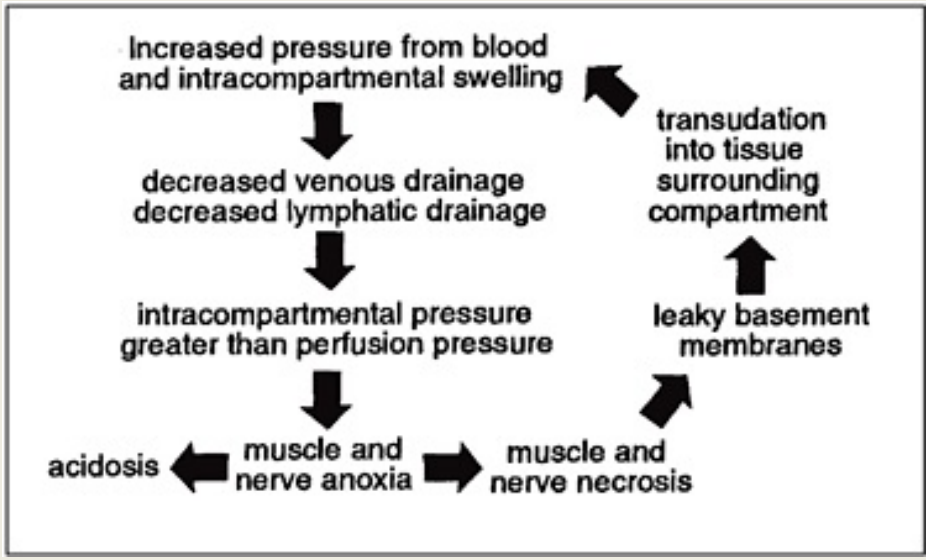
ACUTE COMPARTMENT SYNDROME (ACS)

Mathilde DE QUEIROZ
Department of Pediatric Anaesthesia
Lyon
France

PATHOPHYSIOLOGY

- First description by Von Volkmann in 1881
- **Pressure increases within a confined closed fascial space** => reduced blood flow and tissue perfusion => ischemia soft-tissue damage => necrosis
- Ischaemia => tissue membrane damage and leakage of fluid through capillary and muscle membranes.
- Tissue damage begins after 4 hours of ischemic time and may be permanent by 8 hours
- **True orthopedic emergency** = emergent fasciotomy => favorable outcome if not delayed



ETIOLOGIES

- Trauma : in an osseofascial compartment of **the leg or forearm**, but it may occur in the upper arm, thigh, foot, hand

- Non trauma
  - Surgery : osteotomies, fracture

J Pediatr Orthop. 2016 Oct-Nov;36(7):685-90. doi: 10.1097/BPO.0000000000000526.

Pediatric Nonfracture Acute Compartment Syndrome: A Review of 39 Cases.

Livingston K[1], Glotzbecker M, Miller PE, Hresko MT, Hedequist D, Shore BJ.

  - Reperfusion, ischaemia, burns, bites and poor positioning for prolonged surgical procedures (particularly lithotomy position)

Incidence
- Rare
- 0.1-10%
- Depends on etiology

Table 1 Common aetiology of compartment syndrome

Orthopaedic	Fractures and fracture surgery
Vascular	Arterial and venous injuries
	Reperfusion injury
	Haemorrhage
Soft tissue	Crush injury
	Burns
	Prolonged limb compression
Iatrogenic	Arterial/venous puncture in anticoagulated patients
	Casts and circular dressings
	Pulsatile irrigation
	Surgical positioning—especially prolonged lithotomy position
	Pneumatic antishock garment
Other	Snakebite
	Muscle overuse

Mar BJA 2008

Us….

