WORKSHOPS

Workshop-A1/C1 ~ *Airway (2 hr)*
John T. Algren, MD; Sharma Anshuman, MD; Scott D. Cook-Sather, MD; JGuy D. Dear, MD, FRCA; Morton C. Green, MD; Cathy Krucylak, MD; Richard Levitan, MD; Szabolcs Mandy, MD; Jacquelyn W. Morillo-Delerme, MD; Irene B. O'Hara, MD; Mark S. Schreiner, MD

Workshop-A2/C2 ~ *Managing Epidurals (2 hr)*
T. Mancuso, MD; J. Solodiuk, RN, PNP

Workshop-A3/C3 ~ *What's New for Acute Pain*
C. Houck, MD

Workshop-A4/C4 ~ *Upper Extermity*
J. Tobias, MD

Workshop-A5 ~ *Clinical Trial Design*
Zeev N. Kain, MD

Workshop-B3/D3 ~ *Subarachnoid Blocks*
E. Aladjem, MD

Workshop-B4/D4 ~ *Lower Extremity*
A.K. Ross, MD

Workshop-C5 ~ *Magical Distractions for Children*
J. Christian Abajian, MD

Workshop-B4/D4 ~ *Lower Extremity*
A.K. Ross, MD

Workshop-B4/D4 ~ *Lower Extremity*
A.K. Ross, MD

The Direct Laryngoscopy Video System:
A head mounted, monocular imaging system for displaying and recording intubation as seen by the laryngoscopist.

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Although imaging of airway anatomy has become routine in anesthesia and otolaryngology, imaging of direct laryngoscopy during intubation has been non-existant. Imaging of direct laryngoscopy has the potential to improve intubation education and provide objective recording of laryngeal view for laryngoscopy research studies.

Intubation is amongst the most commonly taught medical procedures in the world. In the US alone, more than 515,000 persons take ACLS or PALS each year and are instructed in how to intubate (1). The challenge of airway education extends also to approximately 750,000 ESM personnel across the United States. Many of these individuals, even those trained at the EMT-Paramedic level, will receive very limited or no intubation practice in an operating room setting. Hands-on training with children is even more limited. Traditional teaching methods (manikins and line drawings) have yielded historically poor initial intubation success rates in both the OR and the pre-hospital setting, ranging from 35-69% (2-9).

Laryngoscopy research has historically depended on the quality of laryngeal view over several seconds as reported by the laryngoscopist during the procedure. This combination of time restriction in the midst of a dynamic clinical setting, along with the lack of objective documentation of laryngeal view has been a methodological weakness of laryngoscopy studies.

Laryngoscopy has been considered to be binocular and it has been traditionally taught that by keeping the left arm straight one achieves a binocular view of the vocal cords (10,11). By selecting restricting the visual input to each eye when the larynx is sighted, it can be easily shown that the larynx itself is sighted monocularly (12). The laryngoscope blade, mouth, tongue, and epiglottis all contribute to restricting visualizion. The procedure is visually analogous to looking down a pipe 8-18 inches long at a target the size of a thumbnail. This makes simultaneous visualization of the larynx by both eyes, or by two persons impossible. Stereoscopic vision occurs when the brain takes the slightly different visual input from each eye (separated in the skull by approximately 6-8 cm) and fuses them into a three-dimensional image (13). The brain cannot fuse very disparate images from each eye, however, and it will then subconsciously suppress the input from the non-dominant pupil (13,14). This explains why even very experienced laryngoscopists may not appreciate that the larynx is in fact sighted monocularly.

The direct laryngoscopy video system (Airway Cam Technologies, Inc. Wayne PA, US Patent # 5,973,728) uses a head mounted, miniature video camera which is sighted through a beam-splitting pentaprism to capture the line of sight perspective from the dominant pupil (15,16) [see Figure 1]. By using a pentaprism the image is reflected through two reflections, thereby rendering the camera's image right-left correct (16). The device allows the prism/camera unit to be directed in front of either eye. Approximately, 20% of persons use their left eye to sight the larynx (12). The right eye is more commonly used because eyedness follows handedness (and right handedness is more common) and because standard laryngoscopes are designed to direct the tongue towards the left and provide a view down the right side of the mouth. The depth of field of the camera system is approximately 6-8 inches. The focus is adjusted through rotation of ring located above the prism unit on the device [see Figure 1].

The direct laryngoscopy imaging system has been used to make three commercially available educational videotapes (Airway Cam Technologies, Inc. Wayne PA, www.airwaycam.com) of intubation which have received very favorable reviews in numerous anesthesia and emergency medical journals (17-20). A recent study of novice intubators using this videotape material in addition to manikin practice showed an improvement in initial intubation success rates from 46% to 88% (21).

From a research perspective, the direct laryngoscopy imaging system has been used for remote telementoring of airway management, in addition to studies on laryngoscopy blades and techniques (22-27). Since the device permits recording of laryngeal view, it is possible to do more detailed comparisons of laryngeal view than traditional Cormack-Lehane grading. A system for quantifying laryngeal view as seen on video recording, called the percentage of glottic opening (POGO Score) has been developed (28-33) [Figure 2]. This scoring system has been shown to have greater interobserver and intraobserver validity that Cormack and Lehane grading (28,29). POGO scores have also been shown to correlate to number of laryngoscopies needed for intubation (33).

Figure 2. The percentage of glottic opening (POGO) scoreTechnique for using the direct laryngoscopy video system [reference Figure 1 for parts identification]:

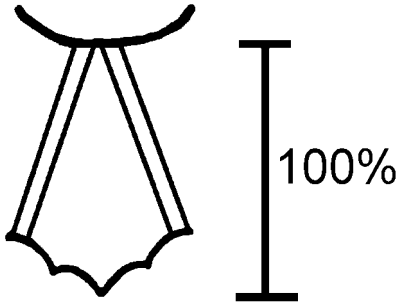
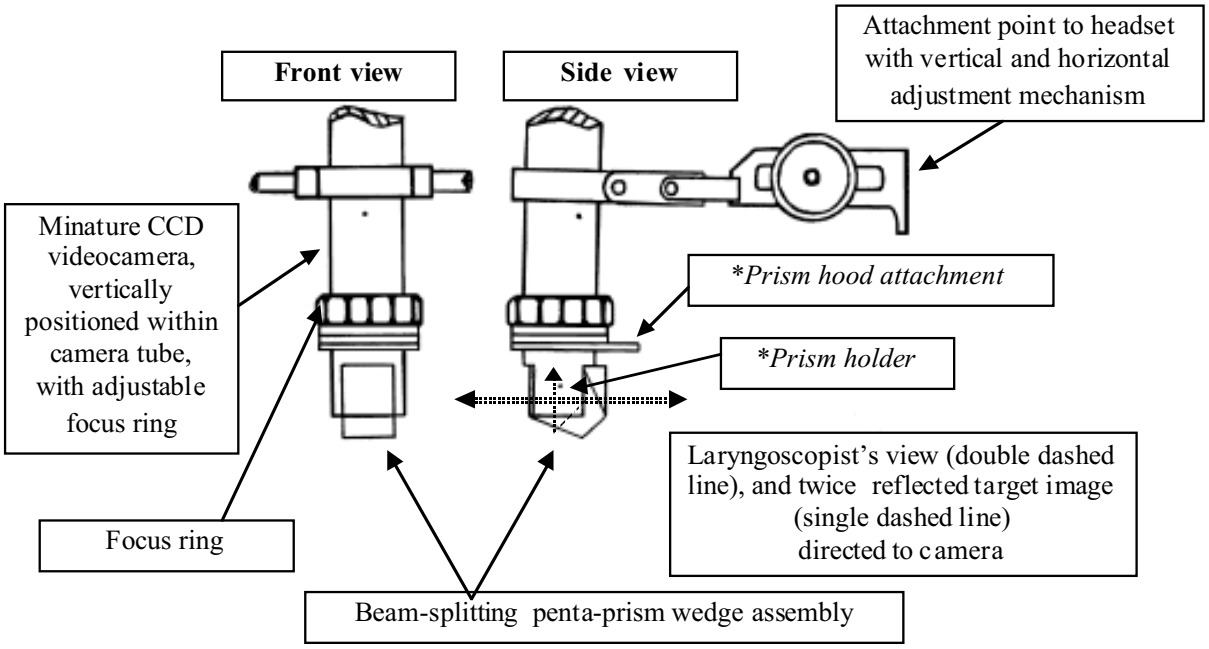


