ANESTHESIA OFF THE GRID

A manual for humanitarian health care workers

JAMES LI MD

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A Manual for Humanitarian Health Care Workers

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For all the doctors, nurses, and students who have lived among their patients in faraway places, treating them as they would themselves with cheerfulness, professionalism, and selflessness. You make medicine the noble profession that it is.

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Introduction

In the developed world, anesthesia is a seemingly ultramodern practice, and the anesthetist is surrounded by equipment that analyzes, records, controls, and monitors a patient's life signs during any given procedure.

In the developing world, anesthesia may be required outside of a hospital, or in a hospital without electricity, running water, or any form of modern monitoring equipment.

This manual is the result of my own practice in the developing world, where I had no intentions of practicing medicine as an anesthetist, but every need to do so while also performing all of the medical tasks needed to treat my patients.

The physician who practices in a remote or resource-scarce region is frequently a generalist but must perform a variety of specialist duties simultaneously, acting at once as internist, pediatrician, obstetrician, parasitologist, intensivist, surgeon, and anesthetist. I have found that those who are successful in such practices are unique individuals, and possess an outlook characterized by simultaneous humility, humor, and resourcefulness. This manual is dedicated to the individuals who have devoted their lives to such practices.

Figure 1 *Kijo, a young but experienced nurse, provides simultaneous aid in anesthesia, patient monitoring, and operating itself.*

A Unique Approach to Anesthesia

"The only means of access to our hospital at present is by walking over the mountains for a week. All supplies have to be carried in by porters who take two weeks for the journey. For the first two and a half years, we worked in a traditional Nepali house with a thatched roof and a floor made of mud and cow dung. In it we did over 100 operations by the antiseptic method, without serious mishap. Later, limited space became available, so that although we enjoyed the advantages of tap water, a concrete floor, a clean ceiling, and adequate window ventilation, we still had to operate on a light outpatient type of table and in the same room in which the outpatients received all their medications, injections, dressings, incisions, and dental extractions. We almost always used epidural or local anesthesia."

Dick JF: Antiseptic surgery. *The Lancet,* 1966.

Health care in remote or poverty-stricken regions is frequently delivered under desperate circumstances. This is particularly true for patients whose injuries or illnesses require urgent surgery. In such cases, a needed procedure may be impossible due to lack of proper anesthesia or skilled anesthetist.

This manual is written for any medical caregiver, from nurse to medical student to surgeon, who must perform anesthesia in a remote locale, where someone more experienced is not available. Though no substitute for training and experience, it provides a basis for effective anesthetic practice where resources are limited, whether by poverty or disaster.

Limited supplies. Physicians in the developing world must deal ingeniously with a lack of supplies, particularly in impoverished and remote areas. Standard care rarely includes capnography, pulse oximetry, or advanced cardiopulmonary monitoring. Typically, only one injectable anesthetic is available, inhalation anesthesia is limited to halothane or ether, manual suction and a bag-valve-mask assembly constitute the only advanced resuscitation equipment, and supplemental oxygen is scarce.

If referral facilities exist at all, they often are beyond the patient's means. Therefore, the physician often finds his or her own expertise stretched beyond all previous training. Generalist physicians are called upon to perform emergency anesthesia and surgery simultaneously in order to save the lives of their patients and may lack formal training in either field.

Figure 2 *Sandra, an Australian general practitioner working in an African district hospital, uses home-made drains to place a chest tube for empyema drainage in an infant.*

Great need. Rather than be overwhelmed by these possibilities, I encourage physicians who are embarking on developing world practices to embrace the challenges they face. The trials of such practices are necessarily imposed by a great medical need, and any contribution to relieve need of this magnitude is tremendously worthwhile and rewarding.

Over the past two decades, tangible gains have been achieved to reduce poverty in every region of the world. Improvements in lifespan, education, and access to clean water and sanitation are encouraging results of efforts that seemed fruitless during the 1990s. Given intense efforts to reduce the burden of infectious disease through global vaccination campaigns, such diseases as polio, tetanus, and measles have been systematically reduced throughout the developing world. Much needed attention and specific programs have also reduced deaths from to HIV, tuberculosis, and malaria across the globe.

Nevertheless, extreme need still exists. Life expectancy for persons born in countries ranked in the bottom five of the latest United Nations human development (UNDP) list is 57 years compared with 82 years for the five highest ranking countries. The supply of physicians underscores this fact. In the developed world, there is one physician practicing for every 358 persons in the population. In the developing world, one physician practices for every 971 persons. In sub-Saharan Africa, the contrast is even more telling, as one physician practices for every 5,263 persons. Thus, the need for physicians remains immense in the underserved impoverished regions of our world.

Further reading. For in-depth coverage of the topics in this manual, a bibliography is provided at the end. One source stands out, however, and serves as the inspiration for this work. Despite being out of print, it remains the definitive guidebook for any serious practice of generalist anesthesia in the third world. This text, "Primary Anaesthesia," is part of a series published by Oxford University Press. The four-part series also includes the excellent two-part, "Primary Surgery" texts. These practical books were created by other long-term practitioners in the developing world and may still be found in medical bookstores throughout the developing world. Alternatively, they are also occasionally available through the organization, Teaching Aids at Low Cost (www.talcuk.org).

Be Prepared

Learn from experienced clinicians. No learning is as effective as that gained while working with an experienced mentor. For clinicians newly embarking upon practice in the developing world, we suggest first practicing with a group of more experienced physicians for the explicit purpose of learning and practicing essential anesthetic techniques.

Ideally, I suggest practice for at least two months at a developing world hospital with experienced staff. The nonprofit agency, INMED, specializes in placing medical workers in the developing world in mentored settings (www.inmed.us).

Simplicity counts. Anesthesia encompasses an enormous field and practitioners may feel overwhelmed at the prospect of mastering a new discipline. However, in the developing world certain simple skills learned well can suffice for almost all situations.

The essential list. For the purpose of providing effective anesthesia in remote locales, it is not necessary to have an exhaustive knowledge of all medications used in anesthesiology. I encourage practitioners to learn a small list of agents chosen to both serve a broad range of cases and perform well under harsh circumstances.

This list may vary depending on previous experience of the health provider. However, three anesthetic methods form the foundation of practice in the developing world — injectable ketamine, spinal anesthesia, and local subcutaneous infiltration. These three are chosen for emphasis in this manual because of their great utility under adverse conditions. In developing world practice this utility is due to widespread use, low cost, ready availability, and well understood side effect profiles which can be practically anticipated. Practitioners who are versed in ketamine, spinal, and local anesthesia possess an indispensable skill, as most any operation can be performed comfortably using one or more of these methods. None require intubation, supplemental oxygen, or more monitoring than periodic measurement of heart rate, blood pressure, and respiratory effort.

Equipment and supplies. The following list of equipment and supplies is recommended for a developing world anesthesia practice. These are chosen for use under many conditions, widespread and inexpensive availability, and minimization of wastable materials.

Essential Medications

Ketamine (in 50 mg/ml and 100 mg/ml vials). Higher concentration vials reduce volume needed for pediatric IM injections.

Atropine (in multi-use vials).

Promethazine. This drug possesses not only antiemetic, but also antihistamine and sedative properties, making it more useful than agents having only one use.

Diazepam. May substitute alternatives such as lorazepam or midazolam if available. Diazepam is the least expensive benzodiazepine.

Lidocaine (lignocaine). An all-purpose solution of plain 2% lidocaine can be diluted and mixed with epinephrine as needed for most types of infiltration anesthesia. Other local anesthetics such as bupivacaine and procaine can be substituted for lidocaine if available.

Lidocaine (lignocaine), hyperbaric. This is 5% lidocaine with 5% to 7.5% dextrose in single use 2 ml vials for spinal anesthesia and is also known as "heavy" lidocaine. Similar spinal agents are available (5% prilocaine in 5% dextrose, 4% mepivacaine in 10% dextrose, and 0.5% bupivacaine in 5% dextrose). Though duration of action varies between agents, the dose of these others is approximately the same as that of lidocaine.

Morphine. May substitute meperidine (pethidine) or other narcotics if available. Meperidine is sometimes more easily available than morphine and can be used in its place.

Powdered succinylcholine (suxamethonium). Once reconstituted, succinylcholine loses efficacy unless refrigerated. Many developing world practices lack refrigerated facilities, so powder is reconstituted as it is required.

Naloxone (in multi-use vials).

Pressor agent (for hypotension due to spinal anesthesia). Ephedrine is frequently available at low cost to developing world practices. Pressors chosen for use in spinal anesthesia should have predominantly alpha-agonistic effects. Alternative alpha agents include methoxamine, phenylephrine, and metaraminol.

Oxytocin (or ergotamine). For uterine contraction following caesarian section.

Epinephrine (adrenaline, in 1 mg/ml multi-use vials). In the developing world, this is probably least useful for resuscitation, since primary cardiac disease is virtually nonexistent. Nonetheless, epinephrine is useful as a supplement for local anesthetic solutions and for treatment of bronchospasm and anaphylaxis.