Intra-osseous-access-associated lower limb compartment syndrome in a critically injured paediatric patient

EJA 2018

Jake Turner and Karl-Christian Thies

Journal of Clinical Anesthesia 47 (2018) 1–2

Contents lists available at ScienceDirect

Journal of Clinical Anesthesia

journal homepage: www.elsevier.com/locate/jclinane

Correspondence

Acute compartment syndrome of the hand secondary to propofol extravasation

Case report

Korean J Pediatr 2015;58(11):454-458

http://dx.doi.org/10.3345/kjp.2015.58.11.454

pISSN 1738-1061•eISSN 2092-7258

Korean J Pediatr

Compartment syndrome due to extravasation of peripheral parenteral nutrition: extravasation injury of parenteral nutrition

Huee Jin Park, MD[1], Kyung Hoon Kim, MD[1], Hyuk Jin Lee, MD, PhD[2], Eui Cheol Jeong, MD, PhD[3], Kee Won Kim, MD[4], Dong In Suh, MD[1]

Departments of [1]Pediatrics and [2]Orthopedic Surgery, Seoul National University College of Medicine, Seoul, [3]Department of Plastic Surgery, Seoul Metropolitan Government-Seoul National University Boramae Medical Center, Seoul, [4]Department of Rehabilitation Medicine, Seoul National University College of Medicine, Seoul, Korea

J Pediatr Orthop B. 2019 Jan 25. doi: 10.1097/BPB.0000000000000593. [Epub ahead of print]

Pediatric acute compartment syndrome: a systematic review and meta-analysis.

Lin JS[1], Balch Samora J[1,2].

- Age = 9.7 yo (SD=5.9)
- Trauma : pedestrian vs motor vehicles ++
- Lower leg = 60%
- Forearm = 27%
- Pressure monitoring = 68%
- **Pain = 88%**
- Paresthesia = 32%
- **Mean time from injury to fasciotomy = 25,4h**
- Good outcome in 85% (>adult)

J Pediatr Orthop. 2016 Oct-Nov;36(7):685-90. doi: 10.1097/BPO.0000000000000526.

Pediatric Nonfracture Acute Compartment Syndrome: A Review of 39 Cases.

Livingston K[1], Glotzbecker M, Miller PE, Hresko MT, Hedequist D, Shore BJ.

- Age = 11.7 yo (SD=7.2)
- Vascular= 28%
- Trauma = 26%
- **Post op = 21%**
- Exertion = 15%
- Pressure monitoring = 59%
- **Pain = 85%**
- Swelling = 72%
- Paresthesia = 33%
- **Mean time from symptom to diagnosis = 48h (9-96h)**
- 31% sequela

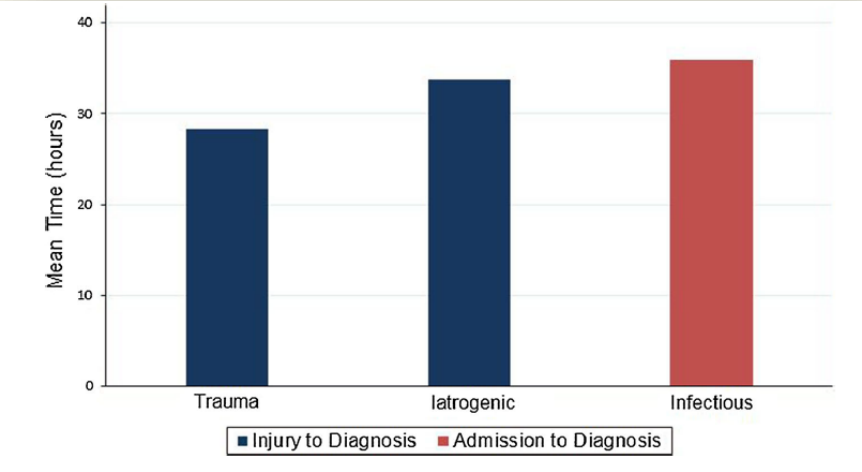
J Child Orthop (2016) 10:453–460
DOI 10.1007/s11832-016-0766-0

ORIGINAL CLINICAL ARTICLE

Compartment syndrome in infants and toddlers

Alexander Broom[1] · Mathew D. Schur[1] · Alexandre Arkader[2] · John Flynn[2] · Alex Gornitzky[2] · Paul D. Choi[1]