Figure 1. Optical path of direct laryngoscopy video system. [Courtesy Airway Cam Technologies, Inc., Wayne, Pennsylvania, all rights reserved. www.airwaycam.com]



1. Turn on control unit for camera and power to video monitor, making sure that cable from camera control unit to monitor, and cable from camera to control unit has been properly attached.
2. Secure to head using rear and top adjustment knobs on headset.
3. Identify which eye is used to sight larynx. If unsure which eye is used to sight larynx, perform laryngoscopy on manikin and sight larynx, keeping head still. Have assistant take a piece of paper and selectively cover one ey and then the other while viewing of larynx with head still is maintained. The eye used to sight the larynx will be apparent when it is covered by paper.
4. Direct camera/prism unit in front of eye used to sight larynx. The prism should be directly and squarely in front of pupil. ***Note**: for adjustments grasp camera/prism unit from prism holder and hood attachment, not from prism itself. These are labelled with an asterisk and are written in italics in the diagram.*
5. While looking on monitor, hold up thumb at approximate distance used for intubation and adjust camera/prism unit up or down to place image at center of screen. ***Note:** for adjustments grasp camera/prism unit from prism holder and hood attachment, not from prism itself. These are labelled with an asterisk and are written in italics in the diagram.*
6. Other adjustments including the rotation of the prism unit, movement of the prism unit up/down etc. may be done, but are usually not needed.

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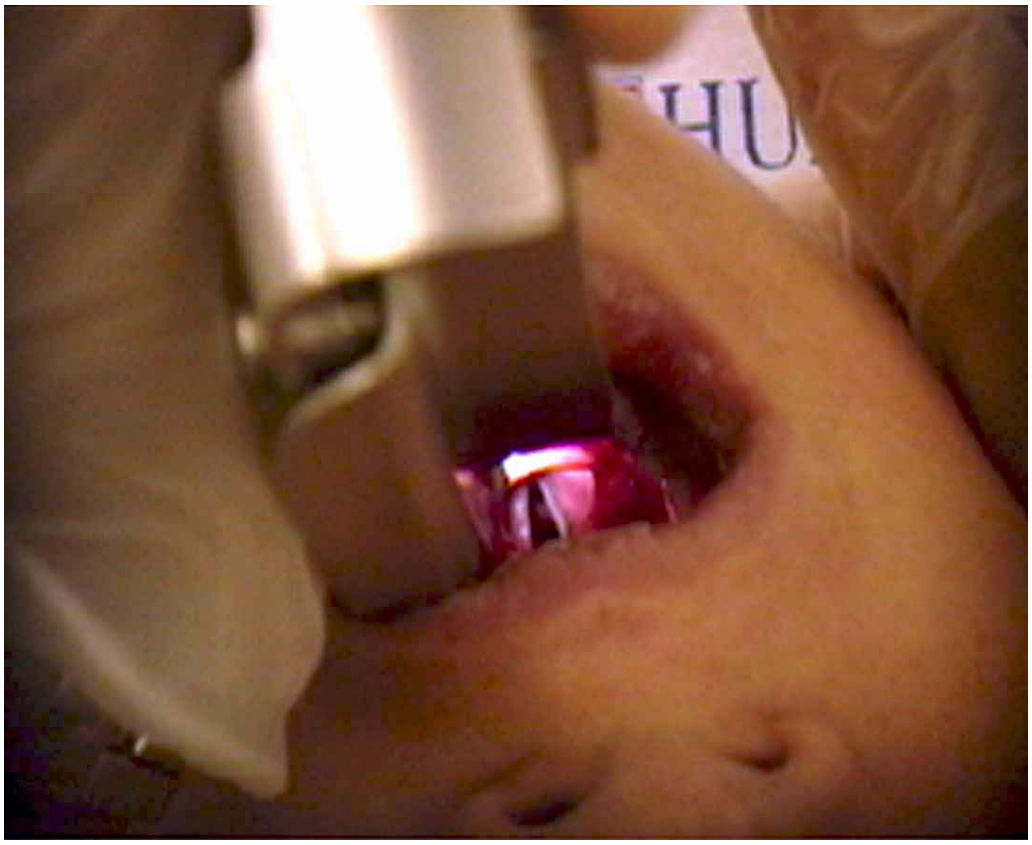

Pediatric Fiberoptic Intubation: A Practical Approach

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Fiberoptic intubation has become an important tool in dealing with anticipated or unanticipated difficult intubation. Early use of this technique may reduce the incidence of respiratory complications like failed intubation, aspiration or esophageal intubation.

The Equipment:

Different sizes of fiberscopes are available for use in pediatrics. Ideally internal diameter of the endotracheal tube should be 1mm larger than the endoscope but smaller tube can be used if the connecter is removed e.g. 3.5mm tube with 3.0 mm scope. The smallest scope available for intubation has the outer diameter of 2.2 mm and can be used for 2.5mm E T tubes. However such scopes do not contain suction channel and because of smaller number of fibers produce a darker image. Also ultrathin scopes are difficult to control. The more useful scope is 3.0 mm scope which can be used for most of the neonates, infants and pediatric patients. These scopes have a working channel and produce a brighter image. Working channel can be used either to insufflate oxygen or as a suction port. However care must be taken not to use high flows to avoid inflation of stomach.

The Pediatric Airway:

Significant anatomical differences exist between neonatal, infant and adult airway. Longer and stiff epiglottis in smaller children is sometimes difficult to work around. A trained assistant can either lift the jaw or pulls the tongue forward to greatly improve the view. Anterior position of larynx in smaller children requires larger ante-flexion of the scope for visualization of the glottis. Neonates tend to have deep set vocal cords, which are also angled anteriorly. To enter trachea, tip of the scope needs to be deflected posteriorly while advancing the scope.

Oral vs. Nasal Route:

Nasal route tends to direct the scope towards the larynx. Highly flexible neonatal fiberscope usually is easier to manipulate through nasal channel. However, hypertrophied turbinates and adenoid tissue can significantly obstruct nasal passages and can be source of bleeding. Surgical site and procedure may also decide the route.

Spontaneous vs. Controlled Breathing:

A paralyzed patient tends to provide better viewing conditions especially for elective intubations. There is no cord movement and minimal fogging occurs at the scope. Any chance of laryngospasm, cough and swallowing is also greatly reduced. Spontaneous technique however may be more suitable in the patients with difficult airways where inability to ventilate may be a major concern.

Practical tips and Troubleshooting:

Most of the problems faced during fibroptic intubation can be fixed by simple maneuvers. It is best to get organized before starting the case. In addition to the equipment, an expert assistant can help with things like jaw thrust, intermittent ventilation and suctioning etc. Following tips may help to troubleshoot common problems:

1. Use of the dominant hand to manipulate the scope and using non-dominant hand to adjust the lever helps to make fine movements.
2. Turn the scope as a unit i.e. both hands should be used to turn the scope to the required side.
3. Loss of orientation is common especially through the oral route. Keeping the scope taut and staying in the midline avoids coiling and thus helps to stay oriented. Use of LMA can also provide

a straighter, unobstructed path to the glottis. However, good positioning of small LMA (size 1 and 2) may only be successful in about 67-78% patients. Recently oral airway devices to guide the scope have become available for smaller children.

4. Difficulty in advancing the tube over the scope may be due to slack. Many times tip of the tube tends to get 'stuck' at the laryngeal inlet either at arytenoids cartilages or epiglottis. Rotating the ET tube first about 90 degrees counter clock wise may solve the problem.4
5. If the ETT is too big a guide wire is passed through the working channel and scope is withdrawn over the wire. A tube changer is advanced over the wire and an appropriate size tube can be advanced over the tube changer.
6. Inability to remove the scope from the placed ET tube can rarely be caused by passage of the scope through the Muphy eye. To avoid this problem scope should always be advanced first. If scope cannot be removed after few attempts, both ET tube and the scope should be withdrawn as a unit.

In summary fiberoptic intubation is a technique that every anesthesiologist must be comfortable with. A graduated training program, which includes both didactics as well as learning of mechanical / visual skills is better than 'see one do one' approach. During learning phase using a video camera or a split beam side arm can improve the teaching.