Optional medications

Pancuronium (in multi-use vials). Pancuronium provides longer paralysis in abdominal operations. Other nondepolarizing neuromuscular blocking agents are also appropriate, but pancuronium is inexpensive and its duration is shorter than others, so that if reversal agents are missing, the patient does not require many hours of hand-ventilation before regaining normal respiratory capacity. Alternative agents include tubocurarine, vecuronium, atracurium, mivacurium, and rocuronium.

Neostigmine (in multi-use vials). For reversing nondepolarizing neuromuscular blockade.

Monitoring equipment

Stethoscope. Two stethoscopes are useful for anesthesia practice in remote areas. The first is the standard clinician's stethoscope. The second is the anesthetist's stethoscope, also known as a monaural stethoscope. The latter has a plug that is worn in one ear and is connected to a length of tubing that attaches to a diaphragm taped to the patient's chest. This is useful for continuous monitoring of a patient's pulse rate, pulse intensity, and breath sounds during an operation. A reusable monaural earplug can be procured from one's home anesthesia service. Under normal circumstances, the earplug is designed to be attached to disposable single-use chest pieces. However, the diaphragm from a standard stethoscope can be repeatedly used with a monaural earplug if detached from the standard stethoscope and attached to a section of nasogastric tubing.

Figure 3 *A modified chestpiece from a regular stethoscope can be connected to a monaural earpiece (not shown) and used for patient monitoring during operation.*

Blood pressure cuff.

Pulse oximeter. Miniature fingertip-sized pulse oximeters are not essential but are now available inexpensively and provide an extra margin of safety in patient monitoring.

Recleanable and reusable supplies

Foot-operated non-electrical suction. Few manufacturers make such devices. One model is available from Ambu (www.ambu.com).

Mouth-operated trap (De Lee) suction.

***Figure 4** Immediate mouth suctioning of meconium in an infant delivered by caesarean section.*

Bag-valve mask. Both pediatric and adult sizes are needed. For children, facemasks fitting neonates, infants, and older children are recommended.

Nasal airways.

Oral airways.

Scalpels.

Three-way tracheostomy dilator (cricothyrotomy tool). A hemostat may serve this purpose, but not as well. Some developing world practitioners carry a scalpel on a shortened handle and a small hemostat for the purpose of immediately performing emergency cricothyrotomy if necessary.

Figure 5 *A young child is resuscitated in a Kenyan district hospital. Proper equipment was lifesaving.*

Universal adult/pediatric laryngoscope handle and blades. An all-purpose adult laryngoscope blade is a curved size 4. This can easily be adapted to adults with smaller airways, but a smaller blade cannot be easily adapted for those with larger airways. For neonatal resuscitation following caesarean section, an assortment of pediatric straight blades (sizes 1 through 3) is recommended. The universal laryngoscope handle runs from AA batteries and fits both adult and pediatric blades.

Endotracheal tubes. For adults, a red rubber non-cuffed 9-0 endotracheal tube can be easily recleaned and used repeatedly. For fasted patients, the large size usually fits snugly through the cords and obviates need for a cuff. However, cuffed tubes are recommended for all adult emergency cases, and an assortment should be obtained. Most pediatric intubations will involve neonatal resuscitation, so neonatal-sized endotracheal tubes should also be obtained.

Nasogastric tubes.

IV tourniquet.

Syringes. When possible, use “Luer-lok” syringes in order to prevent the needles from slipping during local infiltration. To reduce waste, obtain plastic syringes which are autoclavable.

Spinal needles.

Needles for local anesthesia. The following assortment is recommended: short, fine gauge (0.45 x 16 mm) for intradermal injection; medium, fine gauge (0.65 x 30 mm) for subcutaneous injection; long, small gauge (0.8 x 100 mm) for infiltration anesthesia. Also recommended are standard needles for intramuscular injection.

Headlamp or flashlight. For emergency operations at night.

Gloves.

Tools for equipment repair

Combination pliers. (Leatherman or similar)

Sharpening stone. (for scalpel blades and needles)

Restockable supplies

Betadine. (for spinal anesthesia prepping)

Alcohol and cotton. (for IV skin or local infiltration prepping)

IV catheters.

Saline.

Tape.

Safety Issues

The Golden Rules of Anesthesia

Do a preoperative assessment. Patients with conditions such as sepsis, hypovolemia, anemia, heart disease, and diabetes have higher operative morbidity. Most patients in the developing world will not have a well documented chart, nor are full chemistry and hematology panels always feasible. Therefore, the physical exam becomes the most important screening tool for detecting potential risk factors for high surgical morbidity. The risk of operation can often be lowered by treatment in preparation for anesthesia. If the patient is a particular anesthetic risk, try to ascertain this before induction.

When possible, operate on a fasted patient. Aspiration is always possible. However, the risk of not operating is sometimes worse than the risk of aspiration, so the fasting rule is not an absolute one. For patients who must be operated on with full stomachs, pretreatment with antacids can reduce the morbidity of aspiration since acid is worse than neutral aspiration.

The American Society of Anesthesiologists makes the following recommendations for preoperative fasting durations:

Age group	Solids and nonclear liquids	Clear liquids
Adults	6-8h	2-3h
Children >36 months	6-8h	2-3h
Children 6-36 months	6h	2-3h
Children >6 months	4-6h	2h

Unless contraindicated, children should be offered clear liquids up until the recommended period of fasting to minimize the risk of volume depletion and hypoglycemia.

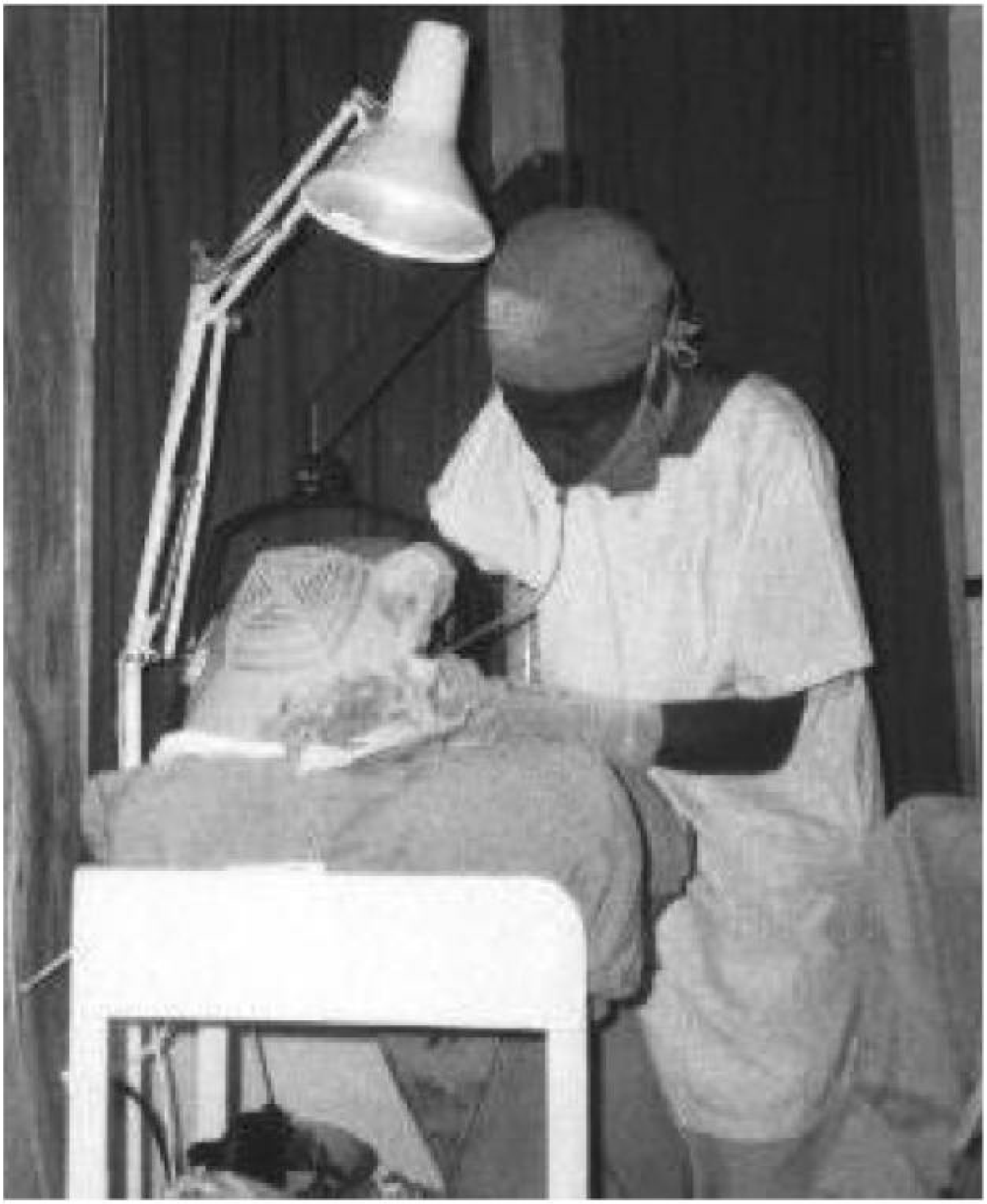
Use a table that can be rapidly placed head down (Trendelenberg position). This follows from the previous rule. If a patient should vomit during anesthesia, dramatic and immediate measures should be taken to prevent aspiration. The patient should be quickly rolled onto one side and the head of the table tipped down, using gravity to facilitate exit of vomitus from the airway and pharynx.

