Intracompartmental Pressure Monitoring Using a Handheld Pressure Monitoring System

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Based on an original article: *J Bone Joint Surg Am.* 2014 Oct 1;96(19):e171.

Introduction

We describe the correct technique for measuring compartment pressure with a handheld device to diagnose compartment syndrome.

Acute compartment syndrome is an orthopaedic emergency that requires accurate and timely diagnosis. Although compartment syndrome is often a clinical diagnosis, measurement of the compartment pressure can validate the clinician's suspicion and provide objective data when the clinical picture is unclear. Handheld intracompartmental pressure monitors are often used to measure compartment pressures. Such devices are relatively simple to operate but proper technique is necessary to obtain accurate measurements. The proper technique (Video 1) is presented below.

Step 1: Device Preparation

Proper preparation of the handheld pressure monitoring device (Stryker Surgical, Kalamazoo, Michigan) is critical to ensure that the device performs appropriately.

- Screw the pressure coupler onto the syringe and then firmly attach a side-ported needle to the coupler.
- Place the assembled syringe-coupler-needle complex into the pressure monitoring device and snap the protective cover on the device shut. If the plastic flange on the syringe prevents the cover from closing, rotate the pressure coupler and syringe as needed until the cover can be closed (Figs. 1 and 2).
- Purge the air from the syringe-coupler-needle complex (typically done with the complex removed from the device) by holding it upright at a 45° angle and slowly compressing the syringe in this position. This fills the coupler and needle with saline solution and ideally removes all of the air between the syringe and the tip of the needle (Fig. 3). If any air bubbles remain, hold the complex vertically with the syringe tip on top and tap the barrel while compress-

ing the syringe plunger to fully eliminate the bubbles.

- Rotate the transducer appropriately to fit it into the pressure monitor, allowing the protective cover to be snapped shut (Fig. 2). The device is now ready for use.

Step 2: Identification of the Compartment of Interest

The needle must be placed in the proper location to appropriately measure a compartment's pressure.

- In general, test all compartments of an anatomic segment if there is a concern that a compartment syndrome might be present. For example, test the anterior, lateral, superficial posterior, and deep posterior compartments of the leg if a compartment syndrome in the leg is suspected.
- It is crucial to understand the surface anatomy and deep fascial anatomy to achieve proper needle placement. Thus, review appropriate anatomic texts and resources prior to compartment testing if you are not familiar with the anatomy.
- Plan the trajectory of needle placement into the compartment of interest to avoid any large neurovascular structures. Prior to actually inserting the needle through the skin, hold the pressure monitoring device in the position of the planned trajectory into the compartment of interest (i.e., straight up and down, parallel with the floor, or any other angle necessary to approach the compartment) and zero the device by pushing its "zero" button (Fig. 4).
- Insert the needle through the skin. A "pop" is typically felt as the needle penetrates the skin.
- Advance the needle until a second "pop" is felt as the needle meets resistance when penetrating the fascial covering of the compartment of interest.
- To aid in confirming that the appropriate compartment has been entered, ask a patient who

can cooperate to contract the muscles within that compartment. If the patient is uncooperative or obtunded, manually squeeze (compress) the compartment of interest. In both cases, this can be done before and/or after the injection step (Step 3). Pressures within the compartment should transiently rise on muscle contraction or compartment compression. If the pressure readings on the monitor remain unchanged, reassess the needle placement to ensure accurate placement.

Step 3: Injection

Inject saline solution from the pressure monitoring device to clear any soft tissue from the side port on the needle that could result in inaccurate pressure measurements.

- With the needle in the appropriate location within the compartment of interest, inject 1/3 mL of saline solution without changing the position of the monitoring device.
- The goal is a contiguous column of fluid from the tissues to the device. If the readings are not showing the characteristic initial rise and settling, you may need to reinject and back the needle up (0.5 to 1.0 mm) to clear any tissue from the side port of the needle and reestablish a column of fluid.

Step 4: Stabilization and Pressure Reading

The pressure must reach a stable state before it is recorded; different pressure thresholds for decompression have been recommended in the literature.

