

Compartment Syndrome

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Disclosure Information

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Conflicts of Commitment/ Effort

Board of Directors: OTA

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Editorial Board: J Knee Surgery, J Orthopaedic Trauma

Medical Director, Director Clinical Research: Hennepin County Med Ctr.

Disclosure of Financial Relationships

Royalties: Thieme, Inc.; Smith & Nephew, Inc.

Consultant: Medtronic, Inc.; DGIMed; Acumed; St. Jude Medical (spouse)

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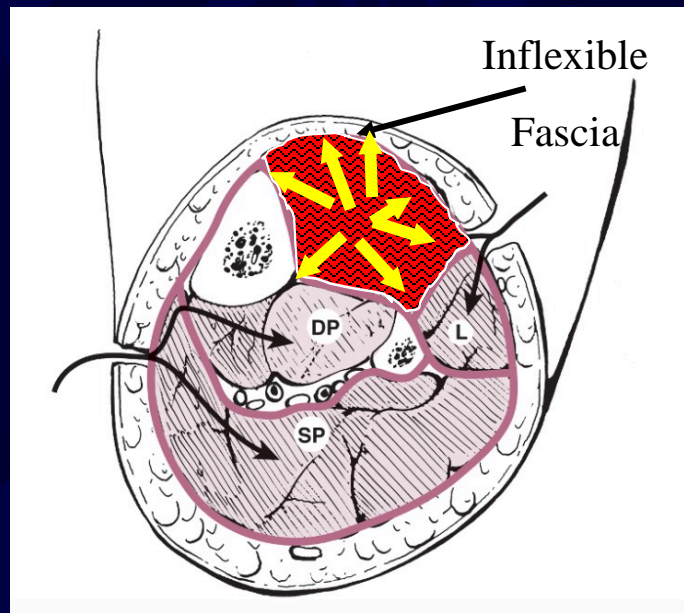
I will not discuss off label use and/or investigational use in my presentation.

Objectives

- Review Pathophysiology of Acute Compartment Syndrome
- Review Current Diagnosis and Treatment
 - Risk Factors
 - Clinical Findings
 - Discuss role and technique of compartment pressure monitoring.

Pathophysiology of Compartment Syndrome

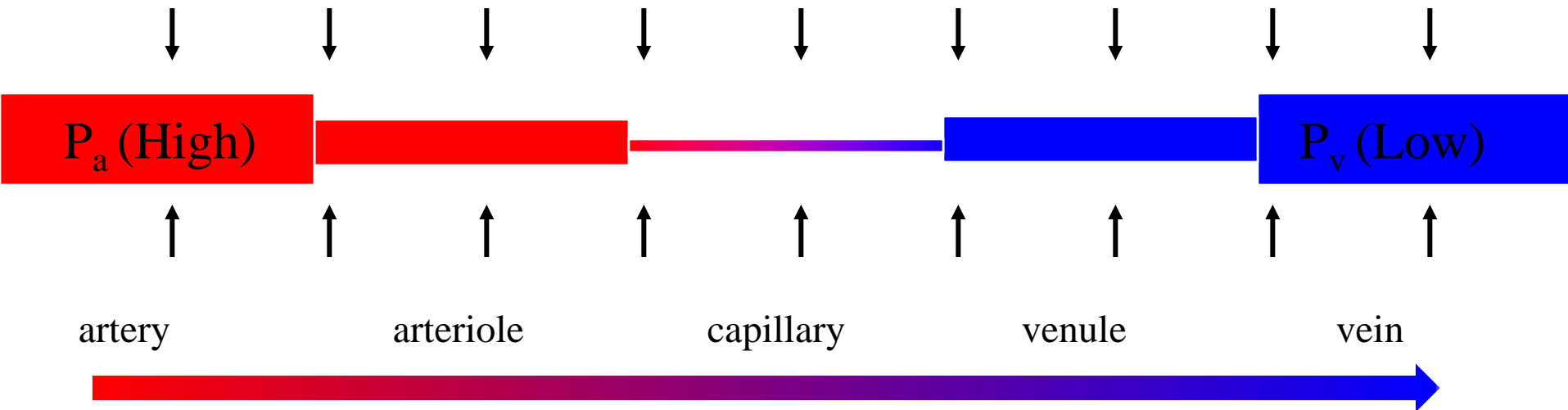
↑ Pressure



Injured Muscle

Vascular Consequences of Elevated Intracompartment Pressure:

