Improving Diagnostic Technology of Acute Compartment Syndrome

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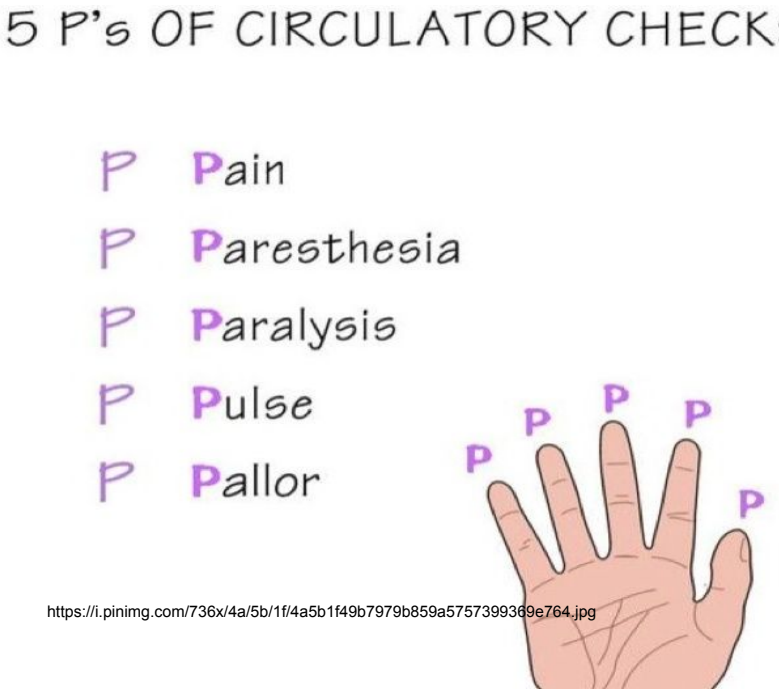
Diagnosing Compartment Syndrome

- Diagnostic issues and challenges of acute compartment syndrome (ACS)
- Current understanding of ACS
- Requirements for ACS technology
  - Continuous biochemical monitoring
  - Ability to reach fascial compartments of varying depths
  - High grade of accuracy
- Comparison of various biochemical markers
  - pH
  - Glucose
  - Sodium conductivity
- Proposed design for diagnosis

Misdiagnosis of Compartment Syndrome in Trauma patients

Clinical Examination



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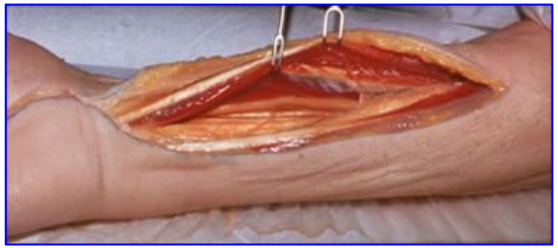
Intracompartmental Pressure Reading

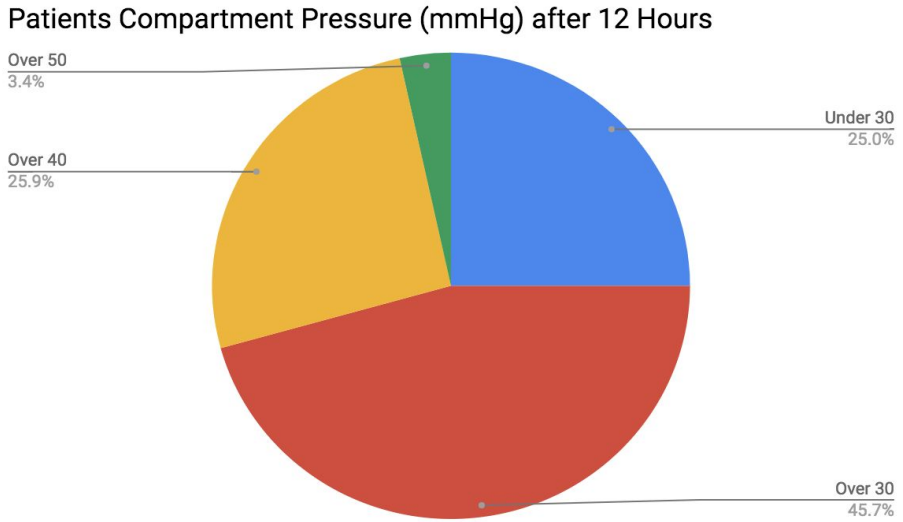
https://www.youcoach.it/sites/default/files/trattamento_contusioni.jpg