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Lighted Stylet Intubation

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Table 1: Commercial Lighted Stylets

Product	Features	Advantages	Disadvantages
Tube-Stat™ Xomed (Jacksonville, FL)	limited reuse bulb 25(oro), 33(naso) cm cost ~$30	modestly bright appropriate stiffness	inadequate length high failure rate
Lighted Intubation Stylet Aaron Medical (St. Ptrsbg., FL)	limited reuse bulb adult, pediatric, nasal cost ~$30	bright light pediatric size (4.0-4.5 mm ID minimum)	adult stylet too long and of inadequate stiffness
Imagica Fiberoptic Lighted Stylet Fiberoptic Medical Products (Allentown, PA)	variable size fiber bundles rheostat controlled light source cost ~$90 + disposable sleeve	brightness adjustable 2.5 mm ID - adult sizes with appropriate stylets can augment light output of metal stylets (AMS)	need separate light source such as for OR head lamp fiberoptic guides tend to be too flexible and difficult to control
Trachlight™ Laerdal (Armonk,NY)	reusable light retractable stylet adult, child, infant cost~$300 handle +$25-30/disposable wand, $50/multiuse	excellent for adults or large children very bright light disposable sleeve	expensive pediatric sizes extremely flexible
Fiberoptic Lighted Intubation Stilette Anesthesia Medical Specialties (Santa Fe, CA)	reusable metal jacketed fiber bundle 33 cm adult 21 cm pediatric cost ~$75 for handle and stylet, $35 for stylet alone	light appropriate for children (may add a light intensifier - *e.g.* 20ga Fiberoptic EndoIlluminator, Storz, St Louis, MO) reusable, thin diameter adult, pedi (3.5-4.5 mm)	light inadequate for many adults light can be too bright for infants switch fragile, but replaceable
The Shuttle™ Anesthesia Medical Specialties (Santa Fe, CA)	fiberoptic bundle for endoscopic visualization adult 33cm (4.5mm ID min) pediatric 21cm (3.5mm ID min) cost ~$925 each	potential for visualization of laryngeal structures ease of use similar to AMS Fiberoptic Lighted Intubation Stilette	unreliable visualization through fiberoptic bundle because of soft tissue encroachment very expensive, and adult and pedi devices do not have interchangable stylets

Table 2: Pros and Cons of Lighted Stylet Intubation

Indications	**Contraindications**
normal larynx but difficult to visualize larynx · TMJ disease · micrognathia · cervical spine instability · facial trauma	· foreign body · laryngeal trauma · airway tumor · epiglottitis · retropharyngeal abscess · if fiberoptic approach is planned (relative)
Advantages	**Disadvantages and Complications**
· no need to visualize larynx · inexpensive · compact · rapid · easily practiced in normal cases · oral or nasal intubation possible · awake or anesthetized pts. · unaffected by presence of blood or secretions · easy to clean	· inability to visualize larynx · room lights dimmed · most practitioners inexperienced · rare cricoarytenoid subluxation · may cause some irritation and bleeding making subsequent fiberoptic approach more challenging

Technique

- Lubricate tip of stylet.
- Cut tracheal tube if necessary so that the stylet remains just inside the tracheal tube. A rubber stopper is helpful for positioning the tracheal tube on a metal fiberoptic stylet. Remove tracheal tube connector when using a rigid lighted stylet.
- Shape stylet-tracheal tube combination into a “hockey stick” configuration. Angles of 90º - 110º appear to work best but there is a wide range of personal preference.
- Head and neck should be in neutral or slightly extended positions. A shoulder roll may be helpful.

Technique (continued)

- When ready for tracheal intubation, dim the room lights.
- With your free hand, open the mouth and elevate the mandible, keeping your hand as far lateral as possible to allow unobstructed midline placement of the lighted stylet. A thumb on the mandibular molars may facilitate this.
- Introduce the stylet into the oral (or nasal) cavity from the side and then bring it immediately to the *midline*, seating it under the tongue. Apply gentle anterior traction.
- A bright light at the level of the hyoid indicates the stylet is in the vallecula. The light should be just as bright or brighter when placed in the trachea.
- With the light midline, advance the stylet with a "scooping" or "rocking" motion, keeping the tip gently abutting the anterior aspect of the trachea. The light should remain continuously bright in the midline as it moves caudad.
- Briefly losing the light and then seeing a bright glow in the midline probably indicates esophageal intubation. This is especially true in infants and small children. The light should remain *continuously* bright.
- If advancing the stylet becomes difficult, the likely hang-up is the epiglottis. Move the stylet back, then down slightly and then advance again (visualize in your mind, the stylet going under the epiglottis). Remember that small changes in handle position translate to much larger movements of the stylet tip.
- In infants and children the *feel* of the stylet advancement is just as important as the appearance of the light. In general, don't hold just the handle of the stylet, hold both the handle and the stylet with a pencil grip in order to improve tactile feel. A click is often felt when advancing past the epiglottis. Small, gentle movements will enable the intubator to locate the stylet in the trachea. Intentionally placing the tube in the esophagus may prove useful as a baseline comparison with the appearance of the light when in the trachea.
- Subglottic narrowing is a cause of technique failure. Having a stylet that can accommodate a smaller than predicted tube will reduce failures.

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Laryngeal Mask Airways

The reusable LMA-Classic™ was first introduced in the U.K. in 1988 and in the U.S. in 1992 as an alternative to the face mask. Since 1988, the manufacturer estimates the LMA-Classic has been used in over 100 million patients worldwide. The LMA-Classic is the most versatile of the LMA products and has the widest range of sizes (8) from size 1 to 6, from neonates to large adults. Even though it is called the "routine-use" LMA, it has been used successfully in various urgent and emergency situations, including adult and neonatal resuscitation. In fact, LMA-Classic use in everyday anesthesia probably contributes to its success in resuscitation, since clinicians gain considerable experience using it in routine settings.

The LMA-Classic is ideally suited for elective, outpatient surgical procedures. It is most often used in spontaneously breathing patients, but can also be used with assisted and controlled ventilation. It can be reused up to 40 times with suitable cleaning.

If intubation through the LMA-Classic is to be performed, it should ideally be done using a fiberoptic scope. Alternatively, use of the LMA-Fastrach should be considered.

The reusable LMA-Fastrach™ is an advanced type of LMA designed to facilitate blind, tracheal intubation. The LMA-Fastrach was designed specifically for the anatomically difficult airway and emergency resuscitation. It permits single-handed insertion from any position. The LMA-Fastrach is a unique device that allows for continuous ventilation during intubation attempts, lessening the likelihood of desaturation.

Available in three adult sizes, the LMA-Fastrach comes with a specially designed, wire-reinforced endotracheal tube. With proper care and handling, the LMA-Fastrach endotracheal tube is reusable up to ten times.

The reusable LMA-Flexible™ has a wire-reinforced, flexible airway tube that allows it to be positioned away from the surgical field while minimizing loss of seal. Available in six sizes, the LMA-Flexible is particularly useful in adult and pediatric procedures where the surgeon and anesthesiologist are competing for access, such as those involving the head or neck. It also acts as a barrier against soiling of the glottis or trachea by blood or secretions from above, making it possible to use the LMA-Flexible for intra-oral and pharyngeal operations. While the airway tube of the LMA-Flexible has a smaller diameter than the other LMAs, its internal diameter is comparable to those found in commonly used endotracheal tubes.

The disposable LMA-Unique™ is similar in design to the LMA-Classic™, but is a one-time use, disposable LMA. The LMA-Unique is especially suited for use in those areas of the hospital where stocking a reusable device is not practical or economical. It has been used as a resuscitation device and in difficult or failed airway situations. It is ideal for use in centers with limited sterilization facilities and may be useful in the pre-hospital setting where intubation is not possible or with infectious patients.

How do I select the correct size of LMA?

Size 1:	Neonates/infants up to 5kg
Size 1½:	Infants between 5-10 kg
Size 2:	Infants/children between 10-20 kg
Size 2½:	Children between 20-30 kg
Size 3:	Children between 30-50kg
Size 4:	Adults between 50-70kg
Size 5:	Adults between 70-100kg
Size 6:	Adults over 100kg

■ Start by choosing the largest size you think will fit and inflate with the smallest volume required to obtain an adequate seal. You will find that the larger the size used, the lower the intracuff pressure needed to obtain an adequate seal.
■ Consider changing to a larger size mask if leaks occur when the lungs are inflated to peak airway pressure < 20 cm H_2O, but check first that this is not due to inadequate anesthesia.
■ It is better to use a large size with small inflation volumes than a small size excessively inflated.
■ Always have a larger and smaller size LMA immediately available.

Why do I have trouble inserting the LMA?

Some of the most common mistakes made while inserting the LMA include:

x **Inadequate anesthesia** may cause coughing or breathholding. Immediately deepen anesthesia and manually ventilate the patient.

x **Suboptimal head/neck position.** When inserting the LMA-Classic, LMA-Flexible and LMA-Unique, keep the patient's head in the sniff position. When inserting the LMA-Fastrach, keep the patient's head in the neutral position.

