Why?
Today PRA is an established technique, part of the clinical daily practice but......
still there are criticisms and controversies coming mainly from the world of “adult anesthesia”

Asleep vs awake
Test Dose
Compartment syndrome
Epidural space detection:
Air vs Normal Saline
Everyday regional anesthesia in children

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group. During the last quarter of the 20th century, a paper published on the use of regional anesthesia in children received a reprimand from the guest commentator who wrote that ‘regional anaesthesia by the caudal, epidural or spinal approach in children had minimal acceptance by American anesthesiologists….’ (39,40). Time has passed,
Coming Soon!

The European Society of Regional Anesthesia (ESRA) and the American Society of Regional Anesthesia (ASRA) Joint Committee

Practice Advisory on Pediatric Regional Anesthesia

G Ivani S Suresh C Ecoffey E Krane PA Lonnqvist A Bosenberg F Veyckemans D Polaner J Neal and M Van de Velde

topics: General + Regional, Test dose, Air vs saline, Compartment syndrome
Timetable

- May/June 2013: ESRA ASRA agreement on Pediatric Committee
- June-October 2014: work “at home”
  - Ivani Bosenberg: Compartment Syndrome
  - Veyckemans Polaner: Test dose
  - Lonnqvist Suresh: Awake vs Asleep
  - Ecoffey-Krane: Air vs Saline

- San Francisco October 2013: first meeting
- Chicago April 2014: 2nd meeting
- Seville September 2014: 3rd meeting
- New Orleans October 2014: final meeting
- Presentation at ESRA and ASRA annual meetings in 2015
- Submission to RAPM
Awake vs Asleep
The dark age

- Paraplegia following intracord injection during attempted epidural anesthesia under general anesthesia
  - Bromage FR, Benumof JL
  - “This case reinforces the admonition against attempting epidural puncture above the termination of the cord in unconscious, areflexic patients, and the opinion that risk of such gravity is only justified as a life-saving measure under exceptional circumstances”
Editorial

The Safety of Epidurals Placed During General Anesthesia

Pediatric subspecialties in medicine, surgery, cardiology, neurology, critical care, and, most recently, anesthesiology have evolved for precisely the reason that children are different than adults and that they pose unique clinical situations which demand specific knowledge, skills, and therapeutic decision making. The practice of adult medicine, and even the lessons learned from case reports of adults, therefore cannot and should not automatically be extrapolated to the care of children in anesthesiology or in any other medical specialty. Specifically, the application of epidural analgesia to the pediatric age group necessitates strategies that take into account the child’s size, age, and ability to cooperate, not a wholesale extrapolation of the common practices for adults, and equally not an abandonment of a valuable clinical tool.

Perhaps the most important difference is that if regional anesthesia is to be performed at all in children, they must be sedated or anesthetized in order to allow the safe performance of a regional block on a still and quiet subject. This practice introduces two concerns. One is the inability as reliably to recognize a positive intravascular test dose in the presence of general anesthetics. The question of test dosing has been addressed by several authors and has led to recommendations that reduce the risk of unintentional intravascular injection of local anesthetics in children (3–8). The second concern is the inability as reliably to recognize a paresthesia while performing a regional block, thus leading to subsequent concern regarding the potential for an increased risk of neurologic injury in children undergoing regional blocks during general anesthesia. Fortunately, the hypothesis of increased risk of neurologic injury has
Editorial

Regional anaesthesia—children are different

Paediatric anaesthesiologists worldwide are adamant that it is safer, and more acceptable to the child, to perform regional anaesthetic under general anaesthesia or sedation (4). This is borne out by the low complication rate in many published series and does not support the misconception that two anaesthetics double the risks. However, because they are performed under general anaesthesia the assessment of these blocks and detection of signs of toxicity is not easy and remains a contentious issue.

Detection of intravascular injection and the signs of local anaesthetic toxicity when either central or peripheral nerve blocks are performed under general anaesthesia has been cause for concern because the symptoms and early signs of toxicity are masked. Is self-report of early symptoms of toxicity likely to be any more reliable in the frightened young child? Indeed general anaesthesia may even be protective by raising the threshold of toxicity.