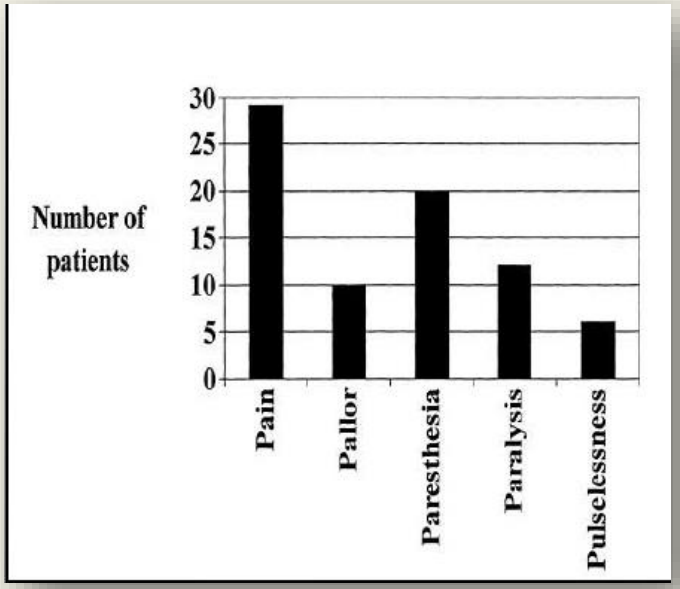
- < 3 yo (period study=15 years…)
- 15 ACS
- Average time from injury or hospital
- Admission to fasciotomy was **31.8 h** (range 2.9–136.3 h). > older…

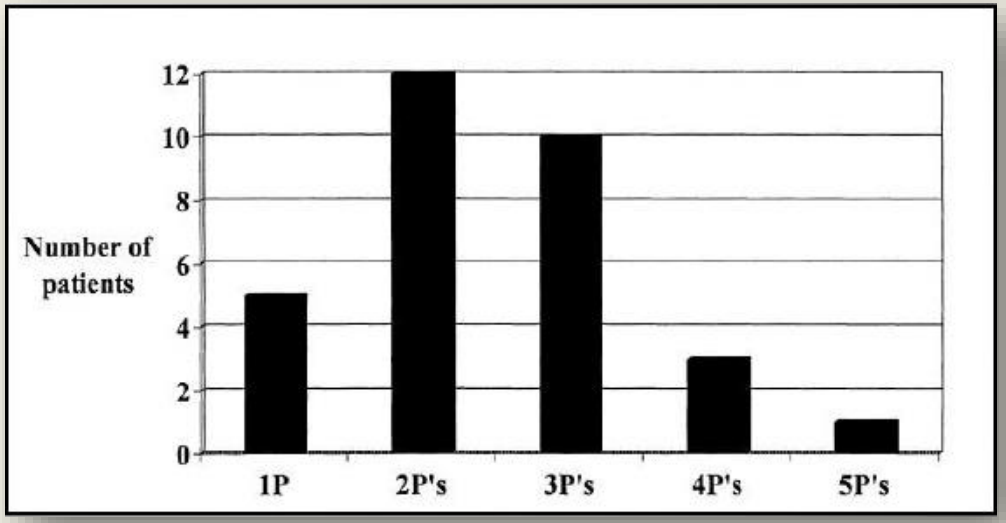


DIAGNOSIS

- CLINICAL!
- The 5 P's in adults
  - **Pain** :
    - Out of proportion
    - With passive stretch of muscles
    - Pain at rest
  - Paresthesias
  - Palor
  - Pulselessness (but damage has been done)
  - Paralysis : pain or real ?

But in children….