- **Incorrect mask deflation.** Attempting to insert the LMA with the cuff partially inflated increases the chances of a downfolded epiglottis.

- **Failure to press the LMA into the palatopharyngeal curve during insertion.**

- **Lack of water-soluble lubricant** on the posterior surface of the LMA.

- **Using a mask that has surpassed its useful life of 40 insertions.** The cuff and airway tubes of the reusable LMAs are manufactured from silicone.

When first gaining experience with the LMA, its use is recommended in the following:

- Short (<1 hour), elective procedures
- ASA 1-2 patients
- Spontaneously breathing
- Supine position or
- Lithotomy position without Trendelenburg for brief procedures (<30 min.)

Examples of advanced uses include:

Eye/Ear/Nose/Throat Adenotonsillectomy Cataract surgery with or without lens implant Intraocular surgery Myringoplasty Reduction of nasal fractures Rhinoplasty	**Dental and oral** Cleft palate repair Laser pharyngoplasty
Abdominal Gynecologic laparoscopy **Other head and neck** Carotid endarterectomy Cervical node biopsy Excision of branchial cyst Laser surgery to face	**Diagnostic tests** Bone marrow biopsy Bronchoscopy Colonoscopy CT scan MRI (LMA-Classic & LMA-Unique Only)
Microlaryngeal surgery Neurosurgery with or without stereotactic frame Thyroid/parathyroid surgery Tracheal/carinal surgery Tracheostomy	**Other clinical situations** Obesity Prolonged surgery Non-supine position (jack-knife, lateral, prone, Trendelenburg) Remote anesthesia for radiotherapy

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Epidural Analgesia in Pediatrics

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Indications

The primary indication for the use of epidural analgesia which we will discuss today is the relief of post-operative pain. Other indications such as treatment of pain from vaso-occlusive crises in children with sickle-cell disease, treatment of children with CRPS type I or II and treatment of children with cancer pain will be only briefly mentioned. Post-operative pain from many surgical procedures can be managed either completely or nearly so with the proper, careful use of epidural analgesia. We will consider different anatomical sites ion turn, examining the particular opportunities and challenges each offers.

Lower extremity procedures are easily managed with continuous infusions of local anesthetic and opioid. In cases when a CPM (continuous passive motion) device is planned in the post-op period, provision of nearly complete sensory block can be the difference between success of the intervention and failure. Many procedures on the hip and lower extremity are for the relief of contractures in children with spasticity, often as a result of cerebral palsy. In these children, many of whom have diminished intellectual capacity, pain assessment is often much more challenging than the placement of the catheter.

Post-op pain from abdominal surgery is well managed with epidural analgesia. GI function if often affected by the procedure itself and it is helpful to avoid systemic opioids which may only worsen the post-op ileus. Bilateral utereral reimplantation , a commonly performed procedure on relatively healthy children, has a remarkably troublefree postoperative course when epidural analgesia is used. The additional catheters left in place do not trouble the patients. Patients with inflammatory bowel disease often have chronic, recurrent abdominal discomfort pre-operatively and also likely will be NPO for several days post-op, conditions which make excellent epidural analgesia all the more appealing.

The recovery of patients following thoracic surgery may be made considerable smoother, possibly with decreased morbidity, by the use of post-op epidural analgesia. Pectus excavatum repairs are done on generally healthy teen-agers. However, several days of hypoventilation, nausea vomiting and ileus could be avoided with the provision of epidural local anesthetic and opioid instead of relatively high doses of systemic opioids needed to treat the severe discomfort after this procedure. The same reasoning applies to any child who has undergone a thoracotomy. Newborns operated on for repair of congenital diaphragmatic hernia (CDH) have a much improved pulmonary outcome if positive pressure ventilation can be minimized or avoided post-op. This goal can be accomplished with the use of epidural analgesia, which does not have the effect of depressing respiratory drive but does relieve the pain associated with respiratory effort.

Yaster published an early report of the successful use of epidural analgesia in the treatment of painful vaso-occlusive crises in pediatric patients with sickle-cell disease and much subsequent clinical experience has borne out these observations. Considerations involved in the use of epidural analgesia in these patients include: the need for sedation/anesthesia for placement, the location of the pain, the immunocompromised state of these individuals and the best estimate of the length of time the intervention will be used.

Data are currently lacking regarding the long-term efficacy of epidural blockade in the treatment of CRPS I and II. Nevertheless the technique has its uses in these challenging patients. Short term relief of the discomfort is a worthy goal in itself and during the time the block is being used, PT and OT, the mainstays of therapy, can be done on a very intense schedule.

Contraindications

There are only a few absolute contraindications to the use of this technique: Infection at the planned site of placement and lack of parental permission or consent. Children of the appropriate developmental level should also assent to the use of epidurals. Assent means affirmative agreement, not simply passive acceptance. Relative contraindications include factors which make success unlikely such as prior spine surgery, abnormal anatomy and actors which make the chance of complications greater such as coagulopathy and hypovolemia. The presence of a poorly characterized neurologic disease also should give one pause before performing an epidural.

Catheter Placement

In pediatrics, most epidural catheters are placed after the induction of general anesthesia. The procedure, done while the child is awake, would be uncomfortable and frightening to the child and the provision of an immobile patient allows easier placement easier for the anesthesiologist. There is a price to pay for the loss of feedback from the patient during this procedure, however. One is never certain that the needle and catheter are in the epidural space until the child can be examined in the PACU and this even exam can be misleading if systemic opioids had been given during the case. In addition, placement of the catheter into a vein cannot be completely ruled out. Aspiration of an intravascular catheter need not yield blood. Several investigators have shown that IV administration of the test dose amount of epinephrine only inconsistently leads to significant increased in HR in anesthetized children. Increasing the test dose amount of epinephrine to 75 mcg/kg increases the sensitivity of the test dose. Increases in blood pressure and T wave amplitude have been used to confirm intravascular placement of epidural catheters, but there remains a small risk of undetected inadvertent intravascular placement. Inadvertent intrathecal placement may not become apparent in the anesthetized child especially in children below the age of 7-8 years, given the minimal hemodynamic response these patients have to spinal anesthesia. Also, if the procedure itself does not require a secure airway, maintenance of mask anesthesia in a child turned on her/his side and curled up for epidural placement maybe difficult and lead to problems. Radiographs and/or fluoroscopy are used to check placement of epidural catheters. These techniques add time to the procedure, but may be well worth the time and effort in situations when the epidural is particularly important such as in the care of patients with RSD admitted specifically for administration of epidural analgesia or in a

child with cystic fibrosis undergoing an open Nissen Fundoplication. Recently, a technique involving the use of a nerve stimulator to determine the exact location of an epidural catheter has been described. Although there are some technical considerations, the technique appears promising.

Epidural Solutions

The most important medications used in epidural analgesia are local anesthetics. Bupivacaine, in various concentrations, and in combination with opioids is probably the most commonly used of the local anesthetics. Levobupivacaine and ropivacaine are two newer local anesthetics which have shown clinical efficacy in early trials. Ropivacaine does not appear, at this point, to offer the greater safety it was initially thought to have, however. The greater clinical and research experience with bupivacaine allows more confidence in dosing. In children, based on pharmacokinetic data, Sethna and Berde recommends infusions of no more than 0.4 mg/kg/hr. They recommend a lower rate of 0.2 mg/kg/hr for infants less than 3 months of age. If 0.1% bupivacaine is used, infusion rates for older infants and children of 0.2-0.4 cc/kg/hr will not exceed the limit mentioned above. Generally bupivacaine is combined with an opioid, usually fentanyl, 2 mcg/ml or hydromorphone, 3-10 mcg/ml. The infusion rates mentioned should be lowered somewhat if the catheter tip is in a thoracic location versus a lumbar location.

Lidocaine can and has been used for epidural analgesia by infusion. An advantage is the ease with which serum levels are obtained, in contrast to bupivacaine. Yaster describes his use of lidocaine as follows: in newborns, a 1 mg/ml solution is used for infusions of 1 mg/kg/hr while older children receive 1.5 mg/kg/hr of a more concentrated solution (3-5 mg/ml). He recommends daily measurement of levels in children and BID levels in newborns.