Most authors in paediatric regional anaesthesia have judged the success or failure, onset and duration of the block by a physiological response (pulse rate, blood pressure, respiratory rate or withdrawal reflex) to a noxious stimulus. This noxious stimulus may be the surgeon’s scalpel, skin pinch or pin prick; all of which test different sensory nerve fibres. Paradoxically this assessment may be easier in the highly anaesthetized child since the awake child may fear the skin pinching, pin prickling approaches of a strange adult (19). Under light anaesthesia the child will consistently respond by movement, increase in pulse or respiratory rate and midriasis (19).
Regional Anesthesia in Anesthetized or Heavily Sedated Patients

Christopher M. Bernards, M.D., Admir Hadzic, M.D., Ph.D., Santhanam Suresh, M.D., and Joseph M. Neal, M.D.

The American Society of Regional Anesthesia and Pain Medicine (ASRA) Practice Advisory on Neurologic Complications in Regional Anesthesia and Pain Medicine includes an evidence- and expert opinion-based section on performing procedures on anesthetized or heavily sedated patients. This practice advisory is based on existing scientific literature, pathophysiological principles, and expert opinion. The advisory panel examined the ability of anesthetized or heavily sedated patients to recognize and report intravascular injection of local anesthetic or impending neurologic injury. The advisory panel also considered whether or not the ability to recognize and report symptoms could actually affect the occurrence of nerve injury or local anesthetic systemic toxicity. The advisory contains recommendations pertaining to both adult and pediatric patients. Reg Anesth Pain Med 2008;33:449-460.
Table 2. Recommendations: Performing Regional Anesthesia in Anesthetized or Heavily Sedated Patients*

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limiting local anesthetic systemic toxicity</td>
<td></td>
</tr>
<tr>
<td><em>The potential ability of general anesthesia or heavy sedation to obscure early signs of systemic local anesthetic toxicity is not a valid reason to forgo performing peripheral or epidural nerve blocks in anesthetized or heavily sedated patients.</em></td>
<td>I</td>
</tr>
<tr>
<td>Limiting neural injury</td>
<td></td>
</tr>
<tr>
<td>Monitoring and prevention</td>
<td></td>
</tr>
<tr>
<td><em>There are no data to support the concept that peripheral nerve stimulation or ultrasound guidance, and/or injection pressure monitoring, reduce the risk of peripheral nerve injury in patients under general anesthesia or heavy sedation.</em> (Class I)</td>
<td>I</td>
</tr>
<tr>
<td>Adult neuraxis</td>
<td></td>
</tr>
<tr>
<td><em>Warning signs such as paresthesia or pain on injection of local anesthetic inconsistently herald needle contact with the spinal cord. Nevertheless, some patients do report warning signs of needle-to-neuraxis proximity. General anesthesia or heavy sedation removes any ability for the patient to recognize and report warning signs. This suggests that neuraxial regional anesthesia should be performed rarely in adult patients whose sensorium is compromised by general anesthesia or heavy sedation.</em> (Class II)</td>
<td>II</td>
</tr>
<tr>
<td>Pediatric neuraxis</td>
<td></td>
</tr>
<tr>
<td><em>The benefit of ensuring a cooperative and immobile infant or child may outweigh the risk of performing neuraxial regional anesthesia in pediatric patients undergoing general anesthesia or heavy sedation. The overall risk of neuraxial anesthesia should be weighed against its expected benefit.</em> (Class II)</td>
<td>II</td>
</tr>
<tr>
<td>Interscalene blocks</td>
<td></td>
</tr>
<tr>
<td><em>Case reports document spinal cord injury during the placement of interscalene blocks in patients under general anesthesia, which heightens concern associated with this practice. Interscalene blocks should not be performed in anesthetized or heavily sedated adult or pediatric patients.</em> (Class I)</td>
<td>I</td>
</tr>
<tr>
<td>Adult peripheral nerve blocks</td>
<td></td>
</tr>
<tr>
<td><em>Because general anesthesia or heavy sedation removes all opportunity for adults to communicate symptoms of potential nerve injury, peripheral nerve blockade should not be routinely performed in most adults during general anesthesia or heavy sedation. However, the risk-to-benefit ratio of performing peripheral nerve blockade under these conditions may improve in select patient populations (e.g., dementia, developmental delay, or when unintended movement could compromise vital structures).</em> (Class II)</td>
<td>II</td>
</tr>
<tr>
<td>Pediatric peripheral nerve blocks</td>
<td></td>
</tr>
<tr>
<td><em>Regardless of wakefulness, infants and children may be unable to communicate symptoms of potential peripheral nerve injury. Therefore, the placement of peripheral nerve blocks in children undergoing general anesthesia or heavy sedation may be appropriate after duly considering individual risk-to-benefit ratio.</em> (Class II)</td>
<td>II</td>
</tr>
</tbody>
</table>