- Pressure, or firm compartments = 80 %
- Excess pain= 80%
- Pallor = 33 %
- Paresthesia =7 %
- Pulselessness = 40 %
- Paralysis =27 %

Broom J Child Orthop 2016, Bae J Pediatr Orthop 2001

So in children…

- They not have the cognitive and verbal ability to provide clinical information particularly in an extraordinary situation, resulting in delays in diagnosis and adequate therapy

- More difficult to achieve cooperation and communication for accurate assessment

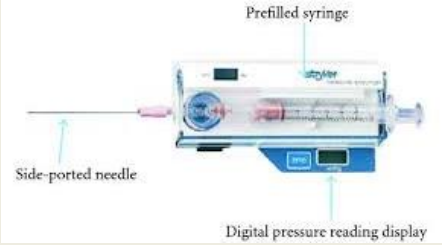
=> The **three A's** for children

- Anxiety
- Agitation
- **<u>Analgesic requirement : increase in frequency and dosage</u>**

Noonan KJ,J Pediatr Orthop. 2010

And the pressure?

- Absolute value ? 30 mmHg in adults
- Difference between compartment pressure and diastolic or mean arterial pressure?
- **The compartmental perfusion pressure is the difference between the mean blood pressure and the compartmental pressure < 30 mmHg**



Normal pressure in children?

European Journal of Trauma and Emergency Surgery
https://doi.org/10.1007/s00068-019-01082-9

ORIGINAL ARTICLE

Check for updates

Compartment pressures in children with normal and fractured lower extremities

Hannah Rachel Bussell[1] · Christoph Alexander Aufdenblatten[2] · Ulrike Subotic[1] · Markus Kalisch[3] · Georg Staubli[4] · Daniel Max Weber[5] · Sasha Sasha Tharakan[1]

Received: 13 October 2018 / Accepted: 30 January 2019

Higher Pressure than adults

J Pediatr Orthop. 2016 Jun;36(4):410-5. doi: 10.1097/BPO.0000000000000471.

Compartment Pressures in Children With Normal and Fractured Forearms: A Preliminary Report.

Tharakan SJ[1], Subotic U, Kalisch M, Staubli G, Weber DM.

Differents types of monitor
Absolute values?
Difference?
Position of the patient
Site/fracture of monitoring

Monitoring may increase clinical awareness and aid diagnosis in the presence of equivocal clinical findings.

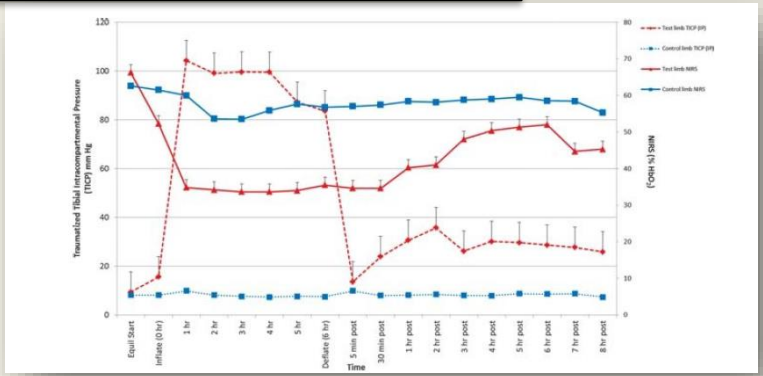
=> Association with clinical signs

And the NIRS?

Comparison of NIRS, serum biomarkers, and muscle damage in a porcine balloon compression model of acute compartment syndrome

J Trauma Acute Care Surg 2016

Steven C. Budsberg, DVM, MS, Michael S. Shuler, MD, Megan Hansen, MS, Elizabeth Uhl, DVM, PhD, *and* Brett A. Freedman, MD, *Athens, Georgia*



■ TRAUMA

Continual near-infrared spectroscopy monitoring in the injured lower limb and acute compartment syndrome

AN FDA-IDE TRIAL ***Bone Joint J* 2018**

Continuous Near-Infrared Spectroscopy Demonstrates Limitations in Monitoring the Development of Acute Compartment Syndrome in Patients with Leg Injuries

Andrew H. Schmidt, MD, Michael J. Bosse, MD, William T. Obremskey, MD, MPH, Robert V. O'Toole, MD, Eben A. Carroll, MD, Daniel J. Stinner, MD, David J. Hak, MD, Madhav Karunakar, MD, Roman Hayda, MD, Katherine P. Frey, RN, MS, MPH, PhD, Junrui Di, MS, Vadim Zipunnikov, PhD, Ellen MacKenzie, PhD, and the Major Extremity Trauma Research Consortium (METRC)*