2-Chloroprocaine has uses in epidural analgesia. The 3% solution has been given via a continuous caudal infusion to provide prolonged intra-operative anesthesia for neonates undergoing lower abdominal procedures. Another use of 3% 2-chloroprocaine is to evaluate the efficacy of an epidural in a patient whose comfort or discomfort is difficult to know. Following incremental administration of 0.5-0.75 cc/kg (15-20 mg/kg) of 2-chloroprocaine, the patient's block may be more obvious and an epidural which might have been removed for ineffectiveness can be continued with adjustments. Twochloroprocaine, 1.5% also may be used as an infusion in the newborn, although there are not yet extensive safety with long-term infusions. The rapid metabolism of 2-chloroprocaone gives it a margin of safety in these patients who are well known to have prolonged elimination of bupivacaine. Newborns and young infants have been shown to develop elevated serum levels of bupivacaine after 48 hours of an infusion of 0.2 mg/kg/hr.

Clonidine has been used an additive to solutions of local anesthetic in epidural solutions and in single dose caudals for some time. It appears to offer additional analgesia without excessive sedation or respiratory depression if given in modest doses. The solutions mentioned by Greco, Houck and Berde are bupivacaine 0.1% + clonidine 0.8 mcg/cc and 1.5% 2-chloroprocaine + clonidine 0.8 mcg/ml.

Other Considerations

The risk of infection is very low in children with percutaneous epidural catheters. Most centers leave such catheters in place for less than 4-5 days and in most cases of postoperative pain treatment this amount of time is sufficient. If it is anticipated that analgesia will be needed for extended periods of time tunneling the catheter can be done. There are cases of tunneled catheters left in place for extended periods without the development of an epidural abscess. If anticoagulation of the patient for DVT prophylaxis, with SQ heparin or PO coumadin is part of the surgical management, the possibility of an epidural hematoma forming upon removal of the catheter must beconsidered. Since the PT/PTT will be monitored on a daily basis, timing removal of the catheter at the time when coagulation is closest to normal should be possible. If low molecular weight heparin will be used, not low dose heparin the risk of bleeding problems is substantially greater

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What's New In Acute Pain?

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OBJECTIVE: *After completion of this workshop, the participant will be able to demonstrate the spectrum of therapies available in the treatment of acute pain.*

Introduction

Treatment options for acute pain have not changed much in the last 50 years and still consists primarily of the same three modalities**: opioids, nonsteroidal antiinflammatory agents** and **local anesthetics**. New treatments specifically targeting the mediators of various types of pain are the subject of considerable research but most have not made it past the experimental phase. Despite this, there have been vast improvements in the treatment of acute pain in the last 10 years primarily due to: 1) new methods for assessing and monitoring pain in children, 2) better understanding of developmental and pharmacologic differences in analgesic treatment at different ages, 3) new modalities that either extend the duration or effectiveness of the therapeutic agent (i.e. clonidine to prolong local anesthetic blockade), and 4) new formulations of drugs that decrease side effects (i.e. COX-2 inhibitors, ropivacaine).

Alpha-2 agonists

The alpha-2 adrenoreceptor agonist, **clonidine**, was first introduced into clinical practice as an antihypertensive medication in the late 1960's. Its usefulness was limited though by its side effects, sedation and dry mouth. These two side effects as well as its hemodynamic and analgesic effects have made it a promising new agent as both a premedication and adjuvant anesthetic agent. Not only does clonidine significantly reduce volatile anesthetic requirements but also provides hemodynamic stability and a decreased sympathetic response to perioperative stimulation. Recent studies have also found it to be a helpful agent for opioid withdrawal, as well as an adjuvant analgesic for both opioid-based and regional anesthetic pain regimens.

Clonidine is a selective partial agonist for alpha-2 adrenergic receptors with an alpha-2 to alpha-1 ratio of approximately 200 to 1. The precise mechanism of its antihypertensive effects is not known but it appears that its effects in the medullary vasomotor center reduce norepinephrine turnover and decrease sympathetic outflow from the central nervous system. (1) It also centrally stimulates parasympathetic outflow, therefore slowing the heart rate. Children, possibly due to the differences in parasympathetic tone noted in early life, generally demonstrate more of a heart rate response and rarely demonstrate significant hypotension when clonidine is administered perioperatively.

The most consistent effect noted after the administration of clonidine in children is sedation. The locus coeruleus in the brainstem is the principle region responsible for the sedative effect of clonidine. (2) Activation of alpha-2 adrenorecepors suppresses the spontaneous firing rate of the nucleus. This results in increasing activity of inhibitory interneurons such as gamma aminobutyric acid (GABA) pathways in the brain. For more information on the mechanisms underlying the sedative and analgesic effects of alpha adrenergic agonists in children, please refer to Kohura Nishina and colleagues' recent review of the use of clonidine for pediatric anesthesia and analgesia. (3)

One of the most interesting aspects of the addition of clonidine to the armamentarium of the pediatric anesthesiologist is the ability of this drug to significantly prolong the duration of single shot caudal blockade. The exact mechanism for this effect is unknown but it appears that clonidine activates the alpha-adrenoreceptors in the dorsal horn gray matter of the spinal cord. (4-6) This appears to be a direct effect at the spinal cord level since it is correlated with concentrations of clonidine in the cerebrospinal fluid but not in the plasma. (6)

Since the analgesic effects of single shot caudal blockade, even with longer acting local anesthetics such as bupivacaine, tend to wear off within four to six hours, extending the analgesic effects of the block without prolonging the motor effects could be quite beneficial. The addition of clonidine 1 – 2 mcg/kg has been shown to prolong single shot caudal blockade with bupivacaine by 46 -114% in several pediatric studies (7-10) and significantly reduce subsequent analgesic requirements over the next 24 hours. Side effects have generally been mild with short lived (< 3 hours) clinically relevant hypotension and bradycardia only observed when larger doses (i.e. 5 mcg/kg) are used. The recent introduction of a preservative-free preparation (**Duraclon**) has made this drug widely available for regional anesthesia in the U.S.

The analgesic effects of clonidine appear to be much greater when the drug is given via the epidural route than intravenously or orally.(11) Despite this, both oral and intravenous clonidine have been shown to reduce both pain scores and analgesic requirements in the perioperative period.(12) Since many children experience several days of pain after major surgery, it has been suggested that the use of the slow release transdermal patch of clonidine may serve as a powerful adjunct to reduce postoperative pain requirements after such notoriously painful surgeries as posterior spinal fusion. To date, published studies of postoperative analgesia via this route have only included adults.

In the doses most commonly used, the side effects of clonidine include sedation, bradycardia, hypotension, and a potential risk of hypoglycemia. The hemodynamic effects of clonidine appear to be much less in children than in adults and, with the low doses used, are generally not clinically significant. Concern has been raised that the lack of sympathetic response may mask early signs of intraoperative hemorrhage (e.g. tachycardia) so careful monitoring of blood loss is recommended when clonidine is used. The lack of sympathetic response has also led to concern regarding intraoperative hypoglycemia when clonidine is administered as a premedication. Studies have

demonstrated both decreases and increases in plasma glucose levels when clonidine is given perioperatively, therefore, blood glucose levels may need to be monitored intraoperatively when clonidine is given as part of the anesthetic. (13)

Nonsteroidal antiinflammatory agents

Ketorolac

Ketorolac tromethamine is the only intravenous nonsteroidal anti-inflammatory agent currently available in the U.S. Not only does it appear to be quite safe for short-term use in children, but also can reduce perioperative opioid requirements by 30 – 40%. (14) A similar reduction in opioid-related side effects has also been observed. (15) Recently, ketorolac has been demonstrated to have a significant effect on the bladder hyperactivity (i.e. "bladder spasms") noted after surgeries such as ureteral reimplantation. These spasms can be quite uncomfortable and are poorly treated with most opioid analgesics and only partially reduced by dilute local anesthetic solutions. Animal studies have demonstrated that bladder spasms appear to be prostaglandin-mediated and are precipitated by capsaicin-sensitive C fibers in the bladder. Therefore, prostaglandin inhibitors such as ketorolac should decrease the release of these inflammatory mediators. In a recent prospective, double-blinded study here at Children's Hospital, Boston, we found that ketorolac significantly reduced both the incidence (25 vs. 83%) and severity of bladder spasms postoperatively in patients receiving epidural analgesia. (16)

By adding clonidine to our single shot caudal blocks with bupivacaine and using ketorolac to reduce the incidence and severity of bladder spasms, we have recently decreased our use of continuous epidural analgesia for routine ureteral reimplantation surgeries. With this regimen, the difference in pain relief between those children receiving continuous epidural analgesia and those receiving single shot caudal blockade with clonidine 2 - 4 mcg/kg is almost indistinguishable. One noticeable difference is that the children in the caudal with clonidine group are able to go to the playroom sooner since they are no longer tethered to an epidural anesthesia infusion pump.