Misdiagnosis of Compartment Syndrome in Trauma patients

30 mmHg pressure threshold

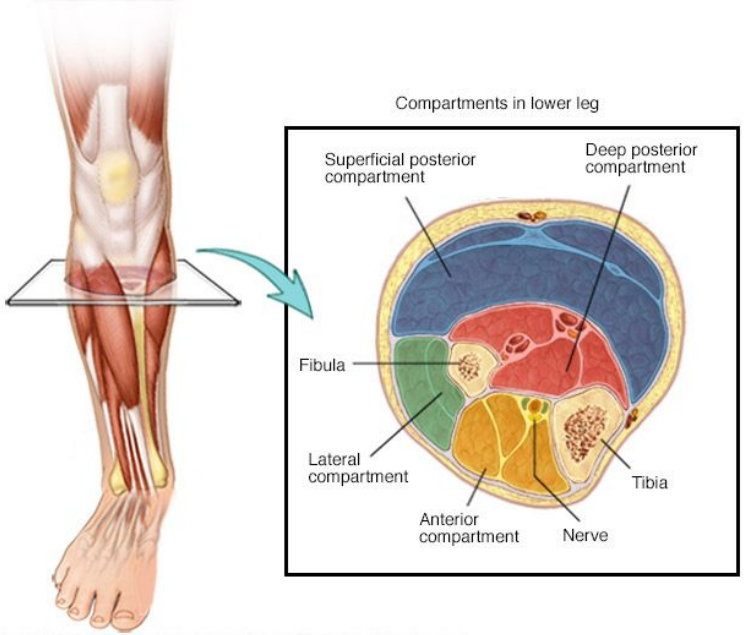
35% false positive rate

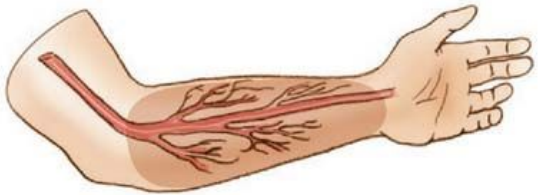


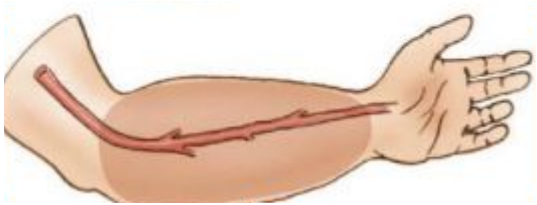


(insert picture of oxygen pressure in compartment)

Acute Compartment Syndrome







- Perfusion gradient ⟶ blood flow
- High compartment pressure ⟶ no blood flow
- Develop ACS ~7 hours after injury
- Outcomes: fasciotomy or permanent muscle damage

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Requirements for ACS Technology

- Continuous biochemical marker monitoring
  - 1 sample/10 minutes
- Depth below skin
  - 1-5 cm
- Standard of care
  - 16 gauge needle max
- Easy to use
- Cheap and disposable

Biomarkers: *pH probe*

Current Specifications

- 3mm probe
- Measures pH 6.0 - 8.0
    - Injured muscle pH ~ 6.27

Modified Design

- Maintain probe width of 3mm
- Elongate probe
- 8cm by 3mm
- Ceramic spear tip encased in glass

Medical Expo Product

Thermo Fisher Scientific Product

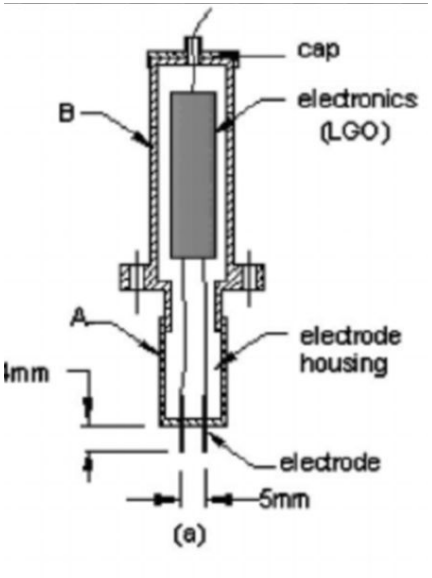
Biochemical: *Conductivity*

Current Specifications

- 12mm diameter
- Measures conductivity $10\ \mu S/cm - 1\ S$
- Continuous measurements