A-V Gradient Theory



$$\text{Local Blood Flow} = \frac{P_a - P_v}{R}$$

Matsen, 1980

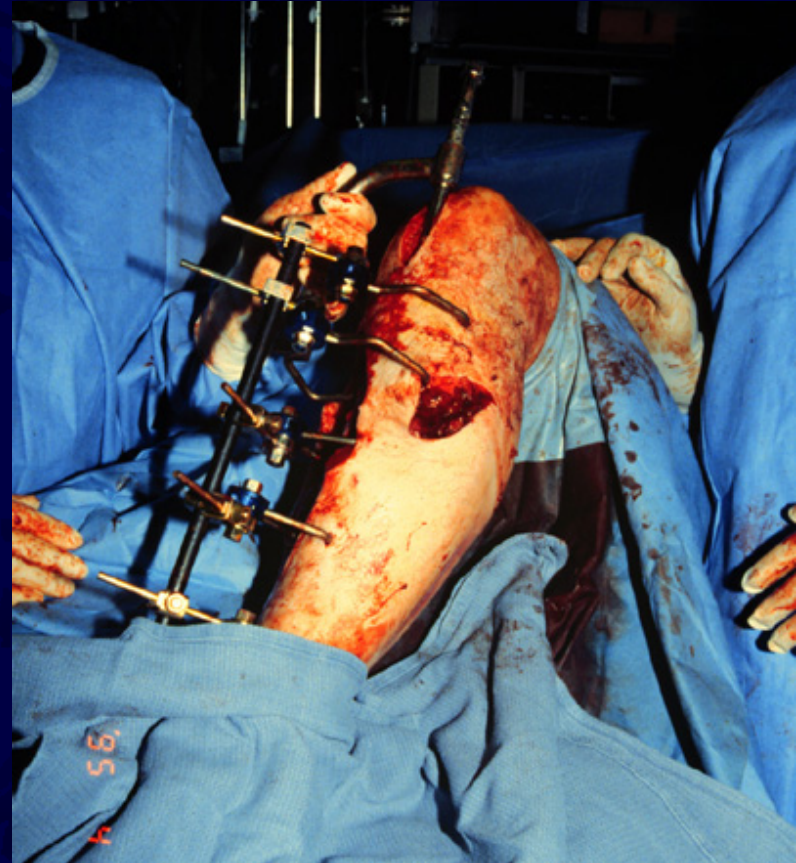
Reported Causes of Compartment Syndrome

- Trauma
 - Fracture
 - Crush syndrome
 - Soft tissue injury
- Bleeding
- Reperfusion Injury
 - Vascular Injury
 - Lithotomy position
- Intensive muscle use
- Burns
- Snakebite
- Venous obstruction
- Injection injuries



Fracture Treatment Increases IMP

- Splinting/casting
- Manipulation
- Traction
- Spanning Ex Fix
- Nailing

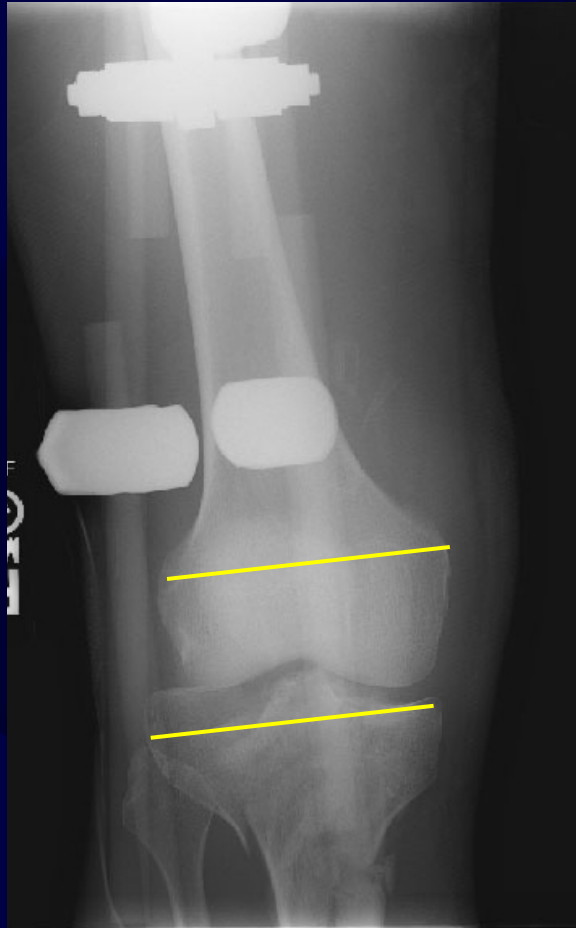


Incidence of ACS

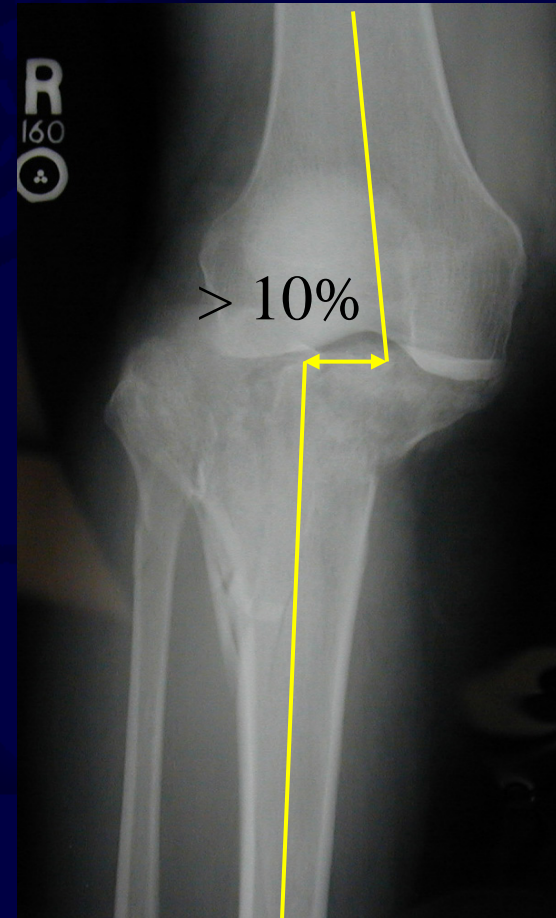
- 2-10% tibial fractures
- 10% Calcaneal fractures
- 18% Schatzker VI plateau fractures
- 41% foot crush injuries
- 48% Segmental tibia fractures
- 53% Medial knee fx/dislocations

“Radiographic Predictors of Compartment Syndrome in Tibial Plateau Fractures.”