"When a patient vomits. roll him to the side, drop his head downward, and suction his oropharynx immediately."

Patients who have received spinal anesthesia should never be placed head down, even if shocked. (For other patients, there is some debate whether the Trendelenberg position actually helps anyone who is hypotensive.) The reason is that further shock and respiratory failure may rapidly ensue if the spinal anesthetic agent is allowed to bathe the upper spinal cord during a head-down maneuver.

Have suction instantly ready. This is the third step in a sequence which should be memorized so that it is both instinctive and immediate when the anesthetized patient vomits: roll him sideways, drop his head, and suction his oropharynx.

Figure 6 *Infant suctioning.*



Check equipment before starting.

Keep the airway clear.

Be ready to control ventilation.

Have a vein open. This is normally done when intravenous anesthesia is used. It is vital in spinal anesthesia, due to commonly observed sympatholytic-associated hypotension. It is less important in children undergoing intramuscular ketamine anesthesia. If intravenous access is warranted, it can be performed in these children after the anesthetic effect has begun, to reduce their discomfort.

Monitor pulse and blood pressure. This is particularly important for children and patients undergoing spinal anesthesia since both groups may decompensate rapidly. The best monitor is a person dedicated to the task, who listens to the patient's heartbeat and respiration simultaneously by means of a monaural stethoscope taped over the patient's left chest.

Always have someone who can apply cricoid pressure (Sellick's maneuver). When intubation is performed, cricoid pressure should begin when the first sedative agent is injected and should not be released until confirmation of proper tube placement has been completed. If, however, a patient actively vomits, the roll, head drop, suction maneuver should be immediately performed, and cricoid pressure gently released simultaneously, in order to prevent esophageal rupture.

Figure *7 Cricoid pressure. With permission.*

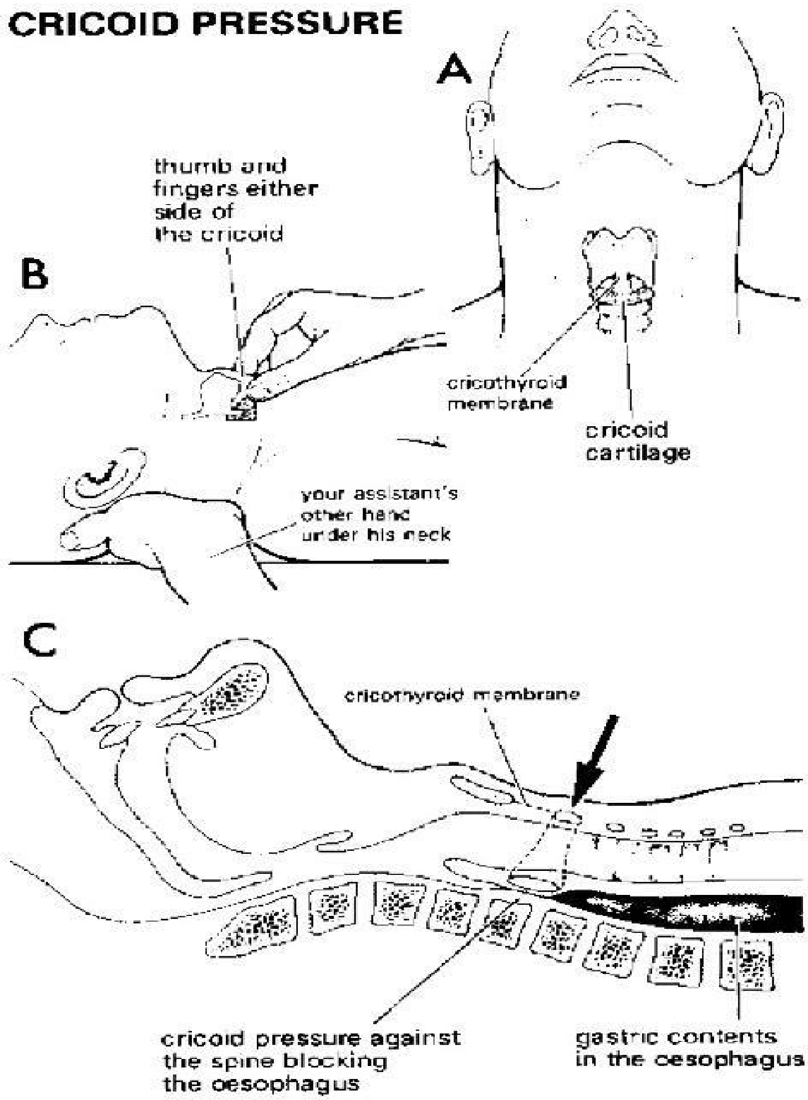


Fig. 16-4 CRICOID PRESSURE. This is one of the most life—saving methods in anaesthesia. Your assistant must know where the cricoid cartilage is, and press it from the moment induction starts, until the cuff is inflated. *Kindly contributed by Michael Wood.*

Recover in recovery position. When the operation is complete, place the patient in recovery position to avoid aspiration while wakening. Recovery position is essentially the same as the roll, head drop maneuver, but is performed prior to vomiting. All post-operative patients should awaken on their sides in the recovery position.

Figure 8 *Recovery position. With permission.*

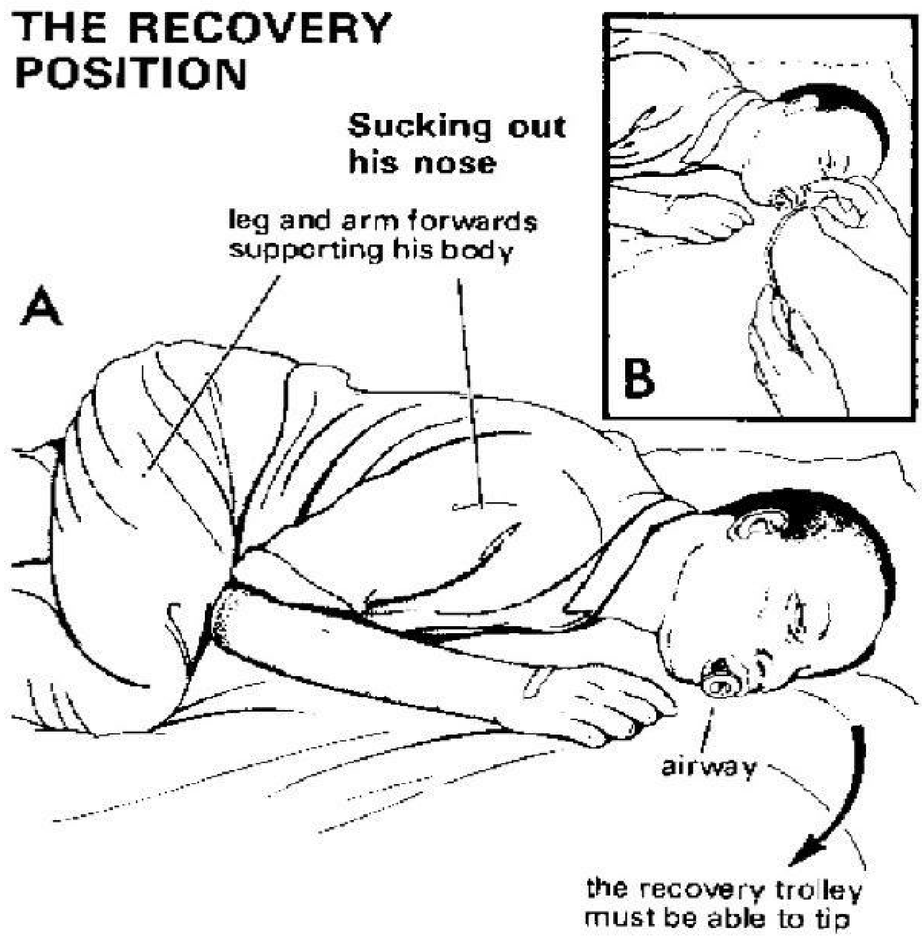


Fig. 4-5 A, THE RECOVERY POSITION is the only safe one for a patient on the trolley on his way to the ward, and in his bed when he gets there. Show your nurses how to place an unconscious patient on his side, with his uppermost arm and leg supporting his body. This position helps to keep his airway clear, it allows his tongue to fall forwards, and it lets blood and secretions drain from his mouth. B, sucking out his nose. Pinch one of his nostrils shut while you suck through the other.

Kindly contributed by John Farman.

Signs of good anesthetic practice

Anesthetized patients are never left alone on the table. They are always monitored by a competent person, before, during, and following operation.