*Anesthetized refers to patients under general anesthesia. Heavy sedation is defined as the patient being sedated to the point of being unable to recognize and/or report any sensation that the physician would interpret as atypical during block placement.
Regional Anesthesia in Anesthetized or Heavily Sedated Patients

- when properly performed regional anesthesia is a safe clinical practice with a risk of serious complication that is not significantly different than that of general anesthesia.
- without heavy sedation or general anesthesia regional blocks would be all but impossible in pediatric anesthesia.
- Based on the available literature....it is our recommendation that anesthesia or heavy sedation should not be considered an absolute contraindication in children. This recommendation is based on human data and general agreement of expert opinion.

CM Bernards, A Hadzic, S Suresh, JM Neal, RAPM 2008;5:449-60
Epidemiology and Morbidity of Regional Anesthesia in Children: A One-Year Prospective Survey of the French-Language Society of Pediatric Anesthesiologists

Elisabeth Giaufre, MD†, Bernard Dalens, MD†, and Anne Gombert, MD†
*Service de Chirurgie Pédiatrique, Fondation-Hôpital Saint-Joseph, Marseille, France; †Pavillon Goselin, Hôtel-Dieu, Clermont-Ferrand, France, and ‡Département d’Informatique Médicale, Hôpital de la Conception, Marseille, France

Table 4. Details of the Reported Complications

<table>
<thead>
<tr>
<th>Complications</th>
<th>Spinals (n = 506)</th>
<th>Caudals (n = 15,013)</th>
<th>Lumbar epidurals (n = 2396)</th>
<th>Sacral epidurals (n = 293)</th>
<th>Thoracic epidurals (n = 135)</th>
<th>Peripheral nerve blocks and local anesthesia (n = 9396)</th>
<th>Total (n = 24,409)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dural penetration</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Uncomplicated</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Postdural headaches</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Spinal anesthesia</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Intravascular injection</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>No clinical effects</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Convulsions</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Cardiac arrhythmia</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Technical problem</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Delayed installation</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Rectal penetration</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Catheter knotting</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Overdose with cardiac arrhythmia</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Transient paresthesias</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Postmorphine apnea</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Skin lesion</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Morbidity rate</td>
<td>1 (2.0/1000)</td>
<td>11 (0.7/1000)</td>
<td>9 (3.7/1000)</td>
<td>2 (6.8/1000)</td>
<td>0 (0.0/1000)</td>
<td>0 (0.0/1000)</td>
<td>23 (0.9/1000)</td>
</tr>
</tbody>
</table>
Epidemiology and morbidity of regional anaesthesia in children: a follow-up one-year prospective survey of the French-Language Society of Paediatric Anaesthesiologists (ADARPEF)

Ecoffey C et al
Pediatric Anesthesia 2010 ; 20: 1061–1069
ADARPEF: Complications

- Complications (41 involving 40 patients)
  - were rare and usually minor.
  - They did not result in any sequelae.
  - The study revealed an overall rate of
    - complication of 0.12%; CI 95% [0.09–0.17],
    - significantly six times
      - higher for central than for peripheral blocks.
- 96% were performed on GA or heavy sedation
Asleep vs. sedated vs. awake: Regional anesthetic complications by patient state at the time of blockade. A report from the Pediatric Regional Anesthesia Network (PRAN)

