Pediatric Spinal Anesthesia: What’s Old is New Again

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Objectives

1. To discuss the debate over anesthetic-related neurotoxicity and its implications in pediatric anesthetic care
2. To review the history of pediatric spinal anesthesia
3. To describe the potential benefits of pediatric spinal anesthesia
4. To provide strategies for implementation of a successful pediatric spinal anesthesia program
Definitions

• **Anesthetic Neurotoxicity**: Damage to neuronal structures secondary to anesthetic or sedative medications resulting in short-term and long-term neurocognitive and behavioral impairments

• **Apoptosis**: The death of cells which occurs as a normal and controlled part of an organism's growth or development
Animal Studies

• Uemura 1985
• Ikonomidou 1999
• Jevtovic-Todorovic 2003
Animal Studies

- Brambrink 2010, 2012
- Creeley 2013
Animal Studies

- Briner 2010
- Amrock 2015
- Lunardi 2010
- Briner 2011
- Zhu 2010
- Stratmann 2009
- Gao 2014
- Loepke 2009
- Deng 2014
- Kanungo 2012
- Catano 2008
- De Roo 2009
- Sanchez 2011
- Xiao 2016
- Ju 2016
- Paule 2011
- Raper 2015
- Capitanio 2012
- Gentry 2013
- Whitaker 2016
Animal Studies

- Rizzi 2010
- Slikker 2007
- Qiu 2016
- Shi 2010
- Zou 2011
- Liu 2015
- Huang 2012
- Lee 2014

And the list goes on…
Human Studies

- Increased risk of learning disabilities
- Deficits in language and abstract reasoning
- Communication and knowledge deficit

Flick 2011
Ing 2012
Graham 2016
"repeated or lengthy use of general anesthetic
and sedation medications during surgeries or
procedures in children younger than 3 years
or in pregnant women during their third
trimester may affect the development of
children’s brains"

https://www.fda.gov/%20Drugs/DrugSafety/ucm532356.htm
Not so fast.....
Human Studies

- No effect on IQ or intelligence
- No difference in outcomes

Bartels 2009 (twin study)
GAS Trial 2016
MASK Study 2018
Human Studies

- PANDA Trial 2016: no effect on IQ at 10 years of age

Original Investigation

Association Between a Single General Anesthesia Exposure Before Age 36 Months and Neurocognitive Outcomes in Later Childhood

Lena S. Sun, MD; Guohua Li, MD, DrPH; Tonya L. K. Miller, MD; Cynthia Salorio, PhD; Mary W. Byrne, PhD, MPH;
David C. Bellinger, PhD, MSc; Caleb Ing, MD, MS; Raymond Park, MD; Jerilynn Radcliffe, PhD;
Stephen R. Hays, MD, MS; Charles J. DiMaggio, PhD; Timothy J. Cooper, PsyD; Virginia Rauh, ScD;
Lynne G. Maxwell, MD; Ahrim Youn, PhD; Francis X. McGowan, MD
Human Studies

JAMA Pediatrics | Original Investigation

Association of Anesthesia and Surgery During Childhood With Long-term Academic Performance

Pia Glatz, MD; Rolf H. Sandin, MD, PhD; Nancy L. Pedersen, PhD; Anna-Karin Bonamy, MD, PhD; Lars I. Eriksson, MD, PhD, FRCA; Fredrik Granath, PhD
Human Studies

• GAS Trial 2019: no difference in outcomes between GA and SA at 5 years of age

Neurodevelopmental outcome at 5 years of age after general anaesthesia or awake-regional anaesthesia in infancy (GAS): an international, multicentre, randomised, controlled equivalence trial

Mary Ellen McCann, Jurgen C de Graaff, Liam Dorris, Nicola Disma, Davinia Withington, Graham Bell, Anneke Grobler, Robyn Stargatt, Rodney W Hunt, Suzette J Sheppard, Jacki Marmor, Gaia Giribaldi, David C Bellinger, Penelope L Hartmann, Pollyanna Hardy, Geoff Frawley, Francesca Izzo, Britta S von Ungern Sternberg, Anne Lynn, Niall Wilton, Martin Mueller, David M Polaner, Anthony R Absalom, Peter Szmuk, Neil Morton, Charles Berde, Sulpicio Soriano, Andrew J Davidson, for the GAS Consortium*
Conclusions