A well-labeled resuscitation tray with a supply of medications is always available.

Figure 9 *Resuscitation equipment should be kept in the operating theater.*

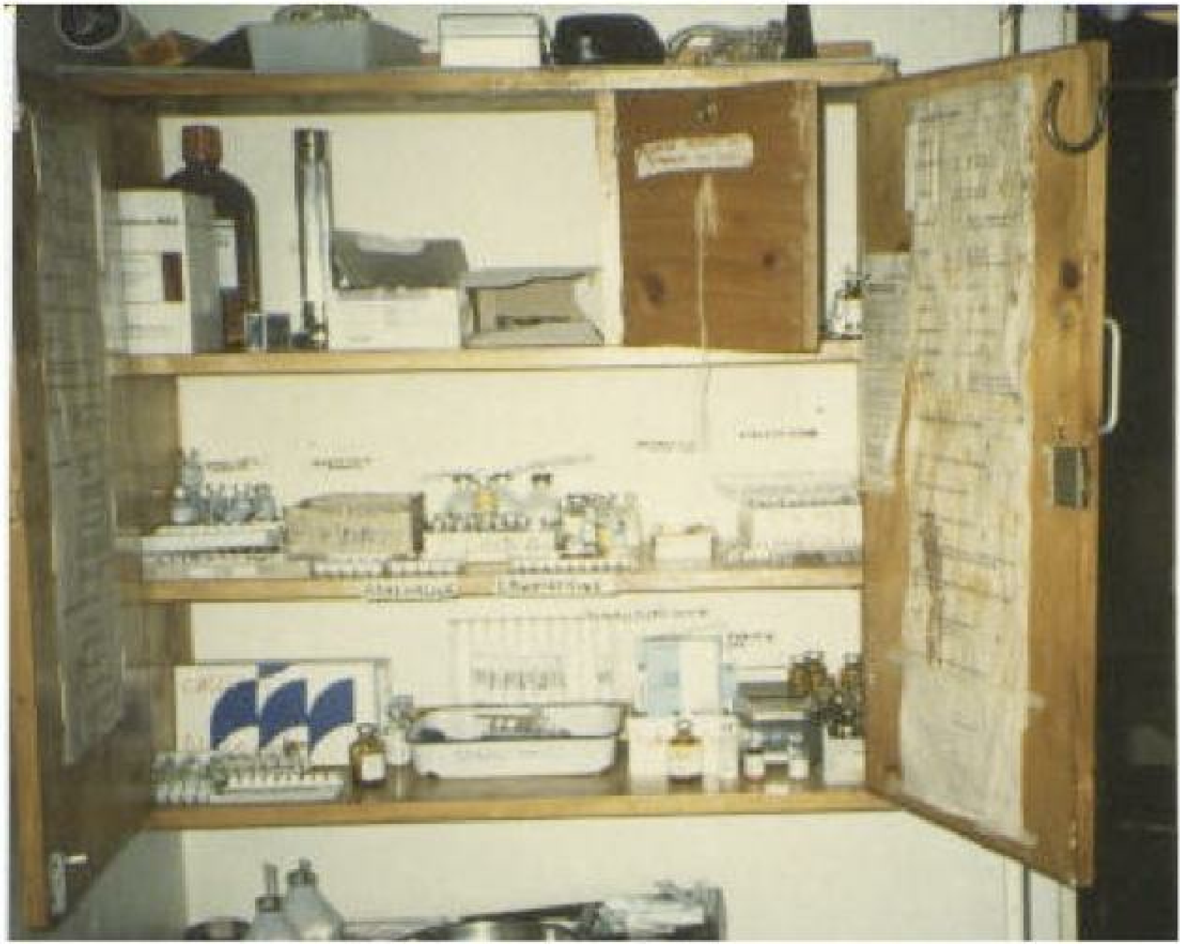


__Figure 10__ Resuscitation medications packaged in a home-made kit for the on-call physician.

When a bottle or bag of intravenous fluid is empty, it is either replaced or removed. If there is a strip of paper down the bottle or bag marking where fluid should be each hour, care is likely very good. Empty drips hanging over a patient's bed are a sign that the management of fluid therapy is poor.

Anesthetic records are kept. Mishaps are discussed constructively in order to prevent future ones.

All anesthetics are given on a table that can be tilted head down in an area where suction is immediately available.

Figure 11 *Safe recovery. With permission.*

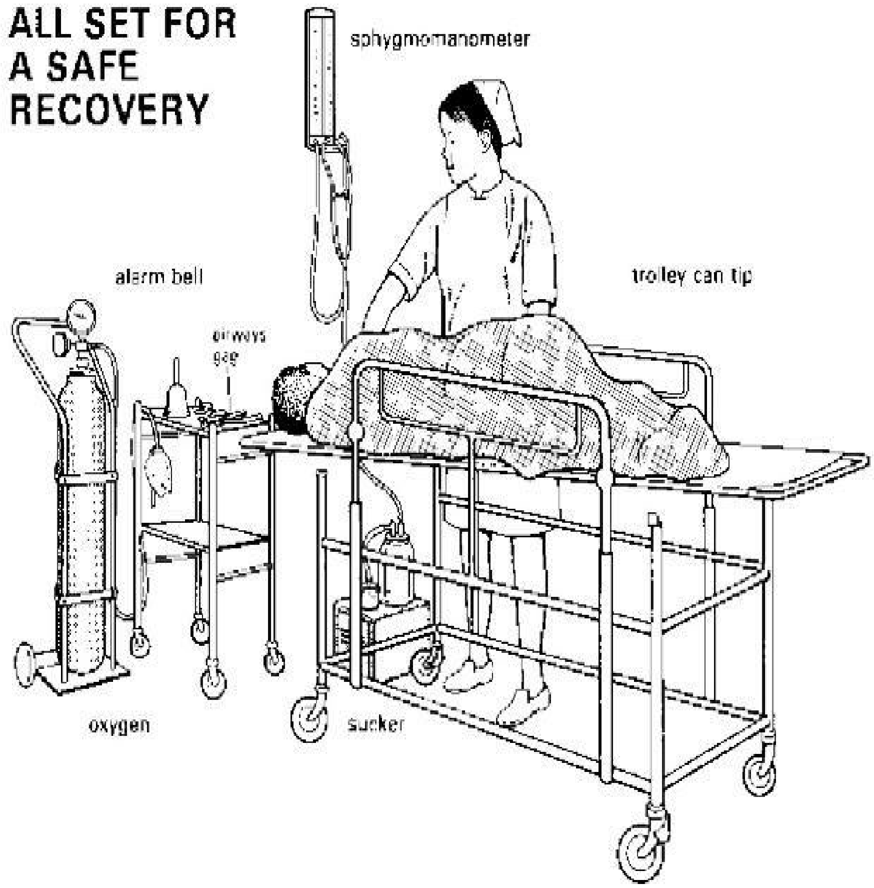


Fig. 4-6 **ALL SET FOR A SAFE RECOVERY** on a trolley which has sides and can tip. There is an oxygen cylinder and a mask, a bell to summon help, a sphygmomanometer, and a sucker. *Kindly contributed by John Farman.*

Local and Regional Anesthesia

methods: Local Anesthesia

Two percent plain lidocaine is inexpensive and can be diluted to other strengths and supplemented with epinephrine for most needs. Multi-use vials can also be autoclaved if sterility after prolonged use is a concern. More concentrated solutions are needed for nerve blocks while solutions as dilute as 0.25% are effective for infiltration anesthesia.

To make 0.4% lidocaine with epinephrine (a solution favored by some hospitals for large-volume infiltration anesthesia), add 20 ml of 2% plain lidocaine to 80 ml sterile saline. Supplement this with 0.5 ml of 1:1,000 epinephrine solution (0.5 mg). This results in an epinephrine dilution of 1:200,000 in 100 ml of 0.4% lidocaine solution.

Injection of lidocaine is painful. The nerves most sensitive to pain are located in the dermis, so intradermal injection is more painful than subcutaneous injection. Pain can be minimized by placement of the needle tip first rapidly through the skin surface, then moving the needle to a desired injection site. Finer needles, slower injection rates, and solutions buffered with bicarbonate (about 1 part standard 8.4% bicarbonate to 10 parts lidocaine) reduce the pain of injection.

Unlike intramuscular injection, for local skin and subcutaneous anesthesia, one needs not withdraw on the syringe plunger to check for intravascular placement of the needle tip. This is usually painful for the patient due to extra needle motion. Further, superficial intravascular injections are usually of no clinical consequence due to the amount of injected agent and size of vessels.

When injecting local anesthesia, use the finest needle available that will not break during injection. The length of the needle should be chosen to minimize need for repeated injections through the skin. For best control of the injection rate, needles should be fitted to the smallest syringe able to contain the desired volume for infiltration.

Inject while pushing the needle forward (as well as when withdrawing the needle) in a gentle fluid motion. Bending a longer needle so that it remains parallel to the skin during injection makes injection in the correct plane easier. Ideally, a patient should feel only a single needle prick per wheal. Whenever possible, subsequent injections should be performed through skin that has already been anesthetized.