Ziran and Becher, J Orthop Trauma 2013;27:612–615



Tibia Width



Femoral Displacement

Consequences of Compartment Syndrome

- Ischemic myonecrosis
 - Ischemic contracture
- Ischemic neuropathy
- Crush Syndrome
 - Rhabdomyolysis
 - Renal Failure

Delay in dx/rx is the cause of a poor outcome

Diagnosis



Diagnosis

- Traditionally based on clinical assessment of the “6 P’s”:
 - Paresthesia
 - Paresis
 - Pain on stretch
 - Pink Color
 - Pulse present
 - Pressure

Diagnosis

- Traditionally based on clinical assessment of the “6 P’s”:
 - Paresthesia: requires detailed exam, may be deficits present upon initial presentation
 - Paresis
 - Pain on stretch
 - Pink Color
 - Pulse present
 - Pressure

Diagnosis

- Traditionally based on clinical assessment of the “6 P’s”:
 - Paresthesia
 - Paresis: Difficult to grade motor strength when there is a fracture and/or splint present
 - Pain on stretch
 - Pink Color
 - Pulse present
 - Pressure

Diagnosis

- Traditionally based on clinical assessment of the “6 P’s”:
 - Paresthesia
 - Paresis
 - Pain on stretch: Difficult to separate from the pain due to the fracture
 - Pink Color
 - Pulse present
 - Pressure

Diagnosis

- Traditionally based on clinical assessment of the “6 P’s”:
 - Paresthesia
 - Paresis
 - Pain on stretch
 - **Pink Color:** These are normal findings too, so not helpful in the diagnosis of ACS
 - **Pulse present**
 - Pressure

Diagnosis

- Traditionally based on clinical assessment of the “6 P’s”:
 - Paresthesia
 - Paresis
 - Pain on stretch
 - Pink Color
 - Pulse present
 - **Pressure: difficult to assess reliably or to quantify**

Problems with Physical Diagnosis

- Literature meta-analysis found that clinical findings have poor sensitivity.
 - Sensitivity of 13-19%
 - Positive predictive value of 11-15%.
 - Specificity = 97% (3% incidence of C.S. in patients without clinical findings)

Ulmer, J Orthop Trauma, 16: 572

Variation in Diagnosis of Compartment Syndrome by Surgeons Treating Tibial Shaft Fractures

Robert V. O'Toole, MD, Augusta Whitney, BA, Nishant Merchant, BS, Emily Hui, MPH, Jennifer Higgins, MS, Terrence T. Kim, MD, and Carlos Sagebien, MD

(J Trauma. 2009;67: 735–741)

- Consecutive patients, same hospital, random surgeon call.
- Incidence of CS varied from 2-24%

DOCUMENTATION OF ACUTE COMPARTMENT SYNDROME AT AN ACADEMIC HEALTH-CARE CENTER

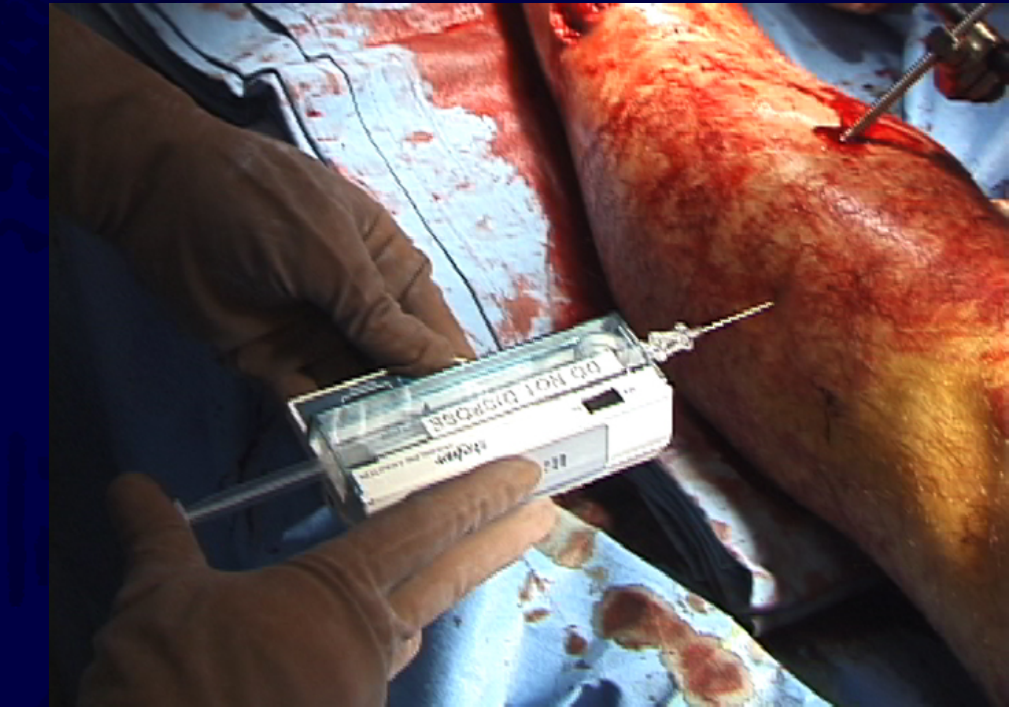
BY BRETT M. CASCIO, MD, JOHN H. WILCKENS, MD, MICHAEL C. AIN, MD,
CHARLES TOULSON, MD, AND FRANK J. FRASSICA, MD

Investigation performed at the Department of Orthopaedic Surgery, The Johns Hopkins University, Baltimore, Maryland

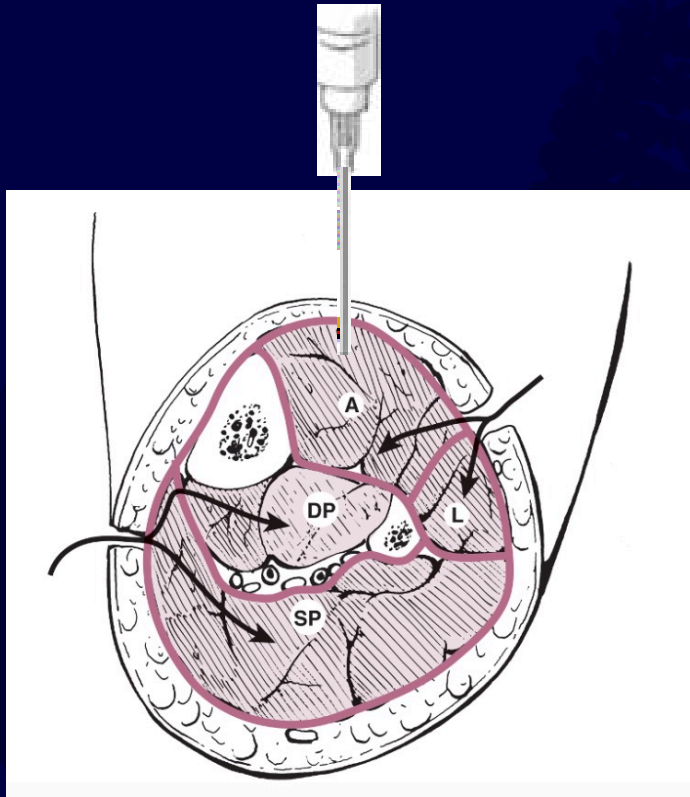
- Inadequate documentation in 21 of 30 cases of CS
 - No date/time
 - Missing info about signs and symptoms
 - Pressures not documented