• Comparing studies in infant animals and human children has limitations
• GAS Trial results are promising
• One brief exposure to GA is likely safe…
Conclusions

• BUT for *longer duration* or *multiple exposures*… conclusive, definitive evidence is not available
Pediatric Spinal Anesthesia

What’s Old is New Again!
History

- 1898: 1st recorded pediatric spinal anesthetic (Bier)
- 1904-1905: more widespread use
- 1940s-1950s: decrease in popularity
History

• 1970s-1980s: resurgence in use
  Apnea of Prematurity
• 1990s-present: sporadic practice
  Reliability and ease of GA
  Inadequate training
  Litigation
Historically-Observed Advantages

- Optimal surgical conditions
- Lack of “surgical shock” and hypotension
- Localized anesthesia/analgesia
- Less postoperative pain
- Minimal PONV
- Earlier return to feeding
- Cheap alternative to GA in areas lacking anesthesiologists
Spinal Anesthesia Review

- Reliable anesthesia from T4 (nipple line) to S5 (perineum)
- Motor, sensory, autonomic blockade
- Limited duration
Spinal Anatomy Review

- **Neonate/Infant**
  - Conus – L2-L3
  - Dural Sac – S2-S3

- **Toddler**
  - Conus – L1-L2

- **Adult**
  - Conus – L1
  - Dural Sac – S1
Spinal Anatomy Review

• Tuffler’s Line
  - Neonates: L5-S1
  - Infants: L4-L5
  - Toddlers: L4-L5
  - Adults: L3-L4
Benefits

• Long-Term
• Short-Term
• Immediate
Long Term Benefits

- Avoidance of potentially neurotoxic agents
- Prevention of surgically-induced hormonal stress response

Short Term Benefits

- Shorter hospital times
- Decreased risk of emergence delirium
- Earlier return to feeding
- Quicker reuniting with caregivers
Time/$$$ Benefits

- **Time**
  - Faster OR turnover
  - Shorter operative, anesthesia, PACU, total

- **Cost**
  - Reduction in direct operating, indirect, and total costs
Immediate Benefits

• Immediate
  o Hemodynamic stability
  o Respiratory stability
  o Decreased use of intraoperative medications
  o Decreased use of opioids
Hemodynamic Stability

- Minimal changes in BP and HR
- Minimal hypotension
- Decreased risk of hypotension in comparison to GA
- No change in cerebral oxygenation

Differences in Blood Pressure in Infants After General Anesthesia Compared to Awake Regional Anesthesia (GAS Study—A Prospective Randomized Trial)

M. E. McCann, MD, MPH,* D. E. Withington, BM,†‡ S. J. Arnup, M.Biostat.,§ A. J. Davidson, MD,¶# N. Disma, MD,** G. Frawley, MBBS,‖¶# N. S. Morton, MD, FRCA,‖¶‡ G. Bell, MB, ChB,‡‡ R. W. Hunt, PhD,¶§§‖‖‖ D. C. Bellinger, PhD,‖¶###*** D. M. Polaner, MD,‖¶‡ A. Leo, MD,¶‡‡ A. R. Absalom, MD,¶§§ B. S. von Ungern-Sternberg, MD, PhD,¶‖¶‖¶‖¶‖ F. Izzo, MD,### P. Szmuk, MD,¶###†**† V. Young, RN,* S. G. Soriano, MD,* and J. C. de Graaff, MD,¶###§§§‖‖‖‖ The GAS Consortium
General Anesthesia Risks

- Hypoxemia
- Aspiration
- Bronchospasm
- Laryngospasm
- Stridor
- 50% respiratory
- 25% Cardiac

Jimenez 2007 Closed claims Study Anesth Analg. 2007 Jan;10
Regional (spinal, epidural, caudal) versus general anaesthesia in preterm infants undergoing inguinal herniorrhaphy in early infancy (Review)

Jones LJ, Craven PD, Lakkundi A, Foster JP, Badawi N

**Figure 1.** Forest plot of comparison: 1 Spinal anaesthesia versus general anaesthesia, outcome: 1.1 Apnoea/bradycardia occurring 12 to 24 hours following completion of operation.