Modified Design

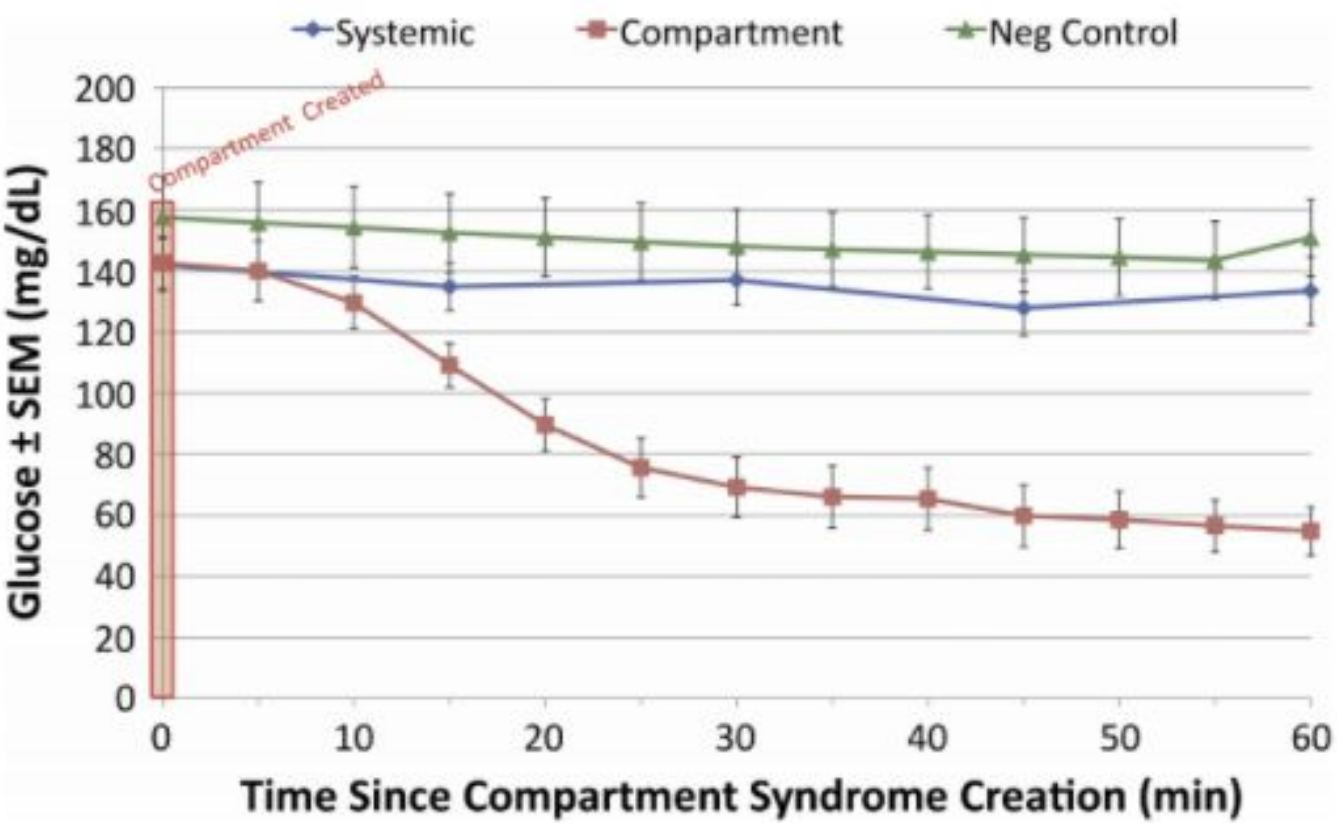
- Place anode/cathode in two 18 gauge needles
- Secured 3 mm apart
- Calculate conductance with multimeter



Atlas Scientific Conductivity Probe

Biochemical marker: *Glucose monitoring*

[10]



Biochemical marker: *Glucose monitoring*

Current Specifications

[11]

- Continuous monitoring
- Calibrate every 12 hours
- Minimally invasive (1 cm)