Intramuscular Pressure Measurement

- Adjunct to clinical examination.
- Represents the only data available in comatose or otherwise non-evaluative patient:
 - Anesthesia
 - Head Injury
 - Sedated
 - Intoxicated

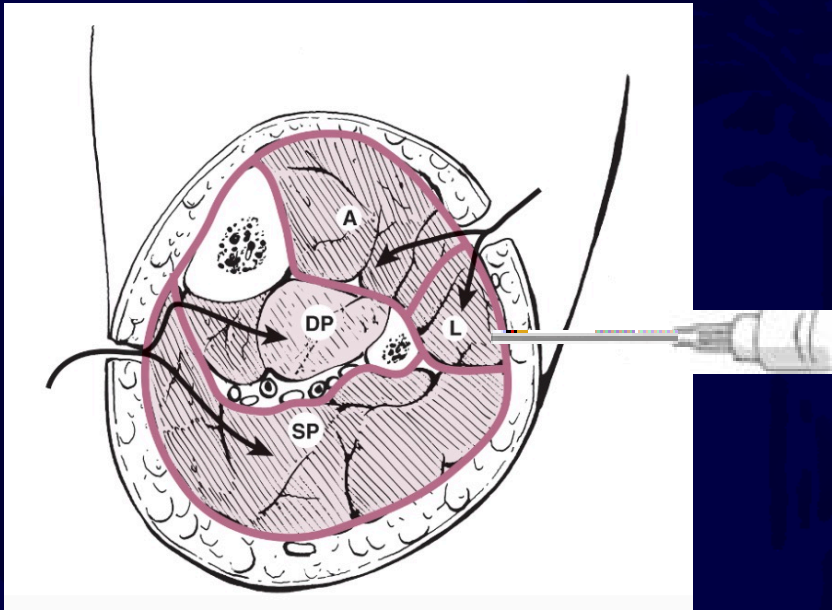


How to measure IMP



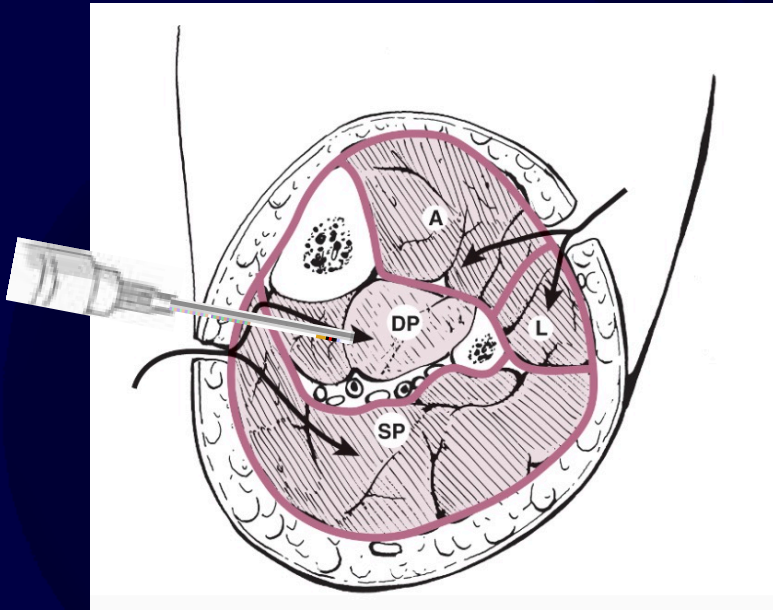
Anterior Compartment:
 ≈ 1 cm lateral to tibial crest

How to measure IMP



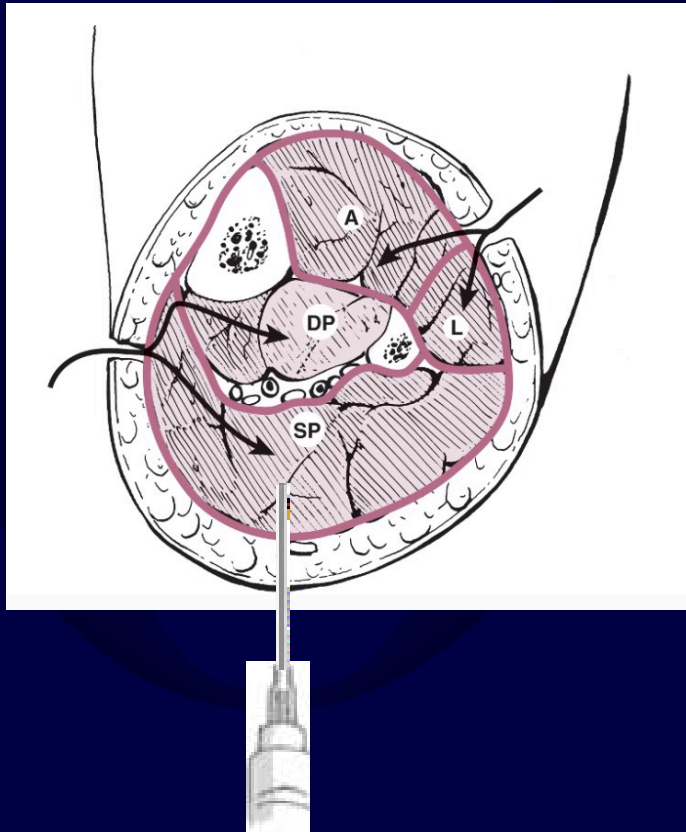
Lateral Compartment:
Just anterior to posterior
border of fibula