COX-2 inhibitors

Two major iso-enzymes, COX-1 and COX-2, have been identified and shown to mediate a different spectrum of biological effects. COX-1 is expressed constitutively and contributes to maintenance of gastric mucosal integrity and barrier function, platelet aggregation, and some aspects of distribution of renal blood flow. COX-2 expression is induced by inflammation or tissue injury, with levels of expression in peripheral and central neurons, and in leukocytes. Several selective COX-2 inhibitors have been introduced into clinical practice in the past several years. Adult studies have found that, in comparison with traditional NSAIDs, several COX-2 inhibitors produced a significantly lower incidence of gastritis or ulcers, and excellent preservation of platelet function. The risk of nephrotoxicity, however, from currently available COX-2 inhibitors appears similar to that of conventional NSAIDs. (17) Available pediatric data on COX-2 specific inhibitors at the time of this writing are largely limited to the drug nimesulide,

which is not available in the U.S. COX-2 inhibitors may be particularly attractive as analgesics for surgeries in which bleeding is a particular concern, including tonsillectomy and neurosurgical procedures. Intravenous forms of the COX-2 inhibitors are currently under investigation but rofecoxib (Vioxx) is available as an oral suspension and has therefore has been used for younger children. The oral suspension is available as 2.5 mg/ml but no pediatric dosage has been established. Currently, for adults the recommended dose for osteoarthritis is 12.5 – 25 mg once a day and a dose of 50 mg has been shown to provide analgesia equivalent to 400mg of ibuprofen for dental pain.

Ropivacaine

Ropivacaine is an amide local anesthetic that has recently become available for use in children and adults. It has the potential advantage of providing a less neuro- and cardiotoxic alternative to bupivacaine. In volunteer studies in adults, ropivacaine exhibited less central nervous system and cardiac toxicity than bupivacaine, with adults tolerating an average of 25% more ropivacaine infused intravenously than bupivacaine before the onset of signs of CNS toxicity (18). Therefore, there is potential interest in the clinical use of ropivacaine in infants and children. Ropivacaine may also have the further advantage of causing less extensive motor block of shorter while inducing a sensory block of similar quality to bupivacaine when administered in equal doses to children for caudal blocks (19,20). A recent neurobehavioral study in rats did not show a significant difference between these two drugs in sensory versus motor blockade, suggesting that the difference may be minor. (21)

Since studies to compare local anesthetic toxicity in infants and children can not ethically be performed, the toxicity and therapeutic index for ropivacaine and bupivacaine was recently compared using infant, adolescent, and adult rats. (21). Using this model, ropivacaine was less toxic (larger dose per kilogram to produce respiratory distress and larger lethal dose per kilogram) than bupivacaine at all ages. For both bupivacaine and ropivacaine, infant rats had larger lethal doses per kilogram than adults.

Clinical studies in children have shown that clearance is somewhat slower for epidural infusions of ropivacaine than bupivacaine, suggesting that the improved safety profile may be less prominent after prolonged infusion. (22)

Conclusions

New modalities are still being developed to enhance the effectiveness and reduce the side effects of our currently available analgesics. Truly revolutionary advances will not be made, though, until we better understand the mechanisms underlying the body's recognition, response and signaling of tissue injury.

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WORKSHOP: Upper extremity blockade

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Introduction

Options for providing surgical anesthesia include both general and regional anesthetic techniques. In the pediatric-aged patient, there is an ongoing increase in the use of regional anesthetic techniques. In children, regional anesthetic techniques are generally combined with general anesthesia and used to provide postoperative analgesia. However, many of the regional techniques can also be used instead of general anesthesia in circumstances where anatomic or physiologic alterations may make the conduct of the general anesthesia more difficult or dangerous or as a therapeutic tool where the sympathetic blockade is used to increase regional blood flow. The following manuscript will discuss the anatomy, technique, equipment, and applications of peripheral nerve blockade of the cervical plexus and the upper extremity including the Bier block.

Cervical plexus blockade

The cervical plexus arises from the nerve roots of the second, third, and fourth cervical nerves and provides sensory and motor innervation to the neck and posterior scalp. The superficial cervical plexus provides sensory innervation to the neck while the deep cervical plexus carries motor innervation. Anesthesia of the latter provides only muscle relaxation without additional sensory blockade and therefore is not necessary for superficial surgical procedures of the neck (lymph node biopsy, tracheostomy). The superficial cervical plexus in approached at the midpoint of the posterior border of the sternocleidomastoid (SCM) muscle. The patient□s head is turned to the side opposite the surgery and the SCM muscle identified by asking the patient to lift their head. A superficial skin wheal is placed and local anesthetic is deposited at the midpoint of the posterior border of the SCM using a 25 gauge needle. Our practice in to then infiltrate with the local anesthetic agent at a 90^{o} angle under the belly of the SCM and along the posterior border of the SCM muscle from the mastoid process to the clavicle using a 3.5", 22 gauge spinal needle.

Anesthesia of the deep cervical plexus is a paravertebral block that is accomplished by placing the needle in the appropriate plane adjacent to the transverse processes of C_{2-4}. The terminal aspect of the transverse processes of the cervical vertebrae divide into an anterior and posterior tubercle to which the anterior and middle scalene muscles attach. The space between these tubercles and between the anterior and posterior scalene muscles form a compartment through which the cervical plexus emerges. Immediately below, in the same fascial plane, is the compartment though which the brachial plexus passes. Various techniques have been described for providing anesthesia of the deep cervical plexus including a single injection at C_3, three separate injections at $C_{2,3,4}$ or a modified approach with an interscalene injection with distal pressure to encourage upward movement of the local anesthetic solution[1]. Our practice involves a single injection at the C_3 level. Since the nerve

roots are contained in a facial plane, a single injection should be sufficient with spread of the local anesthetic solution to surround the branches of the $C_{2,3,4}$ nerve roots. For the deep block, the patient's head is placed in the midline and the mastoid process is identified and a line drawn from the mastoid to the sixth cervical tubercle. The transverse process of $C_{2,3,4}$ can usually be palpated posterior to this line 1 to 1.5 centimeters from the mastoid process depending on the age and size of the patient. As there is no transverse process of C_1, the first process palpated is C_2. A skin wheal is raised and a needle inserted perpendicular to the skin, directly over the transverse process of C_3. The needle is directed in a caudad direction to avoid entry into the intervertebral foramina and inadvertent intrathecal or epidural injection. As the needle is walked in a caudad direction, it will slip off the bone if it is on the transverse process as opposed to continuing to contact bone if the vertebral body is contacted. As the needle is moved posteriorly, the highest point of contact will be the most lateral aspect of the transverse process. Once the most lateral aspect of the transverse process is contacted, the needle is withdrawn 1 to 2 mm and after negative aspiration, 4 to 6 mL of the local anesthetic solution is injected.

Previous reports in adults have demonstrated the efficacy of cervical plexus anesthesia in providing surgical anesthesia for carotid endarterectomy, surgical procedures on the neck including thyroid surgery[2-4]. The author has recently reported his experience with cervical plexus block in two adolescents in whom endotracheal intubation was judged to be difficult due to hemifacial microsomia and limited mouth opening/cervical spine mobility following head and neck irradiation[5]. In both patients, superficial cervical plexus blockade was performed following intravenous sedation and proved to be adequate to provide surgical anesthesia.

Complications related to cervical plexus block involve total spinal anesthesia from intrathecal injection and inadvertent intravascular injection. The latter is especially detrimental should direct intra-arterial injection into the vertebral artery occur. Even small amounts of the local anesthetic agent can result in seizure activity. The likelihood of this complication can be lessened by contacting the transverse process as lateral as possible and ensuring a negative aspiration prior to injection. Inadvertent intrathecal or epidural injection has also been reported if the needle enters the intravertebral foramina (see above). With effective block of the deep cervical plexus, unilateral phrenic nerve blockade will invariably occur. In the patient without underlying respiratory compromise, this generally has no clinical consequence. However, cervical plexus block is not recommended for patients that are dependent on the phrenic nerve for effective respiratory function. In children, careful attention must be paid to the total amount of local anesthetic used to ensure that the recommended maximum doses are not exceeded. With such caveats in mind and attention to detail, cervical plexus anesthesia may offer an option for providing intraoperative surgical anesthesia and postoperative analgesia for surgical procedures of the neck (tracheostomy, lymph node dissection) in children.