The method for local anesthesia is basic. Swab the skin to be anesthetized with an antiseptic solution. Next, inject a small amount of lidocaine solution into the intradermal skin using the finest needle and smallest syringe necessary. The wheal should look like a properly placed tuberculin skin test. Draw up a larger portion of solution and attach a needle long enough to inject, if possible, the entire length of the skin to be anesthetized. Bend the needle appropriately to allow injection to parallel the skin surface. Puncture the skin through the initial wheal, and direct the needle as close to the surface of the skin as possible. Inject the solution in a slow fluid motion while pushing the needle tip forward along the desired skin tract. Proper infiltration will give the skin an "orange peel and sausage" appearance. Withdraw the needle, injecting supplemental solution as needed to finish the sausage-like tract. Finally, and without withdrawing the needle from the skin, inject again in a slightly deeper subcutaneous plane. Properly done, this will create a second broader and deeper tract beneath the superficial one.

The most pain-sensitive cutaneous nerves lie in the dermis, and a common difficulty is being unable to inject as superficially as desired. If this occurs, wait a bit longer before cutting. Subcutaneous injection will eventually block the dermal nerves, but the latency period for effect is longer than in dermal injection.

Figure 12 Local anesthesia. With permission.

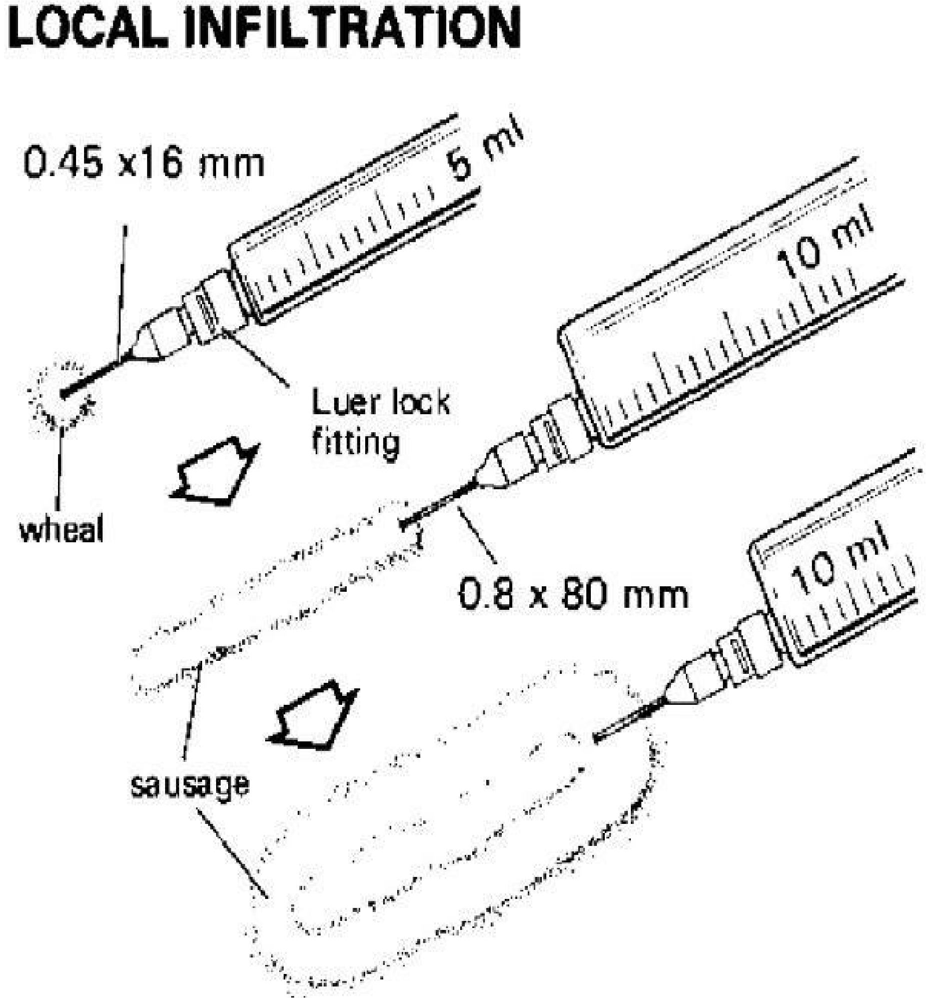


Fig. 5-2 LOCAL INFILTRATION. Raise a wheal and then insert your needle through it. *Kindly contributed by Peter Bewes.*

Field blocks

An alternative to simple infiltration anesthesia is the field block. This is most useful for blocking sensation to a large patch of skin, where local infiltration would require multiple smaller injections. Field blocks work well for abscess incision and drainage, for excision of small skin lesions, and for repair of complex lacerations. If done properly, the patient feels only two pricks.

As illustrated in the diagram, the field block consists of two intradermal wheals placed at opposite corners of an imaginary diamond surrounding the patch of skin to be anesthetized. Through one wheal, a longer needle is placed and a longer deeper wheal is raised, as described above, to form one side of the diamond. The process is repeated by withdrawing the needle without exiting the skin, and redirecting it forward to form the second side of the diamond. Through the opposite intradermal wheal, the entire process is repeated, so that four sides of a diamond are obtained, each intersecting another, and a complete boundary of skin anesthesia is thus placed around the patch to be anesthetized.

Figure 13 *Field block. With permission.*

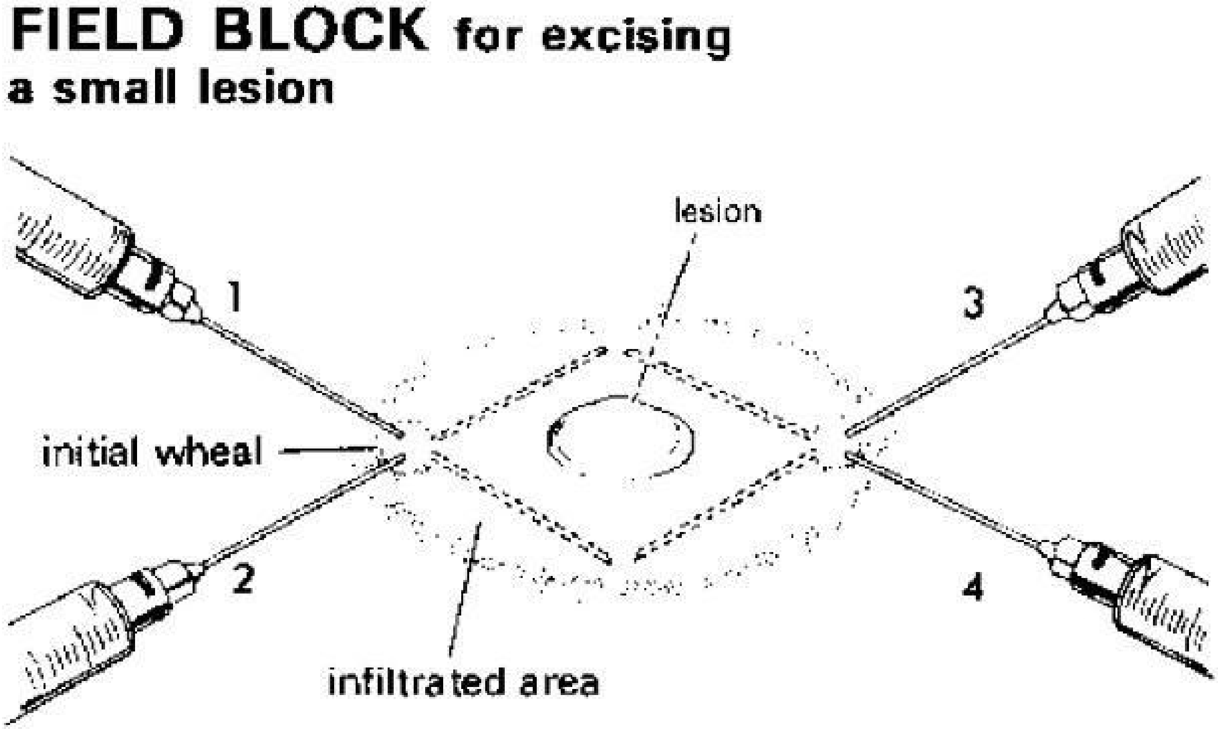


Fig. 5-3 EXCISING A SMALL LESION UNDER LOCAL ANAESTHESIA. Make wheals at either end and insert your needle through them in diverging directions. *Kindly contributed by Peter Bewes.*

Local instead of general anesthesia

Local anesthesia is always the safest technique, particularly when a patient's stomach is not empty. It requires little equipment and obviates concerns about the patient's airway. However, its limitations include the finite amount of local agent which is safe to inject, the inability to inject through infected tissue, and the difficulty of its use on children and anxious patients. Supplement local anesthesia with oral or intravenous anxiolytic agents when necessary for the patient's comfort and surgeon's safety. These can be given before and supplemented intravenously during the operation as needed. Examples of premedication include oral or injectable promethazine, diazepam, morphine, and low-dose intravenous ketamine (0.25 mg/kg).