Medtronic Enlite™ Sensor

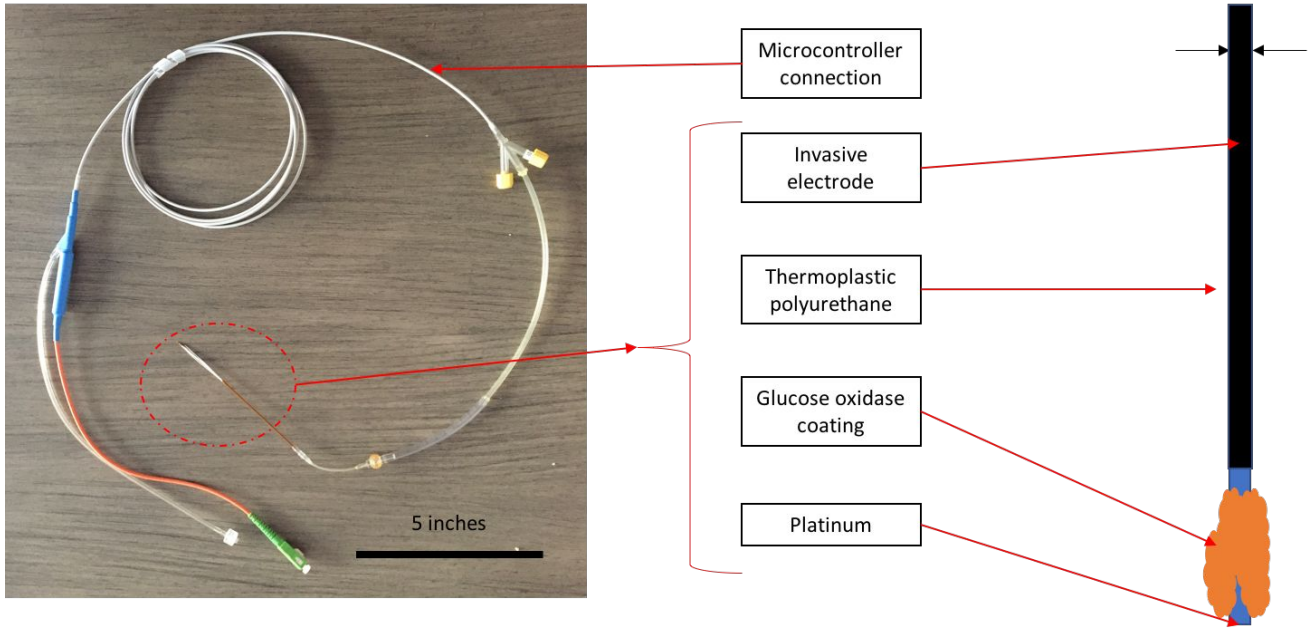
Modified Design

- Use two connected glucose electrodes
  - One in injured compartment
  - One in contralateral compartment
- Measures relative difference in glucose
- Electrodes inserted by placing in two 22 gauge pull away introducers (needles)

Comparison of Potential ACS Detectors

Criteria (Weight)	pH Probe		Glucose Probe		Potassium Conductivity Technology	
Accuracy and Precision (25)	4	20	5	25	5	25
Ease of Analysis (20)	4	16	5	20	2	8
Safety (20)	0	0	4	16	3	12
Ergonomics (15)	3	9	4	12	4	12
Ease of Fabrication (10)	4	8	4	8	3	6
Reusability (5)	4	4	4	4	4	4
Cost (5)	3	3	4	4	3	3
Total	60/100		89/100		70/100	

Future Work with Glucose Detection



***Reference electrode not pictured

References and Acknowledgements

Mayoclinic.org. (2017). *Chronic Exertional Compartment Syndrome*. [online] Available at: http://www.mayoclinic.org/-/media/kcms/gbs/patient-consumer/images/2013/08/26/10/55/ds00789_im00124_fsm7_chroniccompartmentthu_jpg.jpg [Accessed 3 Oct. 2017].

Musculoskeletalkey.com. (2017). *Complications of Supracondylar Fractures of the Elbow*. [online] Available at: https://musculoskeletalkey.com/wp-content/uploads/2016/08/B9781416029021500206_gr9.jpg [Accessed 3 Oct. 2017].

Images-na.ssl-images-amazon.com. (2017). *Cite a Website - Cite This For Me*. [online] Available at: https://images-na.ssl-images-amazon.com/images/I/91tbRtpkTGL._SL1500_.jpg [Accessed 3 Oct. 2017].

-Volkmann's Muscle Ischemia photo taken from Dr. Christopher Doro

mbhes.com/(2017). *A Practical Guide to Conductivity Measurement. [*online] Available at: http://www.mbhes.com/conductivity_measurement.htm.\

Researchgate.net. (2017). *Schematic of different types of conductivity probes.* [online] Available at: https://www.researchgate.net/figure/44887248_fig3_FIG-3-Schematic-of-different-types-of-conductivity-probes-a-Pipe-line-mountable

Thermofischer.net. (2017). [online] https://www.thermofisher.com/order/catalog/product/8163BNWP

Medicalexpo.com. (2017). [online] http://www.medicalexpo.com/prod/mdl/product-84369-538939.html

References and Acknowledgements

[10] Doro, C., Sitzman, T. and O'Toole, R. (2014). Can intramuscular glucose levels diagnose compartment syndrome?. *Journal of Trauma and Acute Care Surgery*, 76(2), pp.474-478.

[11]Medtronic, *Enlite Continuous Glucose Monitor*. 2017 [Online]. Available: https://www.medtronicdiabetes.com/products/enlite-sensor.