- 12300 blocks
- General anesthesia with NB  without NB
- Sedated
- Awake

- Taenzer A, Bosenberg A, Krane E et al
- SPA MEETING 2011:SO83 (Abstract)
- courtesy by Dr Bosenberg
## PRAN Results

Table 4: Postoperative problems identified by patient state at block placement

<table>
<thead>
<tr>
<th>Complications</th>
<th>GA no NMB</th>
<th>GA with NMB</th>
<th>Sedated</th>
<th>Awake</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurologic</td>
<td>15 (0.12%)</td>
<td>15 (0.52%)</td>
<td>6 (0.83%)</td>
<td>1 (0.33%)</td>
<td>36 (0.17%)</td>
</tr>
<tr>
<td>Positive test dose</td>
<td>26 (0.20%)</td>
<td>11 (0.38%)</td>
<td>1 (0.14%)</td>
<td>2 (0.66%)</td>
<td>37 (0.18%)</td>
</tr>
<tr>
<td>Vascular puncture</td>
<td>97 (0.75%)</td>
<td>31 (1.07%)</td>
<td>5 (0.69%)</td>
<td>1 (0.33%)</td>
<td>121 (0.59%)</td>
</tr>
</tbody>
</table>
PRA : Results

Complications are rare after regional anesthesia in children, requiring large databases to generate statistical data. Despite the common assumption that regional blocks are safer in awake than anesthetized patients, there are in fact no data that support this claim. Several published data collections support the safety of using regional anesthesia in the asleep state, but large data collections analyzing complications comparing asleep vs. awake patients are lacking in both the adult and pediatric literature.

These data demonstrate comparable rates of neurologic complications, positive test doses, and accidental vascular punctures in patients in the asleep, sedated and awake states.

However, patients under GA had lower neurologic complication rates when they were not under NMB at the time of block placement.

In summary, these data support the safety of regional block placement in anesthetized children compared with those placed under sedation or while awake, but suggest that neuromuscular blockade is associated with more frequent transient neurologic complications.
Pediatric Regional Anesthesia Network (PRAN): a multi-institutional study of the use and incidence of complications of pediatric regional anesthesia. 

Polaner DM et al. 


- A total of 14,917 regional blocks, performed on 13,725 patients, were accrued from April 1, 2007 through March 31, 2010. There were no deaths or complications with sequelae lasting >3 months (95% CI 0-2:10,000). Single-injection blocks had fewer adverse events than continuous blocks, although the most frequent events (33% of all events) in the latter group were catheter-related problems. Ninety-five percent of blocks were placed while patients were under general anesthesia. Single-injection caudal blocks were the most frequently performed (40%), but peripheral nerve blocks were also frequently used (35%), possibly driven by the widespread use of ultrasound (83% of upper extremity and 69% of lower extremity blocks).
New Trends in Pediatric Regional Anesthesia: Our Experience

17698 total blocks
In PA 1998-2006: 7605 blocks, 4401 (57.9%) central blocks, 3204 (42.1%) peripheral blocks; 105 central continuous infusions (2.4%), 42 peripheral catheters (1.3%).
In PB 2006-2013: 9390 total blocks, 5042 (53.7%) central and 4347 (46.3%) peripheral blocks; 473 central continuous infusions (10.4%), 91 peripheral catheters (2.1%).

Complications: 0.12% in PA (9 dura punctures with 1 headache) and 0.05% in PB (2 dura punctures with 1 headache; 2 infected catheters).

All blocks performed under sedation/general anesthesia
All blocks in spontaneous ventilation

- ASA Poster  San Francisco 2013
previous lumbar punctures and intrathecal chemotherapy for Burkitt's lymphoma at the same level may have facilitated dural breach. 