- Following saline solution injection, pressure readings generally rise and fall to reach a stable state; it is important that this stable state be reached before the pressure is recorded.
- In the absence of a reliable clinical examination, the intracompartmental pressure measurement can be used to determine the necessity of a fasciotomy. However, different pressure thresholds have been recommended in the literature. Some authors have recommended an absolute intracompartmental pressure reading of >30 mm Hg¹ or >45 mm Hg² as the indication for decompression. Others have based the need for fasciotomy on a difference between the diastolic pressure³⁻⁶ or the mean arterial pressure⁷ and the intracompartmental pressure. One clinical series demonstrated that limbs in which the difference between the diastolic pressure and compartmental pressure remained >30 mm Hg did not develop compartment syndrome⁴. However, of the 116

patients in that series, only three were diagnosed with compartment syndrome and although a pressure threshold difference of <30 mm Hg between the diastolic and compartmental pressures was used as the indication for decompression the three patients requiring fasciotomy had a difference of ≤ 15 mm Hg. Therefore, other authors have thought that decompression is not necessary until the intracompartment pressure is within ≤ 20 mm Hg of the diastolic pressure as this is also supported by available basic-science data^{5,6}. That is the current practice at our institution.

Step 5: Repeat Measurements

As mistakes can be made with any single measurement, accuracy may be improved by repeating steps 1 through 4 and averaging the results.

Step 6: Additional Compartments

After the reading is obtained, move on to any additional compartment(s) that need to be evaluated, repeating the steps listed above.

Results

The handheld intracompartmental monitoring device with a side-porting needle has been shown to be extremely accurate in the laboratory⁸. In our recent article⁹, however, we found that trainees routinely made many technical errors using the device in a laboratory-based simulation. Furthermore, residents who made technical errors were more likely to make inaccurate pressure measurements. Fortunately, after a simple directed educational session, both technical errors and measurement errors decreased.

What to Watch For

Indications

- Any patient in whom a compartment syndrome is suspected. The mechanism of injury (high versus low-energy) does not correlate with the risk of compartment syndrome. In general, younger patients are at higher risk.
- Common injuries associated with a risk for this syndrome include high-energy tibial fractures, gunshot wounds to the forearm, and supracondylar humeral fractures in children. All injuries interrupting an extremity's vascular supply are also associated with a risk of compartment syndrome.

- While compartment syndrome is a clinical diagnosis, intracompartmental pressure monitoring can be a useful objective tool for confirming a diagnosis.
- Intracompartmental pressure monitoring can be especially useful in obtunded or intubated patients as well as in nonverbal patients (young children).

Contraindications

- There are probably no true contraindications. In general, this is a safe procedure with minimal morbidity, although each case should be considered individually.
- Potential contraindications include active cellulitis over the area of concern as well as over-anticoagulation to the point where the treating clinician fears a risk of excessive hemorrhage following intracompartmental pressure measurement.
- When there is a clear clinical picture of compartment syndrome, treatment (fasciotomy) should not be delayed to obtain pressure measurements. Similarly, when the clinical diagnosis is clear, fasciotomy should be performed regardless of the intracompartmental measurements.

Pitfalls & Challenges

- In our previous study⁹, the majority of trainees (79%) who did not receive formal training in the use of an intracompartmental pressure monitoring device committed some technical error at baseline. Improper purging and zeroing were the most common errors.
- Errors in assembly, zeroing, or injection can lead to an approximately threefold increase in measurement error.

Clinical Comments

- *How would you recommend teaching orthopaedic residents to accurately measure intracompartmental pressures?* We used a simple didactic teaching session, the content of which is included as an appendix in our article⁹. However, due to the design of the study, the residents also had three separate “hands-on” sessions using the compartment pressure monitors. We believe that combining a skills laboratory with the didactic session is likely the best approach. Animal or human cadaver compartment pressures can easily be elevated to allow residents to practice and objectively demonstrate proficiency.

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Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. None of the authors, or their institution(s), have had any financial relationship, in the thirty-six months prior to submission of this work, with any entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. Also, no author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

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Fig. 1
Incorrect alignment of the syringe flanges prevents closure of the monitor's lid.

Fig. 2
Correct alignment of the syringe flanges (in line with the device or horizontal) allows proper closure of the lid.

Fig. 3
An example of an air bubble that has not been evacuated appropriately from the device prior to use.

Fig. 4
Approaching the compartment of interest with the device and zeroing the device in the position of the planned trajectory of needle insertion into the compartment.