Near-Infrared Spectroscopy Identifies Compartment Syndrome in an Infant

J Pediatr Orthop 2007

Joseph D. Tobias, MD† and Daniel G. Hoernschemeyer, MD†‡*

Depth?
Cut-off?
Reference value?
Cost…

1079-6061/00/4803-0396
The Journal of Trauma: Injury, Infection, and Critical Care
Vol. 48, No. 3
Printed in the U.S.A.

Utility of Near-Infrared Spectroscopy in the Diagnosis of Lower Extremity Compartment Syndrome

Giovanni Giannotti, MD, Stephen M. Cohn, MD, Margaret Brown, RN, J. Esteban Varela, MD, Mark G. McKenney, MD, and Jill A. Wiseberg, MPH

Which analgesia in situation at risk of ACS?

Regional analgesia

Patient analgesia opioid

VS

Anesthesiologist

Surgeon

AJO The American Journal of Orthopedics

Compartment Syndrome in Children: Diagnosis and Management

Am J Orthop. 2015 December;44(12):19-22
Authors:
Hosseinzadeh P Talwalkar VR

Regional anesthesia is used to control postoperative pain in adults and children.[33,34] Injudicious use may mask the primary symptom (pain) of CS.[32,35-38] Use of regional anesthesia in patients at high risk for CS is highly discouraged.

VS

The European society of regional anesthesia and pain therapy and the American society of regional anesthesia and pain medicine joint committee practice advisory on controversial topics in pediatric regional anesthesia I and II: what do they tell us?

Curr Opin Anesthesiol 2017, 30:613–620

Per-Arne Lönnqvist[a], Claude Ecoffey[b], Adrian Bosenberg[c], Santhanam Suresh[d], and Giorgio Ivani[e]

(1) There is no current evidence that the use of regional anesthetics increases the risk for ACS or delays its diagnosis in children.
(2) A comprehensive preoperative discussion with the patient's family and the surgical team should be performed to inform them of this rare but serious complication.

Pediatric Anesthesia 2004 **14**: 622–624

Editorial

What does analgesia mask?

C. LEJUS MD
Service of Anaesthesiology, Hôtel Dieu, C.H.U. Nantes, France

Some current controversies in paediatric regional anaesthesia
Bernard Dalens

Current Opinion in Anaesthesiology 2006,

patient. Since the 'first' presenting symptom is the legal reference, some physicians deny adequate care, especially pain relief, to their patients in order not to 'hide' pain as a presenting symptom.

Journals of anesthesia

Acta Anaesthesiol Scand 2013; ••: ••–••
Printed in Singapore. All rights reserved

ACTA ANAESTHESIOLOGICA SCANDINAVICA
doi: 10.1111/aas.12187

P

Case Report

Compartment syndrome diagnosed in due time by breakthrough pain despite continuous peripheral nerve block

H. Munk-Andersen and T. K. Laustrup
Department of Anesthesia and Intensive Care, Viborg Regional Hospital, Viborg, Denmark

Epidural analgesia and compartment syndrome

Ped Anesth 2009

Suresh Chittoodan
Suzanne Crowe

Evolving Compartment Syndrome Not Masked by a Continuous Peripheral Nerve Block

Evidence-Based Case Management

(*Reg Anesth Pain Med* 2012;37: 393–397)

Benjamin J. Walker, MD, Kenneth J. Noonan, MD,† and Adrian T. Bosenberg, MBChB, FFA(SA)‡*

Pain Medicine 2011; 12: 823–828
Wiley Periodicals, Inc.