**Figure 3.** Forest plot of comparison: 1 Spinal anaesthesia versus general anaesthesia, outcome: 1.4 Postoperative apnoea with preoperative sedatives excluded.

**Figure 2.** Forest plot of comparison: 1 Spinal anaesthesia versus general anaesthesia, outcome: 1.2 Any oxygen desaturation occurring 12-24 hours following completion of the operation.

**Figure 4.** Forest plot of comparison: 1 Spinal anaesthesia versus general anaesthesia, outcome: 1.5 Postoperative apnoea with no preoperative apnoea.
Medication Administration

• Reduced medication administration
  o Decreased use of opioids
  o Decreased overall use of intraoperative medications

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Benefits of spinal anesthesia for urologic surgery in the youngest of patients

K.M. Ebert a,*, V.R. Jayanthi a, S.A. Alpert a, C.B. Ching a, D.G. DaJusta a, M.E. Fuchs a, D.J. McLeod a, E.E. Whitaker b
Safety

• Complications
  o Spinal failure
  o High spinal
  o Hematoma
  o Infection

The Safety and Efficacy of Spinal Anesthesia for Surgery in Infants: The Vermont Infant Spinal Registry

Robert K. Williams, MD*, David C. Adams, MD*, Eva V. Aladjem, MD*, Joseph M. Kreutz, MD*, Kenneth H. Sartorelli, MD‡, Dennis W. Vane, MD‡, and J. Christian Abajian, MD*

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Pediatric Spinal Anesthesia Protocol

Pre-Hospital

- Case Selection
  - Age < 18 months, < 2 years at discretion of anesthesiologist
  - Duration < 120 minutes
  - Procedure: lower abdominal or lower extremity procedures
- In-office discussion between parent/patient and surgeon, pamphlet available
- Pre-procedural phone discussion with anesthesiologist if warranted
- Standard Call Center instructions, standard NPO recommendations reinforcing clear liquids up to 2 hours prior to procedure
- LMX 4% cream order placed by anesthesiologist on day prior to surgery

In-Hospital

Preoperative

- Confirmation of: NPO status, lack of illness symptoms, allergies, anticoagulation status, infection/rash over site of spinal injection, sacral dimple
- LMX 4% cream with tegaderm brought to bedside by pre-op nurse prior to patient arrival
- IMMEDIATE placement of LMX cream with tegaderm (must be 30-60 minutes prior to OR) to lower lumbar spine L1-L1, midline, at above and below the level of the iliac crests
- Bring sucrose, pacifier, blanket, etc. with patient to OR
- Prepare rescue materials: epinephrine, atropine, intravenous fluids, intubation equipment (ETT or LMA)
- Adjust monitor to include parameter: Respiratory Rate
- Have vein-finder or ultrasound in OR
- Calculate maximum local anesthetic dose prior to OR (for spinal + surgical nerve block)
- Place “Patient Awake” sign on OR doors

Intraoperative

- All-Stop Patient Verification
- Attending Surgeon present at verification
- Positioning for spinal: have assistants sit baby up and curl forward, stabilizing head and neck while minimizing movement and assuring patency of airway
- Spinal needle: 25-gauge 1.5-inch Scottoo versus 22/25-gauge 1-inch Quincke
- Moderate speed for injection of spinal medication to (fast) avoid high backpressure (slow) avoid patient moving and spinal failure
  - Isobaric Preservative-Free Bupivacaine 0.5% with epinephrine 1:200,000
    - Dose: 0.4-1 mg/kg, max 5 mg (1 mL)
      - Up to 5 kg: 1 mg/kg
      - > 5 kg: 5 mg