Although blocking cutaneous nerves through local infiltration successfully eliminates most incisional pain, it does not provide muscle relaxation. Thus, regional intercostal blocks, rectus muscle blocks, or spinal anesthesia may also be required.

Several common operations can be performed under local anesthesia. These include caesarean section, ventral and inguinal herniorraphy, and abscess incision and drainage. Of these, local anesthesia for caesarean section should be avoided if the surgeon is first learning to perform the procedure, as muscle relaxation is more difficult when compared to spinal anesthesia. (See chapter on Special Considerations: Obstetrics at the end of this manual for a more detailed discussion about caesarean section anesthesia.)

The intercostal block

Block of the ninth through twelfth intercostal nerves is an alternative method for muscle relaxation in the patient dissociated with ketamine or undergoing abdominal operation with local infiltration. This procedure seems simple, but often fails for novices, so more detailed discussion is left out of this text. It cannot be done quickly, so is not ideal for emergency caesarean section. It also must be performed with great care, in order to prevent pneumothorax, a potentially fatal complication if unrecognized. Higher blocks using this method can also be used for other abdominal operations, but at the risk of respiratory compromise if too many intercostal muscles are paralyzed.

To perform this block, use 3 ml of epinephrine-supplemented 1% lidocaine per injection. Use a small rubber drain on the needle to mark the depth of injection. Palpate the ribs anywhere from the paraspinous muscles to the posterior axillary line. Push the needle through the skin and walk it down the inferior surface of each rib to be blocked. Adjust the rubber drain on the needle so that the needle cannot be inserted more than 5 mm deeper than the point at which the needle touches the rib. Once the needle passes the inferior aspect of the rib, aspirate (to ensure the tip is not in an intercostal vessel), and inject the solution. Allow 10 minutes for the block to take effect.

Inguinal herniorraphy block

This involves infiltration of the skin over the site to be incised, followed by deeper infiltration of the parietal peritoneum and hernia sac once exposed. The technique uses up to 100 ml of epinephrine-supplemented 0.4% lidocaine and gives the surgeon an advantage, since the patient is able to demonstrate the hernia during the operation by coughing. Preparation of 0.4% lidocaine solution is discussed in the General methods section above.

After raising two intradermal wheals at either end of the planned incision, infiltrate the entire length of the site with both intradermal and deep subcutaneous lidocaine. Next, at both ends of the incision site, inject lidocaine in a fanlike distribution just deep to the fascia of the abdominal musculature. The needle should pass through the fascial layer with a palpable pop. Leave about 15 ml of anesthetic solution for the neck of the sac and wait at least 5 minutes for the initial anesthesia to take effect.

When the hernial sac is located, inject the remaining solution around it to anesthetize the visceral peritoneum before ligation.

Figure 14 *Hernia block. With permission.*

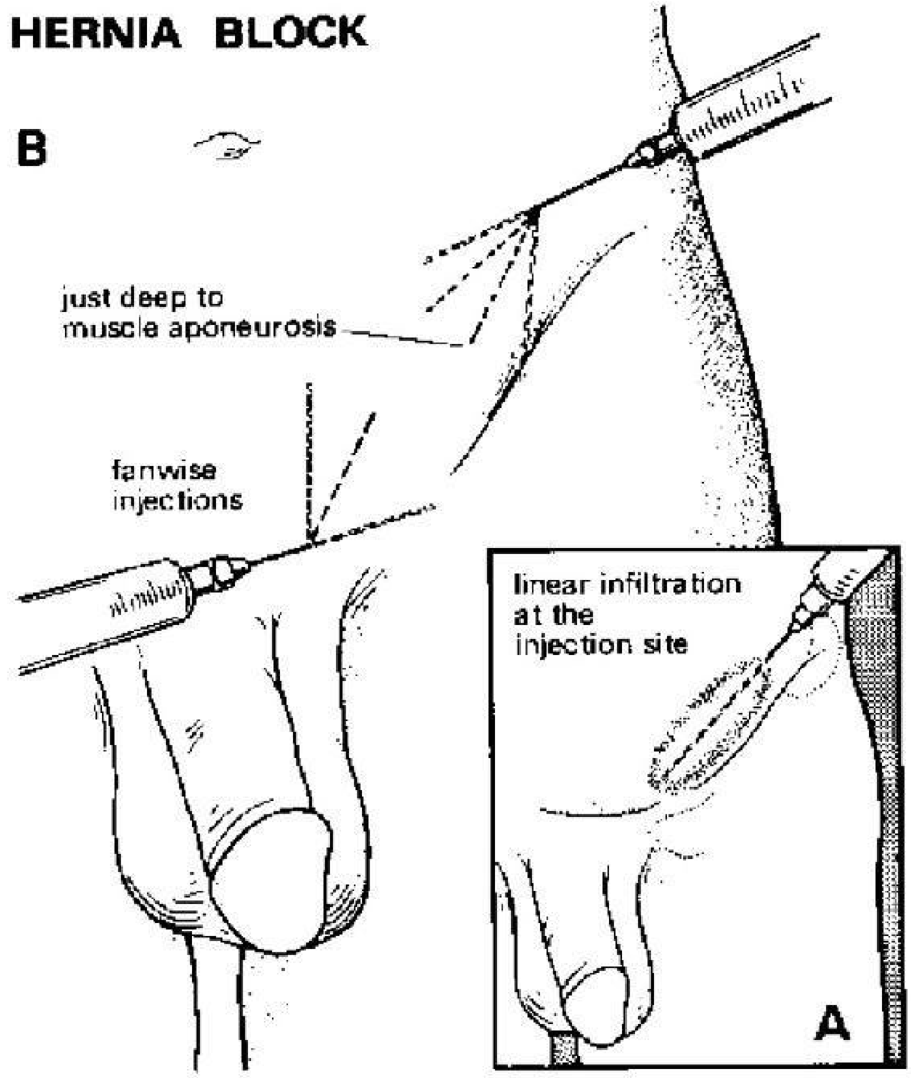


Fig. 6-12 HERNIA BLOCK. You can use this for unstrangulated and strangulated inguinal hernias, and for a femoral hernia. For a femoral hernia you will also have to infiltrate the neck of the sac.

Kindly contributed by Peter Bewes.

Safe dosages

The maximum safe dose of plain lidocaine is 3 mg/kg, or 200 mg total for adults. This safety margin is roughly doubled if epinephrine-supplemented lidocaine is used instead of plain. Lidocaine toxicity is rare and is usually preceded by a metallic taste. It causes central nervous system effects such as seizures. Treatment of toxicity consists of anticonvulsant therapy and support of vital functions.

For adults, these considerations are only important when large doses of lidocaine are used, such as in local infiltration of the abdomen for caesarean section, when general or spinal anesthesia are contraindicated. Such infiltration may require 100 ml or more of local anesthesia solution.

Each percent of solution equals 10 mg/ml of actual agent (or 1 g/100 ml). Thus, 1 ml of 1% solution contains 10 mg of lidocaine and 1 ml of 2% solution contains 20 mg of lidocaine. For a 50-kg woman, 150 mg of lidocaine is the amount contained in only 7.5 ml of 2% of the solution. Injecting 100 ml of 2% solution would give the patient 2,000 mg of lidocaine, more than a dozen times the safe dose.

Such considerations now become obvious for children, who weigh much less than pregnant women. The maximum safe lidocaine dose for a 20-kg child needing repair of a large scalp laceration is 60 mg, the amount of lidocaine contained in only 3 ml of 2% solution. This amount may not be enough to properly anesthetize an area for repair or incision. Thus, the solution must either be diluted, or epinephrine-supplemented solution used, or both.

In the case of the 20-kg child, 60 mg of lidocaine is also contained in 12 ml of 0.5% solution, which for infiltration is as effective as 2%. If epinephrine-supplemented 0.5% solution is used, the maximum safe dose is doubled to 120 mg, and 24 ml of solution can be safely injected, provided that epinephrine can be safely used at the injection site.

Pain Management

"Pain should be considered a medical or surgical emergency, and, as such, ought to be treated as aggressively. We have not been taught this principle, and we often do not, by precept and example, convey it to our students and colleagues. It also appears that we do not practice it. In every major study done to evaluate the management of pain in the hospital setting, our methods of pain relief have been 'weighed in the balance and found wanting.'"

Paris PM, Stewart RD: Pain Management in Emergency Medicine. Appleton & Lange, 1988.

Simple oral analgesics

Despite a multitude of oral analgesics marketed in the developed world, acetominophen and non-steroidal agents are still standards. Both are inexpensive, well understood, and have wide safety margins. Outside the United States, acetominophen is known as paracetamol, and is widely marketed under the brand name, Panadol.