P

ACUTE PAIN SECTION

Case Reports

Did Continuous Femoral and Sciatic Nerve Block Obscure the Diagnosis or Delay the Treatment of Acute Lower Leg Compartment Syndrome? A Case Report

Pediatric Anesthesia 2007 **17**: 520–533 doi:10.1111/j.1460-9592.2007.02230.x

The National Pediatric Epidural Audit

N. LLEWELLYN, RN, RSCN, BA* AND A. MORIARTY FRCA†
**Acute Pain Service and †Department of Anaesthesia, Birmingham Children's Hospital NHS Trust, Birmingham, UK*

Pediatric Anesthesia 2009 **19**: 83–91 doi:10.1111/j.1460-9592.2008.02894.x

Review article

Does epidural analgesia delay the diagnosis of lower limb compartment syndrome in children?

DOUG J.G. JOHNSON MBChB MRCP FRCA AND GEORGE A. CHALKIADIS MBBS FANZCA FFPMANZCA DA(LON)

Department of Anaesthesia and Pain Management, Royal Children's Hospital, Parkville, Vic., Australia

- Review: 12 cases with epidural analgesia
- Pain in 100% : out of proportion, increasing analgesic requirements
- Adults : epidural masked ACS because of leak of monitoring or motor block or expectative attitude

Discussion with surgical colleagues prior to operation will identify patients at increased risk of developing compartment syndrome and this should be communicated to all staff involved in perioperative care. These patients should not have epidural local anesthetic analgesia unless the perceived benefits outweigh the risks.

Should epidural analgesia be prescribed, local anesthetic concentrations should be dilute so as to avoid dense sensory and motor blockade. Avoid-

Table 1
'Red flags' for impending compartment syndrome

Red flags
Increasing pain in the setting of surgery or injury that predisposes to compartment syndrome
Pain remote to the site of surgery
Increasing analgesic use or requirements
Paresthesia not attributable to analgesia
Reduced perfusion of painful site
Swelling
Pain on passive movement of painful site

Journals of surgery…

J Bone Joint Surg Br. 1996 May;78(3):499-500.

Compartment syndrome in tibial shaft fracture missed because of a local nerve block.

Hyder N[1], Kessler S, Jennings AG, De Boer PG.

Femoral and adductor blocks without sciatic block….

J Trauma. 1994 Nov;37(5):867-8.

Tibial compartment syndrome complicating closed femoral nailing: diagnosis delayed by an epidural analgesic technique--case report.

Morrow BC[1], Mawhinney IN, Elliott JR.

Pain despite epidural have been stoped since 48h…..

Pediatric Nonfracture Acute Compartment Syndrome: A Review of 39 Cases

J Pediatr Orthop 2015

Kristin Livingston, MD, Michael Glotzbecker, MD, Patricia E. Miller, MS, Michael T. Hresko, MD, Daniel Hedequist, MD, and Benjamin J. Shore, MD, MPH, FRCSC

Legs ACS / thoracic epidural…….

The European society of regional anesthesia and pain therapy and the American society of regional anesthesia and pain medicine joint committee practice advisory on controversial topics in pediatric regional anesthesia I and II: what do they tell us?

Curr Opin Anesthesiol 2017, 30:613–620

Per-Arne Lönnqvist[a], Claude Ecoffey[b], Adrian Bosenberg[c], Santhanam Suresh[d], and Giorgio Ivani[e]

However, ischemic and acute nociceptive pain are transmitted by different nerve fibers and if using dilute local anesthetics solutions nociceptive pain is blocked, whereas the sensation and transmission of ischemic pain is preserved. Thus, if significant breakthrough pain occurs in a patient with a previously working continuous regional block, this is almost pathognomonic for ACS.

A delay in the diagnosis of ACS is most usually caused by not properly identifying patients that are at risk of developing ACS and to insufficient postoperative monitoring of these patients.

(1) There is no current evidence that the use of regional anesthetics increases the risk for ACS or delays its diagnosis in children.
(2) A comprehensive preoperative discussion with the patient's family and the surgical team should be performed to inform them of this rare but serious complication.