Postoperative

- PHASE 1 BYPASS COMPROMISE:
  - Assessment by Anesthesia Faculty — confirmation of presence of PACU Phase 1 Criteria
  - Centricty PACU Request — choose option “Phase 2” under PACU location
  - Will be admitted to Phase 1 for one set of vital signs with quick discharge to Phase 2
- PO acetaminophen 15 mg/kg x 1 dose in PACU
- IV ketorolac 0.5 mg/kg if > 6 months x 1 dose in OR or PACU (if okay per surgeon)
- Patient may be held upright with head above level of lumbar/sacral spine, no need to stay supine
- Post-op Order: edit Discharge Patient — “Patient must move lower extremities prior to discharge from Phase 2. Document movement in flowsheet. No need to void prior to PACU discharge.”
- Standard PACU discharge criteria
- Specific pediatric spinal anesthesia discharge criteria: movement of bilateral lower extremities (specifically hip flexion), no need for patient to urinate prior to discharge

Questions/Concerns =

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*Updated 10/2019*
Infant Spinal Anesthesia Protocol

• Preoperative
  o Appropriate case selection
  o Discussion between anesthesiologist/parent
  o Case cancellation criteria identical to GA
  o Premedication
  o OR preparation
  o Surgical Attending present at induction
Ultrasound Evaluation of Lumbar Spine Anatomy in Newborn Infants: Implications for Optimal Performance of Lumbar Puncture

Ignacio Oulego-Erroz, MD¹, María Mora-Matilla, MD¹, Paula Alonso-Quintela, MD¹, Silvia Rodríguez-Blanco, MD², Daniel Mata-Zubillaga, MD³, and Santiago Lapeña López de Armentia, MD, PhD¹
Local anesthetic cocktail; Bupivacaine

Dose – up to 5kg = 1 mg/kg, > 5kg = 5 mg
  - Average dose for neonates = 1 mg/kg
  - Average dose for infants/toddlers = 0.5-0.7 mg/kg

Bupivacaine duration:
  - Plain = 30-45 minutes
  - With 1:200,000 epinephrine = 60-90 minutes
  - With 1:200,000 epinephrine, clonidine 1 mcg/kg = 60-120 minutes

Onset – 10-15 seconds
Infants and Local Anesthetics

- Limited hepatic metabolism until 9-12 months
- Reduced levels of alpha 1 acid glycoprotein until age 1
- Decreased epidural fat (less binding, faster blood absorption)
- Larger CSF volume/faster turnover
IV Placement

- Reported on 1554 infants over a 25 year period

- Most IV’s placed after spinal anesthesia without problems

- Some required no IV

The safety and efficacy of spinal anesthesia for surgery in infants: the Vermont Infant Spinal Registry, Williams, RK et al; Anesth Analg. 2006 Jan
Sedation: GOAL = clean anesthetic

- Natural sleep (naptime)

- Sensory deafferentation – like baby yoga, supraspinal effects
  - Neuromodulation via interruption of afferent and efferent signals between CNS/PNS
  - Functional connectivity changes
  - Sedating effect

- Pacifier with sucrose

- Midazolam/Dexmedetomidine
Infant Spinal Anesthesia Protocol

- Postoperative
  - Phase I “bypass”
  - Feed immediately
  - Phase II:
    - LE movement
    - No need to void
Our Experience

• GA Comparable
  o Patient BA
  o 5 week male, 4.4 kg, hydronephrosis
  o Procedure: cystoscopy w/ureterocele incision
Our Experience

- SA
  - Patient RR
  - 6 month male, 7.7 kg, otherwise healthy
  - Procedure: circumcision/chordee repair
Our Experience

- SA
  - Patient FC
  - 16 month male, 10.4 kg, HLHS s/p Norwood, s/p Hemi-Fontan
  - Procedure: circumcision
Development

- Formation of standardized protocol
- Educational program
- Plan for training of anesthesiology, surgical, and perioperative nursing staff
- Collaboration
- Mentorship
Education

• Anesthesiologists, fellows, residents, CRNAs, AAs
• Surgeons, fellows, residents
• Perioperative nursing staff (preoperative, OR, PACU)
• Child-life specialists
Education

• Educational Program
  o Rationale for use of spinal anesthesia in children
  o Perioperative preparation
  o Physical technique
  o Identification and treatment of complications
Implementation

• Anesthesia
  o Champion
  o Super Stars
  o Interested faculty

• Surgeon Training
  o Champion
  o Interested faculty
Summary

• Many unanswered questions regarding anesthetic neurotoxicity, results are promising
• Spinal anesthesia is safe in neonates and infants
• Getting Surgeon support is critical
References

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