How to measure IMP



Deep Posterior:
Just behind posteromedial
border of the tibia

How to measure IMP

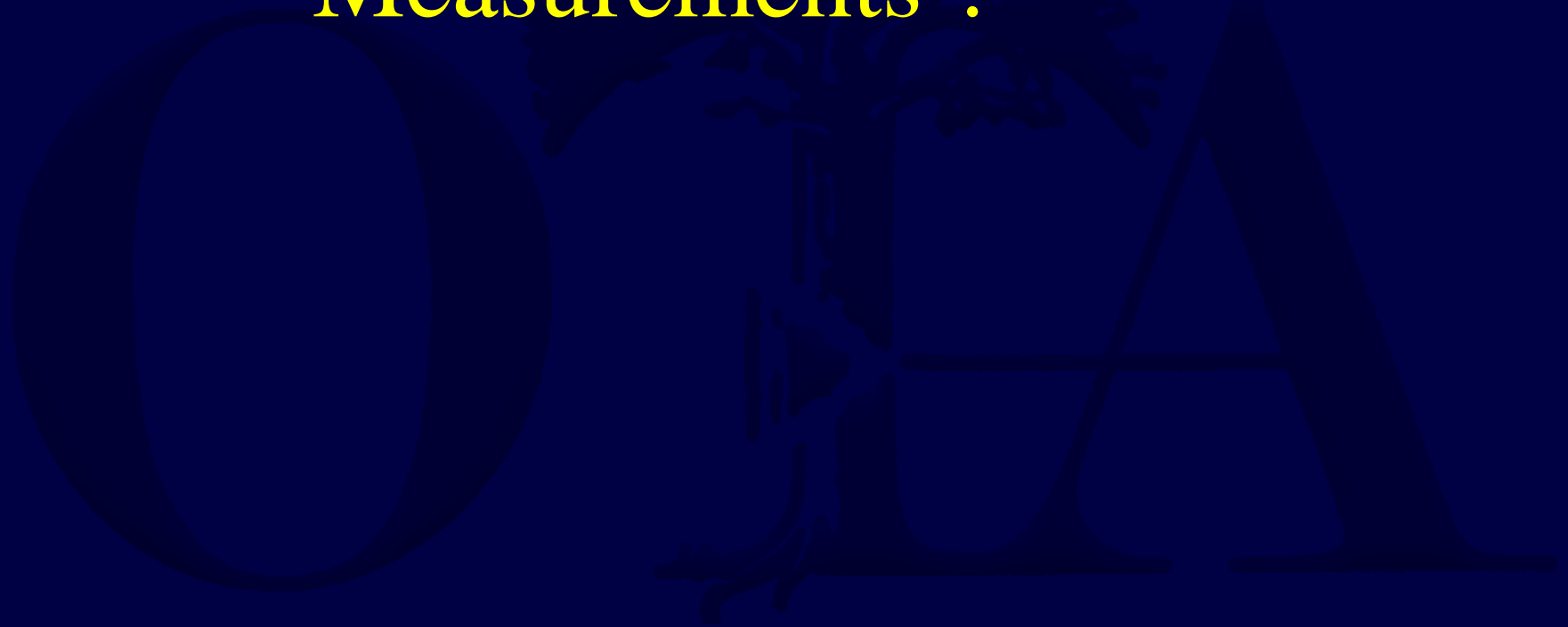


Superficial Posterior:
From posterior
(away from midline)

Intramuscular Pressure Measurement

- Normal resting IMP 0-8 mm Hg in adults, 13-16 mmHg in children.
- Elevated in CS.
- Does **not** measure degree of tissue injury.

How to Interpret Pressure Measurements ?



The absolute pressure at which perfusion ceases varies markedly depending on the clinical situation.

- Duration of elevated pressure
- Systemic blood pressure
- Direct muscle trauma
- Other patient factors:
 - Training of individual
 - Muscle oxidative fiber type