Brachial plexus blockade

The brachial plexus is derived from the ventral branches of spinal roots C_{5-8} and T_1, providing motor innervation of the upper extremity. In addition, it provides sensory innervation to the upper extremity except for part of the shoulder which is innervated by the cervical plexus and an area on the medial aspect of the arm which is innervated by the intercostobrachial nerve. The spinal roots exit the vertebral column and pass between the anterior and middle scalene muscles. At this point, they unit to form three trunks (superior, middle, and inferior). The trunks are blocked during the interscalene approach to the brachial plexus. The trunks split into anterior and posterior divisions which then unit to form cords (lateral, posterior, medial). These cords surround the

axillary artery and are blocked with the axillary approach to the brachial plexus. The cords further divide into the nerves of the brachial plexus.

Axillary blockade:

The most commonly used approach to anesthetize the brachial plexus in children is the axillary block. The patient's arm is abducted 90^{o} from the body and the elbow is flexed so that the hand is over the head or behind it. The block is performed using one of three techniques: transarterial, one injection, or two injection. For the transarterial approach, the artery is fixed against the humerus and a 22 gauge needle is inserted at a 45^{o} to the skin pointing toward the axilla at the arterial pulsation. Constant aspiration is maintained on the plunger of the syringe. The needle is advanced through the artery until blood is no longer aspirated. One half of the local anesthetic solution (total dose = 1 mL/kg of 0.25% bupivacaine, 0.25% levobupivacaine or 0.2% ropivacaine (maximum 30 mL) or 0.5 mL/kg of 0.5% bupivacaine, levobupivacaine, or ropivacaine) is injected posterior to the artery. The needle is withdrawn through the artery until there is no longer blood return and the other half of the local anesthetic is administered. The advantage of this technique is successful blockade of the posterior cord of the brachial plexus which gives rise to the radial nerve as well as effective blockade of the ulnar nerve which may be missed with the interscalene approach.

With the axillary approach, the musculocutaneous branch may be missed. The musculocutaneous nerve innervates the radial (lateral) side of the forearm onto the thenar eminence. To improve the chances of anesthetizing the musculocutaneous nerve, distal pressure should be held as the local anesthetic is injected in an attempt to force the solution up the sheath. Alternatively, a separate musculocutaneous block can be performed.

Other approaches to axillary blockade of the brachial plexus include one and two injection techniques. The needle is advanced at a 45^{o} degree to the skin just above the arterial pulsation. As the fascia is pierced, a loss of resistance is felt or an appropriate twitch noted in a distal muscle group if the nerve stimulator is used. For the one injection technique, the entire volume of local anesthetic is injected. If a two injection technique is used, half of the local anesthetic solution is injected and a second needle is positioned inferiorly to the arterial pulsation and the remainder of the local anesthetic solution injected. If a tourniquet is needed, a ring of local anesthetic solution should be injected high around the medial aspect of the upper part of the arm to anesthetize the intercostobrachial branch of T_2.

A nerve stimulator may be used in the anesthetized or deeply sedated patient. This requires avoidance or reversal of neuromuscular blocking agents. The nerve stimulator is set to the low output setting (0.1-1 mA), the negative electrode is attached to the insulated needle, and the positive electrode attached to the patient using a standard ECG pad. The needle is then advanced until a motor response is noted distal in the extremity to be anesthetized. At this point, the voltage is turned down to 0.2-0.5 mA to ensure that the needle is in close proximity to the brachial plexus. A modification of this technique permits the placement of a catheter into the sheath[6,7]. A single lumen, 3 French, 5 or 8 centimeter central line catheter can be used for this purpose. The 0.018" wire included in the kit will pass though the 22 gauge insulated needle so that the Seldinger technique can be used to place the catheter in the plexus sheath[7]. This allows the use of a continuous infusion to provide continuous postoperative analgesia or sympathetic blockade for the treatment of vascular insufficiency[6-8]. Alternatively, insulated Tuohy needles (18 gauge in varying length) with catheters are sold by different manufacturers for placement of continuous plexus catheters.

Interscalene blockade:

The interscalene approach to the brachial plexus is used less frequently in children because

of a perceived higher incidence of complications including pneumothorax. The interscalene block provides anesthesia of the entire upper extremity including the shoulder. The point of needle insertion is the transection of a line drawn from the cricoid cartilage and the posterior border of the SCM. The trunks of the brachial plexus lie between the anterior and middle scalene muscles. The separation of these two muscles can be felt as the interscalene groove starting at the posterior aspect of the SCM. As the trunks of the brachial plexus are organized in a superior to inferior direction, the lower dermatomes of the brachial plexus (C_8-T_1) are less effectively blocked than with an axillary approach so that there may be less effective analgesia over the distribution of the ulnar nerve. However, the interscalene approach does effectively block the musculocutaneous branch. Even with correct needle placement, phrenic nerve blockade may occur in a significant percentage of patients. Although this is not problematic in healthy, older patients; infants and patients with respiratory dysfunction may be dependent on the diaphragm for respiratory function. A continuous catheter technique can be used as described above for the axillary approach.

Based on the risks of pneumothorax with supraclavicular or infraclavicular approaches and the risks of vertebral artery, epidural or subarachnoid injection with the interscalene approach, Dalens et al investigated the possibility of a novel approach the brachial plexus in the neck known as the parascalene approach[9]. After an evaluation of the anatomy of the neck using cadavers, they developed a new approach to the brachial plexus which avoids the major structures of the neck. The child is placed supine with a towel roll placed under the shoulder and the head turned away from the side of the block. The landmarks used are: 1) the midpoint of the clavicle, 2) the posterior edge of the SCM, and 3) Chassaignac's tubercle (the transverse process of C_6). The latter is identified either by palpation or by extending a line from the cricoid to the posterior border of the SCM. A line is drawn from Chassaignac's tubercle to the midpoint of the clavicle. The needle insertion site is at the point of the junction of the upper two-thirds and lower one-third of this line. A insulated needle is inserted at a 90^o degree angle to the skin and advanced until a motor response is noted in the distal part of the upper extremity. If no response is obtained, the needle is withdrawn and directed more laterally. Dalens and colleagues prospectively investigated the efficacy of their technique in 60 children[9]. The brachial plexus was identified on the first or second attempt in all 60 patients and resulted in complete surgical anesthesia in 97% of the patients. When bupivacaine or etidocaine was used for the block, the duration of sensory analgesia was more than 5 hours. Complications included puncture of a small vein in 1 patient and Horner's syndrome in 2 patients. When the authors compared their results to reports using the supraclavicular approach in adults, they noted a lower incidence of adverse effects and more effective anesthesia as well as easier placement of the block.

Radial, ulnar, and median nerve blockade:

The wrist and hand are innervated by three nerves: the median, ulnar, and radial. Since each must be blocked separately, the technique requires three separate injections. Each nerve is blocked with 0.5 mL/year or 0.2 mL/kg (maximum 5 mL) of 0.5% lidocaine or 0.25% bupivacaine injected with a 22 of 25 gauge needle. No vasoconstrictor is added to the local anesthetic. The median nerve travels between the palmaris longus tendon and the flexor carpi radialis tendon. These two tendons can be identified by asking the patient to flex their wrist. The needle is inserted, perpendicular to the skin, immediately lateral to the flexor palmaris longus tendon, 2 to 3 centimeters proximal to the first crease at the wrist. One mL of the local anesthetic should be injected as the needle is withdrawn to ensure that the palmar cutaneous branch is also anesthetized. The ulnar nerve is anesthetized using a similar technique with the needle inserted medial to the ulnar artery. The radial nerve is approached from the lateral aspect of the wrist. The extensor pollicis longus tendon

(superior border of the anatomic snuff box) is identified by having the patient extend the thumb. Starting at the base of the first metacarpal, local anesthetic (0.5 mL/year up to 5 mL) is injected along the course of the tendon to the dorsal radial tubercle. The needle is withdrawn to the point of insertion and an additional 2 to 3 mL is injected perpendicular to the extensor pollicis longus across the anatomic snuff box to a point just distal to the extensor pollicis brevis.

Digital nerve blockade:

Digital blocks of the finger can be used to provide anesthesia during brief procedures such as removal of foreign bodies or suturing of lacerations. The block may be used alone or following intravenous sedation in younger children. Sensory innervation of the digits is supplied by four nerves: two along the ventral aspect and two along the dorsal aspect of the digit. These nerves are approached bilaterally from the side of the digit. After superficial infiltration, a 22 or 25 gauge needle is inserted perpendicular to the skin from the lateral aspect of the digit, down to the bone. The needle is then withdrawn and angled anteriorly over the superior aspect of the bone where 1 to 2 mL of 0.5 or 1.0% lidocaine is injected. Vasoconstrictors are not added to the local anesthetic since the arteries supplying the fingers and toes are end-arteries. The procedure is repeated with the needle directed along the inferior surface of the bone and then from the opposite side of the digit.