**Epidural anesthesia should not be attempted at the same intervertebral level as prior recent lumbar punctures**.”
Thus, according to current worldwide consensus, PRA should in the vast majority of cases be performed under general anesthesia or heavy sedation to ensure maximum safety against potential complications.
Awake vs Asleep

- Management of hypertrophic pylorus stenosis with ultrasound guided single shot epidural anesthesia in awake children: 20 cases

“Placing a thoracic epidural for a pyloromyotomy is like making love in canoe standing up: why would you want to do it when there are easier ways to achieve the same satisfying result?”
Awake vs Asleep
(possible conclusions)

- PRA under general anesthesia or deep sedation is associated with acceptable safety and should be viewed as standard of care.

- The overall risk for complications is approximately 1: 1,000 and the risk for long-lasting sequelae is extremely rare (approximately 1.25/100,000).
How can we control the safety of our blocks under anesthesia?
TEST DOSE
Editorial

Regional anaesthesia—children are different

How reliable is a ‘test dose’ popular in adults and subsequently used in children? Is it because there is no better alternative rather than absolute faith in the technique? An increase in heart rate used as evidence of intravascular injection in adults, is unreliable in children unless adrenaline is added to bupivacaine and prior anticholinergics administered (34). Does plain bupivacaine cause any heart rate or ECG changes in small ‘test doses’? (35). Sevoflurane as opposed to halothane may further negatively influence the reliability of the test dose even when prior administration of anticholinergics has occurred (35). T wave elevation may be a more reliable early marker of toxicity than heart rate response but this too requires the addition of adrenaline for increased reliability (36,37). Any dysrhythmia should be treated with caution (38). Indeed so should tachycardia since it may indicate painful injection—a danger sign in the awake patient!
# Caudal Epidural Block: A Review of Test Dosing and Recognition of Systemic Injection in Children