Of the non-steroidal class, ibuprofen and diclofenac are the least expensive, are widely available, and have the least potential for causing gastrointestinal hemorrhage. Outside the United States, diclofenac is available over-the-counter, and is widely marketed under the trade name, Voltaren. Both diclofenac and aspirin are available in many countries as intravenous agents, and can also be used as antipyretic agents for febrile patients who are unable to take oral medications.

Opiate analgesics

The prototype opiate analgesic is morphine. The major distinction between opioid agents lies in relative potency rather than mechanism of action. One minor distinction rests in the relative degree of histamine release caused by the different agents. Histamine release may lead to bronchospasm, hypotension, vomiting, and urticaria. Morphine, for example, causes slightly less histamine release than meperidine, but both cause much more than fentanyl.

Morphine is most commonly given by intramuscular or intravenous injection. A starting intramuscular dose is 0.1 mg/kg, about 7 mg in an average adult. Small but frequent intravenous doses titrated to effect are more effective than larger infrequent intramuscular doses. The starting dose for intravenous morphine is roughly a quarter the intramuscular dose, 0.03 mg/kg (2 mg in an average adult), titrated to effect. Maximum dose is 0.5 mg/kg, though some patients are tolerant and require more.

Meperidine is similar to morphine but has approximately ten times less potency. It is mentioned here as an alternative to morphine, due to broader availability in some regions. Outside the United States, meperidine is known as pethidine. A starting intramuscular dose of meperidine is 1 mg/kg, about 70 mg in an average adult. The starting dose for intravenous meperidine is 0.25 mg/kg titrated to effect.

When combined with diazepam, both morphine and meperidine may cause apnea. Apnea is also possible if high doses of each agent are given alone, but is much more of a risk when used in combination with a benzodiazepine. To prevent such occurrences in anesthesia of this type, the minimum dose of opioid should be used, carefully titrated with diazepam to effect. In some centers, combination diazepam and meperidine sedation is used routinely for dilation and curettage procedures, and when this is done, appropriate monitoring of the patient is needed.

When performing combination sedation with diazepam and either morphine or meperidine, always give the opioid first through the intravenous line. Diazepam is painful to inject, and this pain can be moderated by injecting the analgesic agent first.

Ketamine for analgesia

In areas where morphine is expensive or not widely available, patients suffering severe pain, as from cancer or multiply fractured ribs, can receive ketamine by low dose infusion. This method is identical to ketamine infusion for anesthesia, described later in this manual, but is dosed at a rate low enough so only analgesic effects of ketamine are obtained.

To infuse ketamine for analgesia, first give a small bolus (0.25 mg/kg) of ketamine intravenously, titrated carefully to eliminate pain but not produce dissociation. Next, hang a solution of 0.5 mg/ml ketamine in saline to run at about 15 to 30 drips per minute, using a non-microdrip chamber (15 drops/ml). Titrate the solution to maintain analgesia.

Figure 15 *This girl received multiple dressing changes for a painful hand burn under ketamine analgesia without dissociation (2 mg/kg IM).*

General Anesthesia in the Field Setting

"In developing countries, the surgeon is often confronted with situations in which surgery is required urgently but in which neither anaethesiologist nor trained anaesthetist is available. In some instances, the surgeon may resort to conduction anaesthesia in its varying forms, eg spinal, nerve block, or local. In many cases, however, conduction anaesthesia is neither appropriate nor available. Often the demands on the time of the surgeon and the comfort of the patient are better serviced if the patient can be put to sleep."

Ketcham DW: Where there is no anaesthesiologist: the many uses of ketamine. *Tropical Doctor*. 1990.

There are times when local anesthesia is not appropriate for surgery. The operation may require muscle relaxation, the patient may be anxious, or the field of operation may be too large to safely anesthetize with local agents. In these situations, three methods are commonly used in resource-scarce regions: dissociative anesthesia with ketamine, spinal anesthesia by epidural or subarachnoid routes, and inhalation anesthesia. In certain cases, muscle paralysis is often added using long-acting intravenous nondepolarizing agents, or in particularly resource-scarce regions, the short-acting depolarizing agent, succinylcholine.

Epidural and inhalation anesthesia are beyond the scope of this discussion due to their increased complexity and equipment requirements. Both ketamine and spinal (subarachnoid) anesthesia are discussed in detail below. The use of neuromuscular blocking muscle relaxants is not complex but is unsafe for the inexperienced, due to increased possibilities of aspiration and asphyxia. It is, however, within the scope of the practitioner experienced in advanced airway management, who is skilled in both intubation and rescue cricothyrotomy. Use of muscle relaxants makes fine operations (such as thyroidectomy) and all abdominal operations much easier for the surgeon. In a few cases, surgery would be impossible without such relaxation. Therefore, a brief discussion of use and methods follows the sections on ketamine and spinal anesthesia.

KETAMINE

"Ketamine produces a most useful state of dissociative anaesthesia. The patient rapidly goes into a trance-like state, with widely open eyes and nystagmus. He is unconscious, amnesic and deeply analgesic. His airway is remarkably preserved, with his head in almost any position, far more so than with any other anaesthetic. Not surprisingly, this remarkable drug has made many operations possible that would otherwise have been impossible for lack of a trained anaesthetist. Ketamine is especially useful if you have no recovery ward and patients have to recover in their own beds. Ketamine is remarkable safe and is certainly the safest anaesthetic if you are inexperienced. Nevertheless, it is not absolutely safe, so be vigilant. In some hospitals without a trained anaesthetist, 90 percent of the operations are done with ketamine. Intramuscular ketamine acts rapidly. You can also give it intravenously as a bolus injection or as a drip, either alone or with relaxants."

"Dissociative anaesthesia and intravenous analgesia," in Primary Anaesthesia, King M (ed.): Oxford University Press, 1990.

"Nothing in my wildest dreams of minimal equipment ever approached the simplicity and safety of the ketamine technique under these true test conditions…"

Spoken by anesthesiologist Roy Wilson shortly after the Guatemala earthquake of 1976, when he and a second anesthesiologist administered IV ketamine to facilitate 150 unintubated surgical cases over a 36-hour period. Monitoring consisted of only visual observation with infrequent blood pressure measurements. Wilson RD, quoted in Corssen G, Reves JG, Stanley TH: Intravenous anesthesia and analgesia. Philadelphia, Lea & Febiger, 1988.

***Figure 16** Radical mastectomy under ketamine IV drip.*

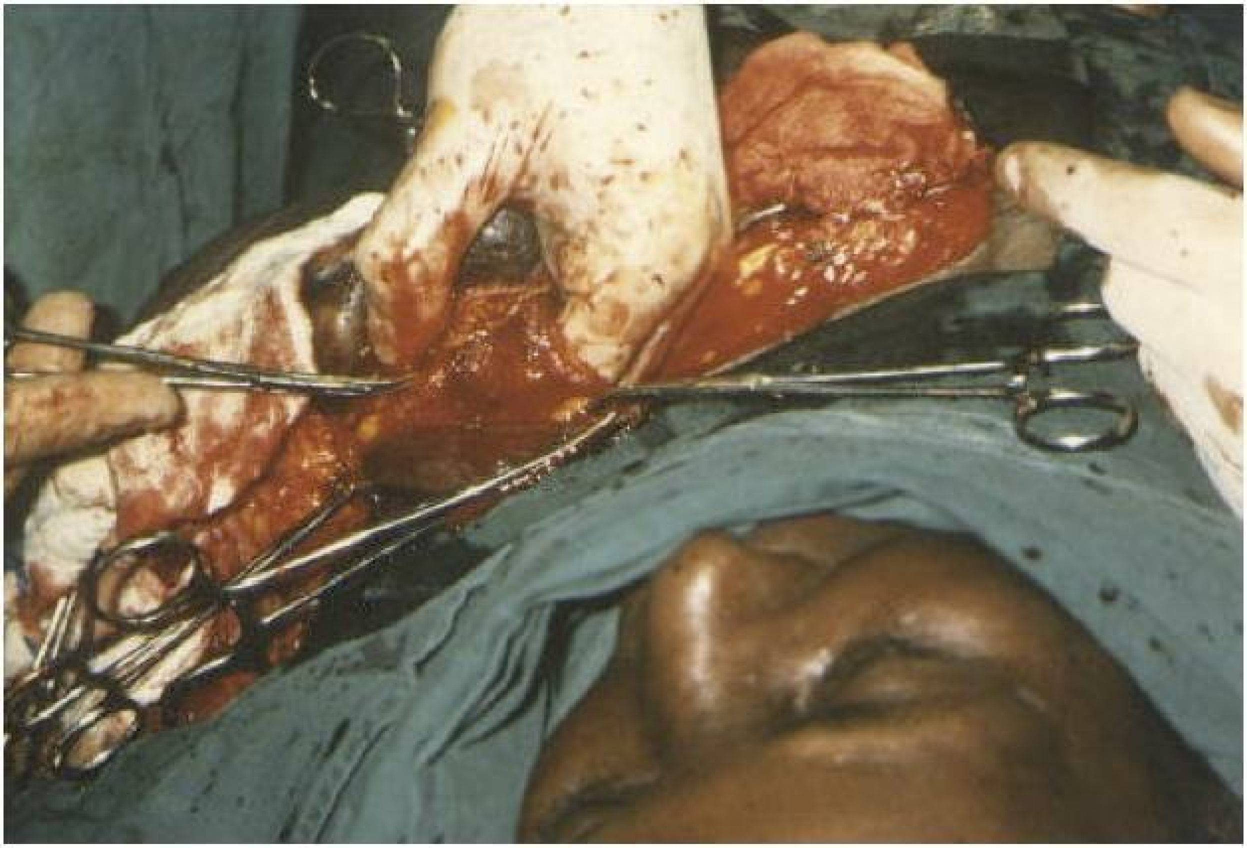


***Figure 17** A typical dissociative state. This child received multiple hand debridements under IM ketamine anesthesia.*