Bier block:

The Bier block involves the intravenous administration of a local anesthetic distal to an inflated tourniquet. This technique is generally used instead of general anesthesia, as it provides no postoperative analgesia. It has seen application outside of the operating room in the emergency department for the reduction of forearm fractures[10]. Its major advantage is its ease of placement. Disadvantages include a limited duration of anesthesia (60 minutes), the relatively large dose of local anesthetic required, and the fact that no postoperative analgesia is provided. The technique involves placement of a double tourniquet apparatus on the involved extremity. The extremity is raised above the heart and exsanguinated through the placement of an elastic bandage. Alternatively, if placement of an elastic bandage is too painful due to trauma of the involved extremity, the extremity can be elevated and the axillary artery compressed for 5 minutes. The proximal of the two tourniquets is then inflated and the local anesthetic injected over 60 to 90 seconds. The dose of local anesthetic includes 0.5 mL/kg for upper extremity procedures and 1 mL/kg for the lower extremity. The local anesthetic most commonly used is lidocaine (0.25-0.5%) although the risks of adverse effects may be lowest with prilocaine. More recently, 0.2% ropivacaine has been suggested an effective alternative, its advantage being the presence of continued anesthesia for 10-15 minutes following tourniquet deflation[11]. The concentration of the local anesthetic is limited to 0.5% to avoid the risks of toxicity. No vasoconstrictor is added to the local anesthetic; however, the addition of a small dose of an opioid (fentanyl 1 mcg/kg) or clonidine (1 mcg/kg) may improve the density of the block and delay the onset of tourniquet pain while the addition of a small dose of a neuromuscular blocking agent pancuronium (0.01 mg/kg) may prevent unwanted movement. Prior to injection, the functioning of the tourniquet should be double checked since the greatest risk of the procedure is local anesthetic toxicity. If the patient complains of tourniquet pain during the procedure, the distal cuff is inflated and the proximal cuff is deflated.

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Lower Extremity Blocks in Pediatric Patients

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Objectives: This workshop will provide the participants with an overview of the anatomy of the lower extremity, the pharmacology of the local anesthetic used for peripheral nerve blocks, the use of a nerve stimulator, and the techniques for blocking the nerves that are specific to the lumbar and sacral areas. Hands-on demonstration with a child model will allow for identifying important landmarks and improve block technique.

Introduction: Peripheral nerve blockade in anesthesia has become increasingly popular with the improvements in equipment, local anesthetics and techniques. Many procedures in pediatric surgery are amenable to the use of peripheral nerve blocks that offer the advantages of site-specific pain relief and prolonged postoperative analgesia.

Anatomy: The lower extremities are supplied by nerves originating from the lumbar plexus and/or sacral plexus. Above the knee, the lower extremity is supplied by the lumbar plexus originating from L1-L4 and includes the femoral, obturator, and lateral femoral cutaneous nerves. With exception of the distribution of the saphenous nerve which is a sensory branch of the femoral, the lower extremity below the knee is supplied by branches of the sciatic nerve (tibial and common peroneal) which originates from nerve roots of L4-S3.

Local Anesthetics: The choice of local anesthetic for a peripheral nerve block depends on desired duration of surgery, desired duration of motor block (if any) and, most importantly, consideration of maximal allowable dosing. Most preschool-aged children and younger receive a dense surgical block of a peripheral nerve at modest concentrations of local anesthetics. Bupivacaine 0.25%, levobupivacaine 0.25%, or ropivacaine 0.2%, may be used with success. Higher concentrations, i.e. bupivacaine 0.5%, levobupivacaine 0.5%, or ropivacaine 0.5% should be used in children greater than 5-8 years of age to get desired intraoperative anlagesia and prolonged duration. Other concentrations between these ranges may also be used depending on the age of the child. Epinephrine 5 mcg/cc (1:200,000) improves safety in performing a block by decreasing the peak maximal concentration of absorbed local anesthetic and by acting as a warning sign of intravascular injection.

When dosing for a peripheral nerve block, particular attention needs to be paid to the maximal allowable doses of local anesthetic on a per kg basis. Volumes for lower extremities blocks are typically between 0.5-1 cc/kg. Plexus blocks usually require higher volumes when compared to a simple peripheral nerve block. When combining these two blocks for example, the lumbar plexus will receive 2/3 the total and the sciatic 1/3 the total and the maximal allowable dose should not be exceeded. The maximal allowable dose of bupivacaine, levobupivacaine or ropivacaine is 3 mg/kg, assuming the

use of epinephrine. Although these doses are the current recommendation, it is conceivable that they will be expanded for ropivacaine and levobupivacaine to a higher mg/kg allowance based on improved safety data as it develops.

Techniques of lower extremity blocks:

To improve success in performing any peripheral nerve block, a nerve stimulator and blunt insulated needle of the appropriate length should be employed. The nerve stimulator should be set at 1-1.2 mAmps with a frequency of 2 Hz. Once desired muscle response is seen from appropriate nerve stimulus, the voltage should be able to be decreased to less than 0.5 mAmps with continued, but decreased, muscle response. Local anesthetic may then be injected slowly and incrementally if there is no resistance.

The contraindications to performing a peripheral nerve block are infection at the site of injection and parent refusal.

Femoral Nerve Block

Indications: Surgery of leg above the knee, pain management for femur fracture (without use of nerve stimulator), or in conjunction with sciatic block for distal extremity surgery.

Technique: Supine child with foot rotated outwardly. Needle inserted 0.5-1 cm below inguinal ligament and 0.5-1 cm lateral to femoral artery. Pop through fascia lata. Distal pressure during injection will encourage cephalad spread and *perhaps* provide a "3 in 1" block of femoral, lateral femoral cutaneous, and obturator nerves. Complications include intravascular injection and frequent aspiration for blood should be practiced.

Fascia Iliaca Compartment Block

Indications: Same as femoral with better success at anesthetizing LFC and obturator nerves in addition to femoral nerve. May also be used for muscle biopsy procedures of thigh for MH susceptible children.

Technique: Supine child with needle inserted 0.5-1 cm below junction of lateral one-third and medial two-thirds of inguinal ligament. No nerve stimulator to be used as goal of block is spread of local anesthetic behind iliacus muscle, not specific location of particular nerve. Loss of resistance is felt as a pop through fascia lata and another through fascia iliaca. Local anesthetic should be injected if no resistance is encountered. Complications are rare.

Lumbar Plexus Block

Indications: Surgery of upper leg or hip.

Technique: Child in lateral decubitus position with legs flexed at hip and knees. A line is drawn between iliac crests, and another line is drawn parallel to spinous processes and on ipsilateral side through posterior superior iliac spine. Needle is inserted at line intersect and parallel to skin. Nerve stimulator should be used looking for strong quadriceps response, "patellar kick". Complications include epidural spread with medial injection, and damage to retroperitoneal structures with inappropriate depth of needle.

Sciatic Nerve Block-Posterior Approach (Dalen's modification)

Indications: Surgery of lower extremity below the knee.

Technique: Child in lateral decubitus position with legs flexed at hips and knees. Needle insertion is at midpoint of line between tip of coccyx and greater trochanter of the femur. Direct the needle medially and toward lateral border of ischial tuberosity looking for response in foot of either peroneal or tibial nerve stimulation.

Sciatic Nerve Block-Raj Approach

Indications: Surgery of lower extremity below the knee such as club foot repair.

Technique: Child supine with ipsilateral leg lifted to flex at knee and hip. Needle is inserted at midpoint between ischial tuberosity and greater trochanter of femur. Stimulation in foot is desired.

Sciatic Nerve Block-Popliteal Fossa

Indications: Surgery of lower extremity below the knee.

Technique: Although originally described for prone position, the ease of lifting the leg in children allows this block to be performed in the supine position. Find the apex of the popliteal fossa triangle and divide the triangle into medial and lateral halves. The point of needle insertion is 1 cm lateral and 1-2 cms proximal to the popliteal crease. Advance the needle slightly cephalad until foot stimulation is achieved. Large volumes of local anesthetic may improve success in this block that otherwise may have 10% failure rate due to proximal branching of common peroneal and tibial nerves.

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