Muscle Injury Related to Pressure *and* Time



Compartment Syndrome is also a pressure-time phenomenon

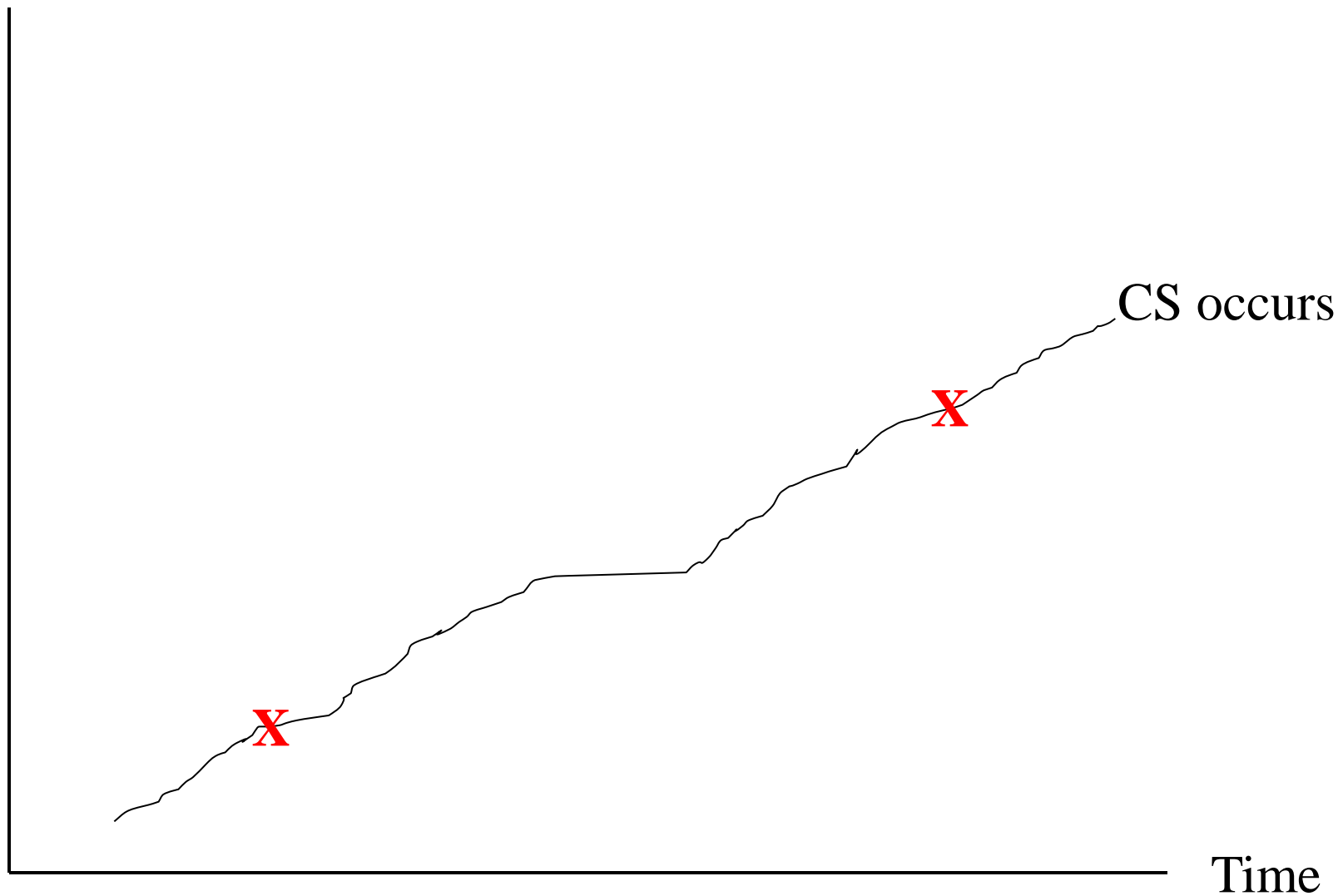
- Tissue doesn't become irreversibly damaged until it has been ischemic for 6 -8 hours.
- In patients with extremity injury, you don't know when the clock started.