Joseph D. Tobias, MD

## Table 1. Summary of Studies of a Simulated Test Dose (IV Administration) in Pediatric-Aged Patients

<table>
<thead>
<tr>
<th>Reference</th>
<th>Anesthetic</th>
<th>Test drug (μg/kg)</th>
<th>Criteria evaluated</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desparmet et al. (7)</td>
<td>1 MAC halothane</td>
<td>Epinephrine 0.5 in lidocaine 1 mg/kg</td>
<td>HR, % change in SBP</td>
<td>Positive HR response: ( \geq 10 ) bpm. Atropine increases HR sensitivity. Higher dose more sensitive: ( 17/21 ) with 0.05 μg/kg versus ( 22/23 ) with 0.075 μg/kg.</td>
</tr>
<tr>
<td></td>
<td>50% nitrous oxide/oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Atropine—randomized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2 MAC halothane</td>
<td>Isoproterenol 0.05, 0.075 in 0.5 mg/kg lidocaine</td>
<td>HR ≥10 bpm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50% nitrous oxide/oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No atropine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kozek-Langenecker et al. (12)</td>
<td>Anesthetized &amp; awake state; 1.2 MAC halothane</td>
<td>Isoproterenol 0.05, 0.075 or 0.1 in 0.25 mg/kg bupivacaine</td>
<td>HR ≥20 bpm</td>
<td>All 3 doses of I. effective in awake state. Higher dose more sensitive during anesthesia. HR: 100% sensitive (15/15) with and without atropine. SBP—100% sensitive with atropine and 10/15 without atropine.</td>
</tr>
<tr>
<td></td>
<td>70% nitrous oxide/oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No atropine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanaka and Nishikawa</td>
<td>1 MAC sevoflurane</td>
<td>Epinephrine 0.5 in 1 mg/kg lidocaine</td>
<td>HR ≥10 bpm, SBP ≥15 mm Hg</td>
<td></td>
</tr>
<tr>
<td>(14)</td>
<td>60% nitrous oxide/oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Atropine—randomized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sethna et al. (15)</td>
<td>1 MAC isoflurane</td>
<td>Epinephrine 0.5, 0.25 in 1 mg/kg lidocaine</td>
<td>HR ≥10 bpm, SBP ≥15 mm Hg</td>
<td>HR: 19/21 with 0.5 μg/kg and 21/21 with 0.75 μg/kg. SBP: 17/21 with 0.5 μg/kg and 19/21 with 0.25 μg/kg.</td>
</tr>
<tr>
<td></td>
<td>100% oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Atropine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kozek-Langenecker et al. (16)</td>
<td>1 MAC sevoflurane or halothane</td>
<td>Incremental doses of isoproterenol in saline</td>
<td>HR ≥20 bpm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70% nitrous oxide/oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No atropine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanaka and Nishikawa</td>
<td>1 MAC sevoflurane</td>
<td>Epinephrine 0.5 in 1 mg/kg lidocaine</td>
<td>HR ≥10 bpm, SBP ≥15 mm Hg</td>
<td>Positive response in 16/16, 13/16, 16/16 with HR SBP, T-wave respectively. Increase in T-wave amplitude occurred earliest.</td>
</tr>
<tr>
<td>(22)</td>
<td>67% nitrous oxide/oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Atropine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kozek-Langenecker et al. (25)</td>
<td>1 MAC sevoflurane or halothane</td>
<td>Epinephrine 0.5 in saline</td>
<td>HR ≥10 bpm, SBP ≥15 mm Hg</td>
<td>T-wave more sensitive than HR or SBP. T wave, SBP more sensitive with sevoflurane than with halothane. HR and T-wave 100% sensitive with epinephrine. HR 100% sensitive with I. No change in T-wave noted with I. 0.125 μg/kg not sensitive. 0.25, 0.5, 100% sensitive for T-wave criteria. 0.5–100% for HR criteria.</td>
</tr>
<tr>
<td></td>
<td>70% nitrous oxide/oxygen</td>
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<td></td>
<td>No atropine</td>
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<tr>
<td>Tanaka et al. (25)</td>
<td>1 MAC sevoflurane</td>
<td>Epinephrine 0.5 in bupivacaine 0.25 mg/kg or I. In lidocaine 1 mg/kg</td>
<td>HR ≥10 bpm, T wave ≥25%</td>
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<td></td>
<td>67% nitrous oxide/oxygen</td>
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<td>Atropine</td>
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<tr>
<td>Tanaka and Nishikawa</td>
<td>1 MAC sevoflurane</td>
<td>Epinephrine 0.125, 0.25, 0.5 in 0.25, 0.5, and 1 mg/kg lidocaine</td>
<td>HR ≥10 bpm, SBP ≥15 mm Hg, T wave ≥25%</td>
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<tr>
<td>(26)</td>
<td>67% nitrous oxide/oxygen</td>
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<td>Atropine</td>
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*IV = intravenous; I = isoproterenol; HR = heart rate; SBP = systolic blood pressure.*
Although the initial practices focused on HR or blood pressure changes to detect inadvertent systemic injection, Freid et al. (17) in 1993 reported electrocardiographic changes (ST-T wave changes) and bradycardia with inadvertent systemic injection in five neonates and infants during caudal epidural block. Although they noted ST-T wave changes, no tachycardia occurred in any of the five patients. The changes were reproducible in two patients with repeated dosing, and in two patients blood was noted in the tubing or hub of the needle after administration of the test dose. In the fifth patient, the serum bupivacaine level was 2.6 μg/mL after the administration of 1 mg/kg of bupivacaine. The authors referred to bupivacaine toxicity data from animal studies (18,19) and suggested that the electrocardiogram (ECG) changes were related to the local anesthetic, bupivacaine, and not epinephrine. They also observed HR slowing and increased reflex HR slowing. Support for the suggestion that the ECG changes are related, at least in part, to the local anesthetic is provided by the recent report of Tanaka et al. (20) of a 2-mo-old infant who developed increases in T-wave amplitude during the caudal injection of a mixture of 0.25% bupivacaine and 1% lidocaine without epinephrine.

Fisher et al. (21) reported changes in T-wave amplitude (increase by ≥25%) in 25 of 30 patients with known intravascular injection in a prospective, observational study of epidural anesthesia over a 12-mo period. No attempt was made to control the anesthetic...