‘best practice rules’

(a) Single shot for both peripheral and neuraxial blocks: use 0.1–0.25% bupivacaine, levobupivacaine, or ropivacaine concentrations because they are less likely to mask ischemic pain and/or produce muscle weakness than more concentrated solutions (Evidence B4);

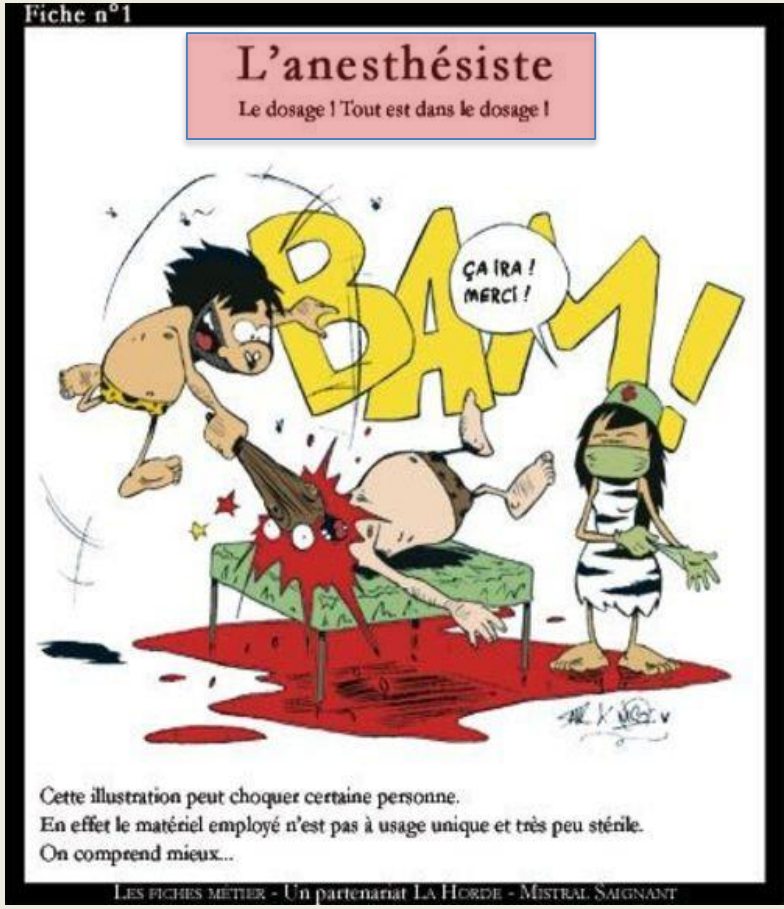
(b) For continuous infusions, bupivacaine, levobupivacaine, or ropivacaine concentrations should be limited up to 0.1%;

(c) In cases of patients having tibial compartment surgery or other high-risk surgeries for compartment syndrome, restricting both volume and concentration in sciatic catheters is advisable;

(d) The use of local anesthetics additives should be with caution because they can increase the duration and/or density of the block;

(e) High-risk patients should have appropriate follow-up by acute pain services to allow early detection of potential signs and symptoms;

(f) If ACS is suspected, compartment pressure measurements should be urgently assessed.



And what about Patient Controlled Analgesia Opioids?

Anaesth Intensive Care. 2010 Mar;38(2):359-63.

Compartment syndrome and patient-controlled analgesia in children--analgesic complication or early warning system?

Yang J[1], Cooper MG.

Injury. 2000 Jun;31(5):387-9.

Acute compartment syndrome masked by intravenous morphine from a patient-controlled analgesia pump.

Harrington P[1], Bunola J, Jennings AJ, Bush DJ, Smith RM.

Injury. 2004 Mar;35(3):296-8.

Does patient controlled analgesia delay the diagnosis of compartment syndrome following intramedullary nailing of the tibia?

Richards H[1], Langston A, Kulkarni R, Downes EM.

PLASTIC AND RECONSTRUCTIVE SURGERY, *April 1996*

DOES PATIENT-CONTROLLED ANALGESIA LEAD TO DELAYED DIAGNOSIS OF LOWER LIMB COMPARTMENT SYNDROME?