Pressure



Time

Pressure



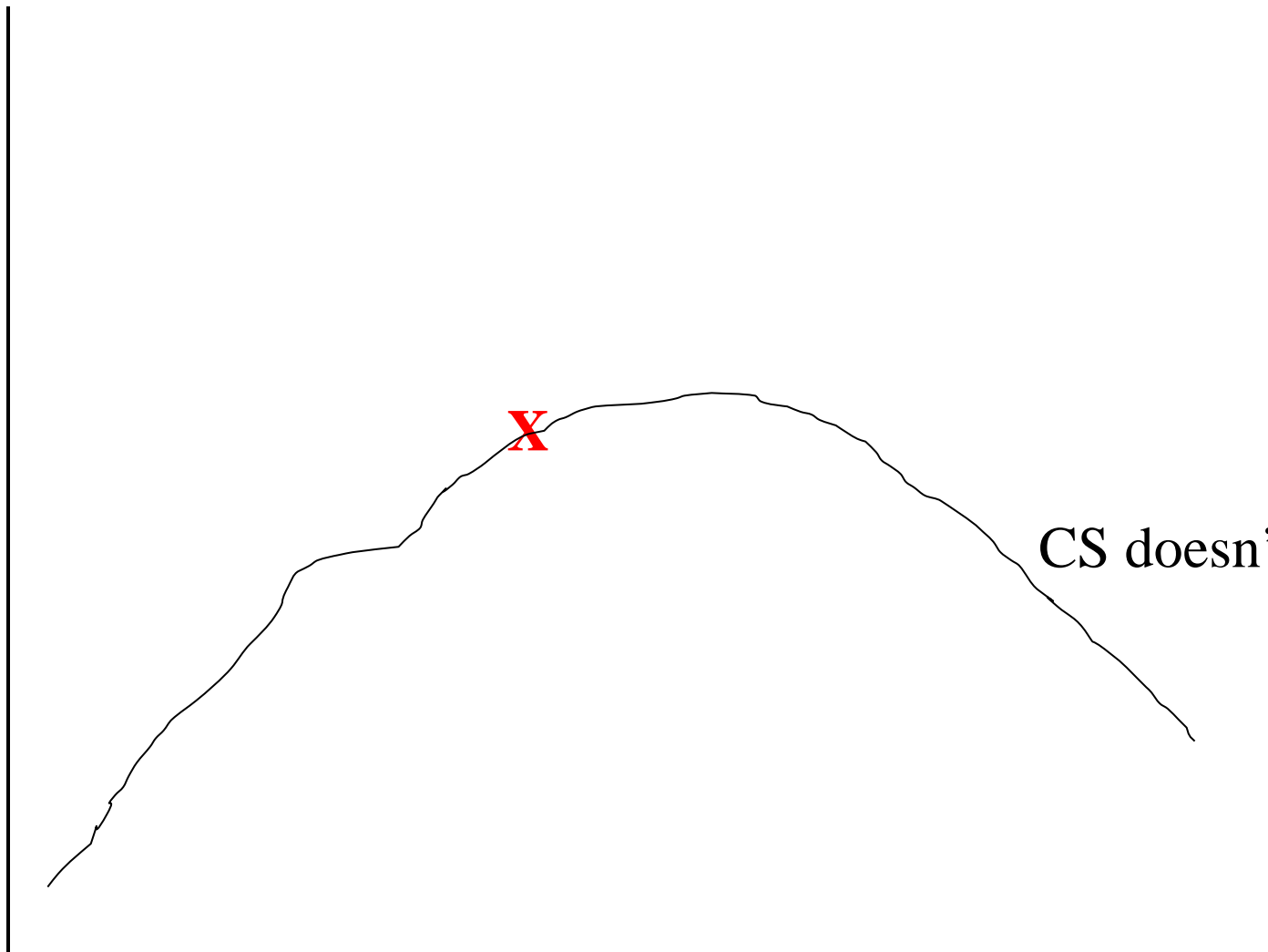
CS occurs

X

X

Time

Pressure



X

CS doesn't occur

Time

Quantitation of Skeletal-Muscle Necrosis in a Model Compartment Syndrome*†

BY ALAN R. HARGENS, PH.D.‡, DONALD A. SCHMIDT, M.D.‡, KAREN L. EVANS, B.A.‡,
MARY R. GONSALVES, B.A.‡, JOHN B. COLOGNE, B.A.‡, STEVEN R. GARFIN, M.D.§, SCOTT J. MUBARAK, M.D.§,
PHILLIP L. HAGAN, M.S.‡, AND WAYNE H. AKESON, M.D.§, SAN DIEGO, CALIFORNIA

*From the Department of Surgery (Orthopedics), Veterans Administration
and University of California Medical Center, San Diego*

ments acted as control muscle. The results in these experiments identify a threshold pressure level (thirty millimeters of mercury) and duration (eight hours) at which significant muscle necrosis occurs at normal blood pressure. Our findings imply that a quantitative

J Bone Joint Surg Am. 1981;63(4):631-636.

ACUTE COMPARTMENT SYNDROME IN TIBIAL DIAPHYSEAL FRACTURES

M. M. McQUEEN, J. CHRISTIE, C. M. COURT-BROWN

From the Royal Infirmary of Edinburgh, Scotland

- Continuous monitoring associated with earlier diagnosis of compartment syndrome, earlier fasciotomy, more rapid fracture healing, and improved outcomes:

	Monitored	Non-monitored
Time to Fasciotomy	16 hrs	32 hrs
Sequelae of CS	0/12	10/11
Mean time to union	17 weeks	25 weeks

COMPARTMENT MONITORING IN TIBIAL FRACTURES

THE PRESSURE THRESHOLD FOR DECOMPRESSION

M. M. McQUEEN, C. M. COURT-BROWN

From the Royal Infirmary of Edinburgh, Scotland



1st 12 – hours

2nd 12 – hours

IMP > 30

53

28

IMP > 40

30

7

IMP > 50

4

0

PP < 30

1

2



3 Patients had Fasciotomy

No patient had any sequelae of CS at follow-up

Perfusion Pressure (ΔP)

- Currently, the “differential pressure” is considered the most reliable indicator of when **fasciotomy is not necessary**:
 - MAP- IMP < 45 mm Hg
 - DBP - IMP < 30 mm Hg

BP

> 30 mm HG

IMP

Perfusion Pressure (ΔP)

- Currently, the “differential pressure” is considered the most reliable indicator of compartment syndrome:
 - MAP- IMP < 45 mm Hg
 - DBP - IMP < 30 mm Hg

BP

< 30 mm HG

IMP

Baseline Compartment Pressure Measurements in Isolated Lower Extremity Fractures without Clinical Compartment Syndrome

Michael J. Prayson, MD, James L. Chen, MPH, Douglas Hampers, MD, Molly Vogt, PhD, James Fenwick, MD, and Richard Meredick, MD

J Trauma. 2006;60:1037–1040.

- 19 isolated LE fractures in alert patients w/out CS
- Avg IMP 35.5 ± 14 mm Hg

<u>Threshold for fasciotomy</u>	<u># Patients meeting criteria</u>
IMP > 30 mm Hg	95%
IMP > 45 mm Hg	63%
”Delta P” < 30 mm Hg	84%
”Delta P” < 20 mm Hg	58%

No patient developed CS at follow-up

“Based on our data, use of direct **compartment measurements with existing thresholds** and formulations to determine the diagnosis of compartment syndrome **may not accurately reflect a true existence** of the syndrome. A search for other quantitative measures to more accurately reflect the presence of compartment syndrome is warranted.”

Prayson et al, 2006

Intra-operative IMP

- ΔP may be artifactually low due to anesthesia - induced hypotension.
- How to calculate ΔP in this setting?

Diastolic Blood Pressure in Patients with Tibia Fractures Under Anesthesia: Implications for the Diagnosis of Compartment Syndrome

- 246 consecutive patients undergoing tibial nailing under general anesthesia
- Blood pressures preoperatively, intraoperatively, and postoperatively were documented.

	Preoperative	Intraoperative	PACU	Inpatient Floor
SBP	134 ± 16	113 ± 12	142 ± 18	133 ± 16
DBP	74 ± 10	56 ± 11	73 ± 11	76 ± 9