Subsequent observations led to the suggestion of changes in T-wave amplitude or the ST segment as more sensitive means of identifying inadvertent systemic injection. Additionally, HR slowing or the development of nodal or sinus bradycardia were uncommon but specific signs of systemic injection. Subsequent analysis has demonstrated that changes in T-wave amplitude occur earliest, followed by changes in HR and then changes in systolic blood pressure. These ECG changes may be related primarily to the local anesthetic (bupivacaine) itself and not necessarily the epinephrine.
An epinephrine-containing test dose reliably causes an increase in heart rate (HR) >20 bpm in awake adult patients when it is accidentally given IV (6). During general anesthesia, however, HR changes are remarkably depressed in both adult and pediatric patients, possibly because of the direct effect of general anesthetics on sinoatrial nodal activity. Hence, the accuracy of the test dose, according to the adult HR criterion, is clinically unacceptable (3,6–8). In addition, the effect of a small dose of epinephrine on HR depends on the arterial baroreflex sensitivity, which is also affected to a differing extent by each volatile anesthetic (9). Furthermore, posi-

The major finding of our study is that a simulated IV test dose produced reliable increases in T-wave amplitude in monitor lead II electrocardiography when a 25% increase was considered as a threshold of a positive response. Although 25% could be considered an arbitrary number, it was chosen as a threshold in a previous study (11). The 25% increase could also be

In our study, the peak change of the T-wave occurred almost within a circulation time, approximately 10 and 50 s earlier than those of HR and SBP, respectively. Although a significant increase in the T-wave amplitude also occurred, we did not observe
Test Dose

• “The indicators of inadvertent systemic injection may be delayed for up to 60–90 s after the fractional test dose, suggesting an appropriate observation period of 90 s after the test dose before delivery of the remaining local anesthetic solution.

• Even after a negative test dose, the remaining volume of local anesthetic should be administered in incremental volumes of 0.1–0.2 ml/kg).

• To add further safety to the technique, the block should be performed maintaining spontaneous ventilation.

• Such a practice will allow the possibility to detect the cessation of spontaneous respiration as a sign on inadvertent injection of the local anesthetic”

• Mossetti V & Ivani G  Pediatr Anest  2012
The safety and utility of pediatric epidural analgesia is well established, but the risk of permanent neurological injury is unknown and largely must be extrapolated from adult literature. In this article we present a series of 4 cases of long-term or permanent neurologic complications associated with epidural analgesia. Possible mechanisms of injury and implications for practice are discussed. (Anesth Analg 2012;115:1365–70)

An additional possible mechanism, which may be unique to children, relates to the effects of the hydrostatic pressure created by the injection of the test dose, initial loading dose, or infusions into the epidural space. High peak pressures during injection into the epidural space, and sustained pressures upon completion of the injection, have been recorded using a pressure transducer in adult and pediatric patients. The pressures transduced in the epidural space of children are higher than pressures transduced in adult epidural space. Sustained pressures in pedi-
Sistemic Local Anesthetic Toxicity

- CNS

Several studies have demonstrated that the use of an appropriate local anesthetic “test-dose” (e.g., epinephrine, isoproterenol) can help identify unintentional intravascular local anesthetic injection. Importantly, the dose of epinephrine or isoproterenol and the diagnostic criteria for considering a cardiovascular response to be positive may be different in anesthetized versus awake patients (and in “elderly” patients) but the sensitivity is still high if the appropriate test dose and criteria are used. In contrast, patient report of CNS symptoms can never be 100% sensitive because of the large number of patients incapable of either sensing or adequately communicating their symptoms (e.g., young children, demented patients, patients with a language barrier).