British Journal of Anaesthesia **102** (1): 3–11 (2009)
doi:10.1093/bja/aen330 Advance Access publication November 19, 2008

BJA

REVIEW ARTICLES

Acute compartment syndrome of the lower limb and the effect of postoperative analgesia on diagnosis†

G. J. Mar*, M. J. Barrington and B. R. McGuirk

sider it unreliable. Physical examination is also unreliable for diagnosis. There is no convincing evidence that patient-controlled analgesia opioids or regional analgesia delay the diagnosis of compartment syndrome provided patients are adequately monitored. Regardless of the type of analgesia used, a high index of clinical suspicion, ongoing assessment of patients, and compartment pressure measurement are essential for early diagnosis.

There is a lack of appreciation by some authors of the importance of the pharmacology of epidural analgesia in the clinical presentation.

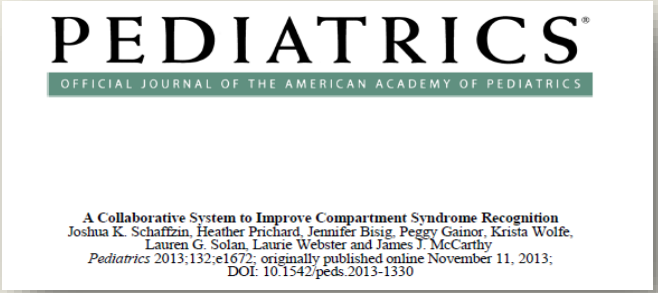
Pediatric Anesthesia 2004 **14**: 622–624

Editorial

What does analgesia mask?

C. LEJUS MD
Service of Anaesthesiology, Hôtel Dieu, C.H.U. Nantes, France

Pediatric data related to complications masked by efficient analgesia are rare. The rationalization is most likely that our young patients still frequently suffer from too light analgesia. The masking of surgical symptoms or complications does not really constitute a problem as long as a regular, clinically appropriate examination is carried out. The monitoring includes the evaluation of postoperative pain with scores according to the age. Any unusual postoperative painful episode or one not regressing with usual treatment must lead to the search for a possible complication. The use of self-administered



PEDIATRICS

OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

A Collaborative System to Improve Compartment Syndrome Recognition

Joshua K. Schaffzin, Heather Prichard, Jennifer Bisig, Peggy Gainor, Krista Wolfe, Lauren G. Solan, Laurie Webster and James J. McCarthy

Pediatrics 2013;132;e1672; originally published online November 11, 2013; DOI: 10.1542/peds.2013-1330

- After a serious safety event involving a failure to diagnose ACS at our in- stitution, we identified a lack of aware- ness about ACS among physicians and nurses and inconsistency with orders and monitoring of patients at greatest risk for developing ACS.

- Create a reliable system for recognition of patients at risk and monitoring for ACS that could withstand frequent provider turnover
- Individual interventions, including pocket card distribu- tion, electronic medical record order set, and direct discussion by team leaders,
- Neurovascular assessment was defined as an order for neurovascular assessment every 2 hours
- Proper order entry increased from 23% at baseline to 90%.

CONCLUSION

- Rare but real emergency
- Know the situation at risk
- Monitoring patients at high risk
- Education of medical and paramedical staff for supervision
  - Lack of compartment pressure monitoring and inadequate assessment and observation are the most common factors associated with a missed diagnosis.

- **Discussion** with surgeons for analgesia strategy
  - **Balance risk/benefit : the optimal analgesia**
  - Monitoring
  - Education
  - Regional anesthesia is not a contraindication
  - Avoidance of dense sensory or motor block and unnecessary sensory blockade

39e CONGRÈS ANNUEL DE L'ADARPEF

Association des Anesthésistes Réanimateurs Pédiatriques d'Expression Française

27 & 28 MARS 2020
MONTPELLIER

Save the date

INFORMATIONS SUR
www.e-adarpef.fr

Renseignements : COMM Santé
Tél. 05 57 97 19 19 - info@comm-sante.com
www.e-adarpef.fr