Tornetta et al, *OTA* 2006

➤ Use preoperative DBP when making intra-operative decisions -

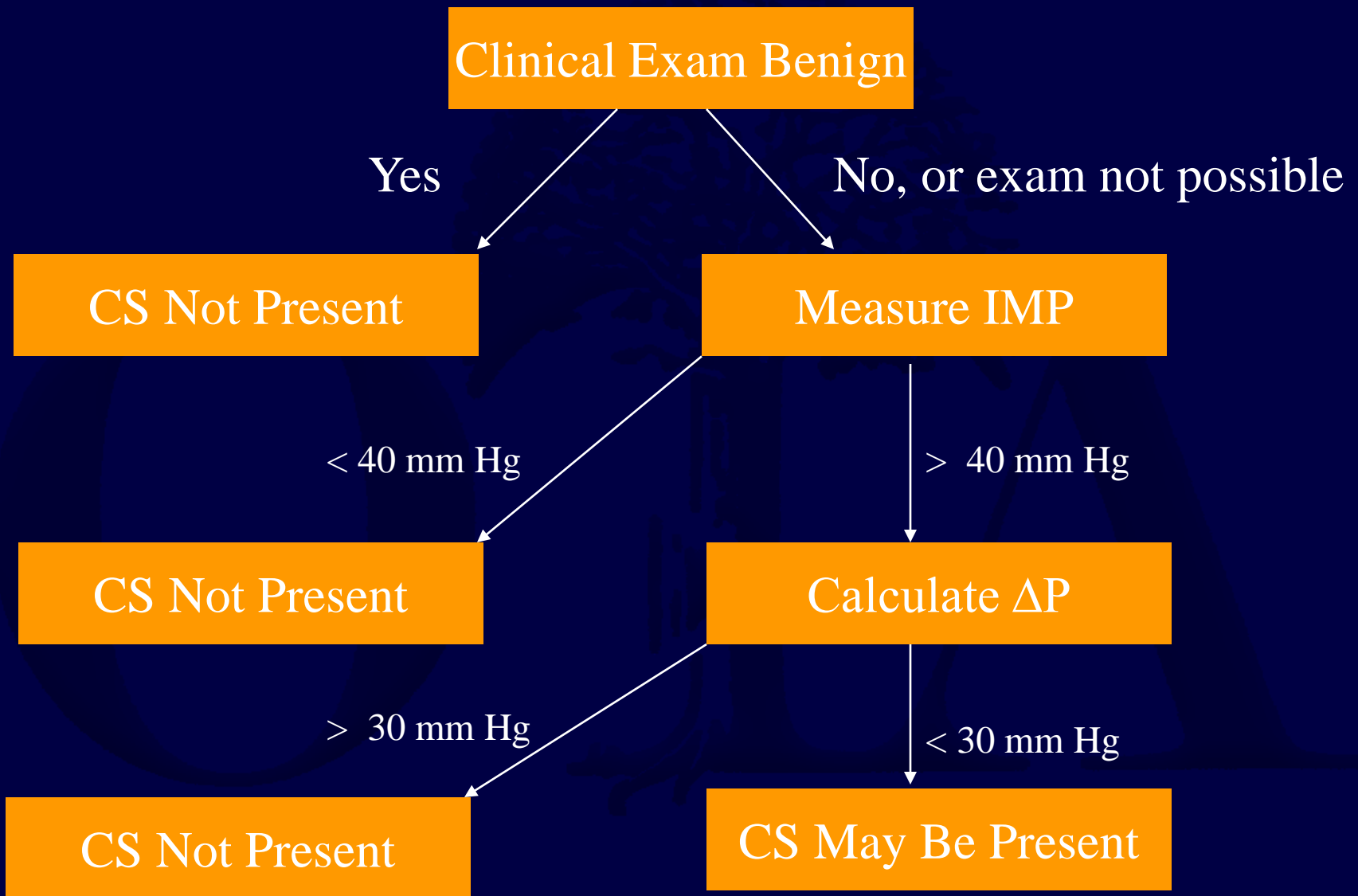
Unless the patient will be under anesthesia for a long time

Acute Lower Extremity Compartment Syndrome (ALECS) Screening Protocol in Critically Ill Trauma Patients

*Roman Kosir, MD, Frederick A. Moore, MD, John H. Selby, MD, Christine S. Cocanour, MD,
Rosemary A. Kozar, MD, Ernest A. Gonzalez, MD, and S. Rob Todd, MD*

“ALECS is a capricious entity, insidious in onset and elusive of diagnosis. No single physical finding or clinical or laboratory findings establish the diagnosis; it is a combination of intuitive integration of available findings and above all an alertness to the possibility of the emergence of this entity that leads to early diagnosis and treatment.”

Diagnostic Algorithm



Treatment of Compartment Syndrome





Compartment Syndrome

=

If you think about it, do it!

Fasciotomy

Technique of Fasciotomy

- Longitudinal skin incision that extends the *entire length* of the compartment.
- Release of fascia of involved muscle.
- Skin left open.



Fasciotomy Pearls

- Mark incisions ahead of time
- Make *long* incisions
- Find superficial peroneal n. in lateral compartment fasciotomy before release
- Beware of saphenous n. and vein medially
- Deep posterior compartment most easily identified distally where FDL is just behind tibia. Proximally, release soleus off posterior tibia.

Complications of Fasciotomy

- Muscle Weakness
- Chronic venous insufficiency
- Tethered scars
- Impaired sensation
- Ulceration
- Costs

Comparison of Fasciotomy Wound Closures Using Traditional Dressing Changes and the Vacuum-Assisted Closure Device

John Zannis, MD, Jeff Angobaldo, MD, Malcolm Marks, MD, Anthony DeFranzo, MD, Lisa David, MD, Joseph Molnar, MD, PhD, and Louis Argenta, MD

- 458 patients / 804 fasciotomies.
- Higher rate of primary closure using VAC compared to wet-dry dressings (79% vs 50%).
- Time-to-closure shorter in VAC group
 - Primary closure 7.1 vs 9.6 days
 - Secondary closure 8.5 vs 11.5 days

Summary – Current Dx / Rx

- Both the clinical exam and pressure thresholds can reliably tell us who does *not* have ACS.
 - Perfusion pressure has well-validated thresholds for when fasciotomy is not needed (PP \geq 30 mmHg).
 - Knowledge of pressure vs time trends further helps differentiate those who are developing ACS.
- Other diagnostic modalities needed:
 - biomarkers

Thank You

For questions or comments,
please send to ota@ota.org