The argument that aware patients could meaningfully detect an intravascular injection of local anesthetic is appealing, but is not universally applicable. For example, seizures that result from systemic absorption of local anesthetic generally occur after most or all of the local anesthetic has been injected; thus premonitory symptoms typically occur too late to prevent a toxic dose from being administered. Moreover, seizures that occur as a

Moreover, appropriate sedation can actually decrease the risk of seizures. Sedative hypnotics (e.g., benzodiazepines, barbiturates, propofol) and volatile anesthetics significantly raise the threshold for local anesthetic-induced seizures and may increase the safety margin for local anesthetic CNS toxicity. This assumes that anesthesia or heavy sedation are not accompanied by significant respiratory depression, which can in fact lower local anesthetic-induced seizure threshold because increased $P_aCO_2$ displaces local anesthetics from plasma protein binding sites.
Sistemic Local Anesthetic Toxicity

• Cardiovascular

Unlike CNS toxicity, which can occur from absorption of local anesthetic properly deposited at the intended block site, the local anesthetic concentrations required to produce severe cardiovascular toxicity can probably be reached only by intravascular injection. Consequently, prevention of cardiovascular toxicity probably rests entirely on the ability to prevent significant intravascular injection of local anesthetic. Indeed, the available data suggest that the most effective method to prevent intravascular injection is by slow, incremental injection of a local anesthetic solution containing a marker of intravascular injection (e.g., epinephrine, isoproterenol) while simultaneously monitoring for the objective cardiovascular response. Therefore, in terms of preventing cardiovascular toxicity by preventing intravascular injection there is no reason to believe that there is any advantage in avoiding blocks in anesthetized or heavily sedated patients.

example, Ohmura et al.\textsuperscript{21} showed that volatile anesthetics (sevoflurane) and propofol raise the threshold for early (dysrhythmias) but not late (asystole) manifestations of bupivacaine cardiovascular toxicity in rats. Similarly, Bernards et al. showed that benzodiazepine premedication increased the dose of bupivacaine required to produce cardiac dysrhythmias and prevented the early hypertension and tachycardia experienced by control animals.\textsuperscript{22} However, consistent

this is a class I recommendation (Appendix 1). The recent introduction of ultrasound-guided regional anesthesia may change these recommendations in the future. Ultrasound guidance allows for the use of significantly lower local anesthetic volumes\textsuperscript{26} and may facilitate avoidance of intravascular injection. However, seizures have been reported despite the use of ultrasound guidance.\textsuperscript{27}
Test Dose (possible conclusions)

In clinical practice, there may be false negative results of test doses when the test-dose is only partially administered IV or when the general anesthetic agents can blunt the hemodynamic effects of epinephrine. A negative result following the injection of a test-dose therefore is reassuring but does not rule out vascular placement of needle or catheter. Any injection of a LA solution should be performed slowly, in small aliquots (0.1 to 0.2 ml.kg-1) and with frequent intermittent aspiration.
Compartment Syndrome
Warning Signs

- ‘Red flags’ for impending compartment syndrome
- 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
Warning Signs

• Prompt diagnosis is however critical as muscle can tolerate only 4 h of ischemia without injury
Warning Signs

- children might be at increased risk of developing compartment syndrome in the lower limb, as the difference between mean arterial pressure and compartment pressure is less, and thus a smaller increase in compartment pressure is required to cause a compartment syndrome.
Monitoring

- the use of an intracompartmental pressure monitor system (Stryker *) can verify a high compartment pressure (over 30 mmHg)
Fasciotomy for Compartment Syndrome
Compartment Syndrome (possible conclusions)

- Concentrations commonly used in children (0.1-0.25%) are unlikely to block ischaemic pain.
- Increasing pain, distal motor weakness should be considered warning signs.
- Careful detailed examination, compartment pressure measurement remain the cornerstone for diagnosis and treatment.
anesthesiologist’s weapons
Loss of Resistance Technique: Air vs Normal Saline

- Air: risk of air embolism
- NS: dilution, no easy detection of dura puncture
- The use of both LORA and LORNS are supported by different international experts and as long as they are used appropriately they can both be safely used in infants and children
Our Golden Rules:

- Monitoring is mandatory:
  1. ECG changes
  2. Slow injection
  3. Spontaneous breathing

- asleep child = safety
Pediatric Regional Anesthesia should be considered a safe procedure to be performed in the daily clinical practice but......

in experienced hands
18° Congresso Nazionale
Società di Anestesia e Rianimazione Neonatale e Pediatrica Italiana
S.A.R.N.e P.I.
Old and New
Torino, 18-20 Settembre 2014

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