ability to accurately measure the pressure of the fluid in the IV bag, as determined by the pressure demonstrated on the sphygmomanometer.
At station #3, performance will be assessed by the ability to correctly perform a two incision fasciotomy of the leg and forearm or identify the mistakes that were made in the cadaver dissection.

**Suggested proficiency benchmarks**

At station #1, it is suggested that learners be able to place the needle in each of the four compartments of the leg, in succession, without error. Learners should place the needle definitively in one spot, state which compartment they believe they are in, leave the needle stationary, then check their placement with the feedback screen on the model.

At station #2, it is suggested that learners accurately identify the pressure in the IV bag, on two separate occasions, within 5 mmHg of the sphygmomanometer.

At station #3 it is suggested that learners be able to correctly identify all forearm and hand anatomy made during the dissection and fascial release.

**Methods for learner debriefing and feedback**

An instructor should be overseeing each station. This could be a senior resident or faculty member. Real time feedback should be supplied with specific, constructive critiques. After each learner has performed the task, he/she should be asked what went well and what could have been done differently. The instructor should then review what he/she thought went well and what could have been done differently. Learners who do not demonstrate proficiency should repeat the task until proficiency is demonstrated. Feedback should be provided after each iteration. Three failed attempts to demonstrate proficiency should lead to a one-on-one session at a later date after the learner has had a chance to practice the skills involved in the module in question.

**Periodic Curriculum Review, Evaluation, Validation, and Refinement**

Review can be performed during residency training as indicated.