Characteristics of an ideal anesthetic agent

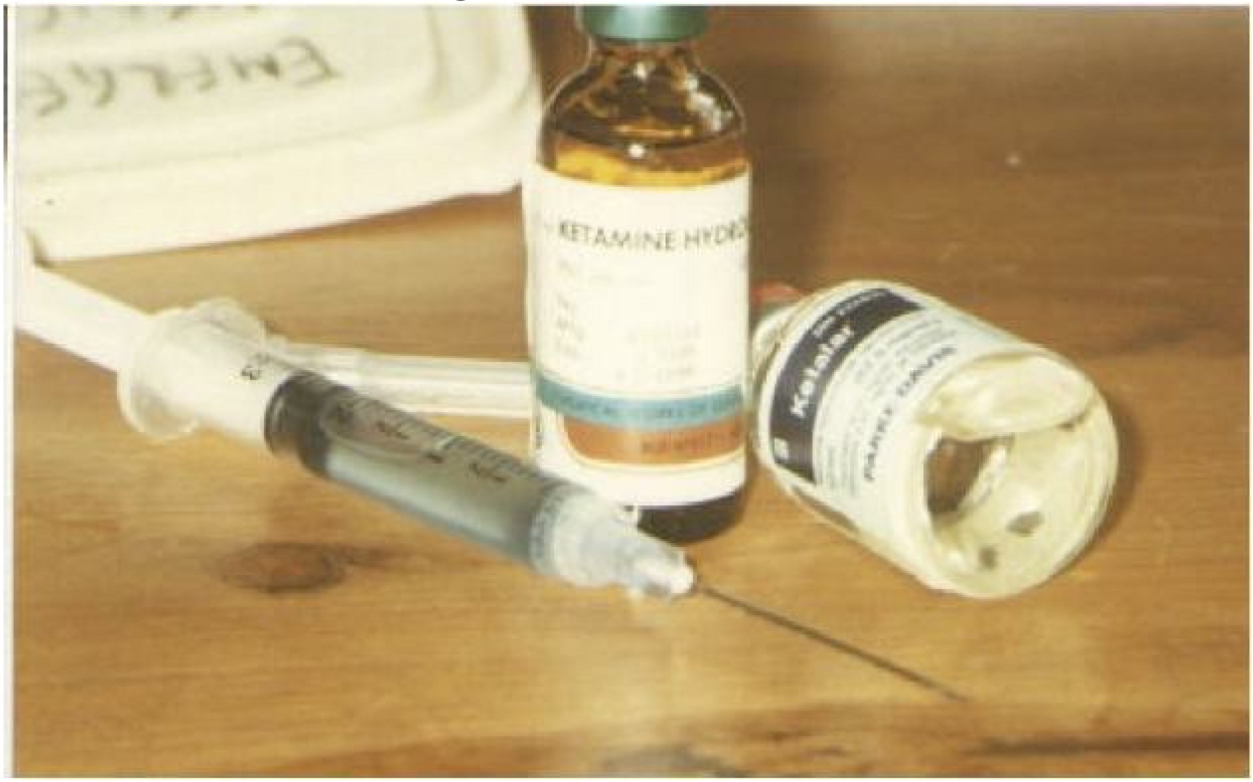
An ideal anesthetic agent has been described as one which provides effective relief from the anxiety, pain, and memory of an unpleasant procedure, while offering safety over a wide spectrum of clinical situations. In the parlance of anesthesia, this agent would provide dependable anxiolysis, analgesia, and amnesia at once. Since few such agents exist, combinations of drugs are most commonly used to achieve such goals.

This section describes an agent which closely represents the ideal for use in remote medical practice, for ketamine is unique in its ability to safely provide anxiolysis, analgesia, and amnesia simultaneously. Its effects are potent: analgesia is roughly double that of morphine and amnesia is on the same order as midazolam. Ketamine use obviates the need for local anesthetic infiltration during surgery or in wound repair. When given skillfully and in a calm environment, it is more often than not a pleasant experience for patients. It can be used safely without supplemental oxygen or intubation. It produces neither hypotension (except in severe states when catecholamine stores are totally depleted) nor respiratory depression (unless injected too rapidly), so is ideal for use in emergency cases when patients are in mild to moderate shock.

Ketamine's therapeutic range makes it one of the safest sedative agents for most emergency clinical situations. Distinct and useful effects are obtained when administered at different doses. Low dose ketamine infusion provides potent analgesia, making such useful in conjunction or in lieu of narcotics in areas with scarce resources. Low dose injection adds anxiolytic effects to analgesia, making it useful in performing minor procedures such as wound debridement and painful dressing changes for burn victims. In higher doses, amnesia and complete cognitive-corporeal dissociation is added, making it useful as a single agent for more complex but brief emergency procedures. In yet higher doses, the combination of effects makes prolonged surgical anesthesia possible. As such, ketamine may be used as a single agent for emergency surgery of nearly all types.

The bulk of clinical experience with ketamine comes from the developing world. In such countries, it is routinely and safely administered thousands of times daily by non-anesthetists operating in areas with few resources.

Figure 18 *Ketamine vials.*



Indications: Ketamine

Ketamine provides effective sedation for a wide variety of clinical procedures. Virtually any painful or otherwise anxiety-provoking procedure may benefit from its effects. In the developing world, where expense and availability of opioids are a concern, ketamine is used in patients with severe pain syndromes such as metastatic cancer or multiple rib fractures. It is commonly used to reduce the pain and anxiety associated with painful wound debridement and dressing changes. It is the recommended agent for field sedation in cases such as vehicle extraction at accident scenes and emergency amputations.

Other examples of common use include emergency orthopedic manipulations, incision and drainage of abscesses, facial procedures, operations on several sites at once where local anesthesia would exceed limits, face-down procedures, and emergency operations on hypotensive patients. Due to higher rates of laryngospasm with pharyngeal stimulation, it is not ideally suited for intraoral or airway operations, although in skilled hands it has been used successfully for dental procedures, tonsillectomy, esophagoscopy, and bronchoscopy.

Ketamine provides no muscle relaxation, so may make an emergency abdominal operation such as appendectomy or caesarean section more difficult. Nonetheless, ketamine has made possible many operations that would be otherwise impossible with no anesthetic, and is considered the agent of choice by many for emergency abdominal operations where the surgeon must also perform as anesthetist.

Figure 19 *An infant with approximately fifty abscesses, incised under ketamine IM anesthesia.*

Figure 20 *Incision and drainage of thigh abscess under ketamine.*

Figure 21 *An orthopedic operation done under IV bolus ketamine.*

Figure 22 *Another orthopedic operation done under IV bolus ketamine.*

Premedication?

Some clinicians routinely premedicate all patients with promethazine or a benzodiazepine to reduce post-procedure agitation, though this may prolong the recovery period. Promethazine is widely used in Africa for adult premedication, and may have some advantage over the benzodiazepines due to its additional antiemetic effects, though controlled studies are lacking. Ketamine may be combined with an antisialogogue to reduce its stimulant effect on oral and respiratory secretions. Either glycopyrrolate, in a dose of 0.01 mg/kg (maximum dose 0.2 mg) or atropine, in a dose of 0.01 mg/kg (0.1 mg minimum to 0.5 mg maximum) are acceptable. Pretreatment 30 minutes prior to ketamine administration is best, but both glycopyrrolate and atropine may be mixed in the same syringe as ketamine if time is short. Some physicians forego the use of an antisialogogue (more often in adults), preferring ketamine-induced hypersalivation to the additional tachycardia caused by atropine or glycopyrrolate.

Basic methods: Ketamine

Overview. For children, intramuscular injection is usually the least traumatic method of obtaining effective sedation. Centers which mandate intravenous access for all sedative procedures may negate the benefit of ketamine's anxiolytic properties by requiring performance of a painful procedure (intravenous placement) before initiating sedation. Intramuscular injection alone has proven safe in large reviews. If intravenous access is mandatory, one technique which may preserve the goal of anxiolysis is to first administer intramuscular ketamine at an anxiolytic or greater dosage. Following effect, an intravenous line can be established without patient distress and any remaining doses of ketamine needed either by intravenous or further intramuscular administration can be given.

For adults, intravenous infusion is usually the safest and most easily titratable to effect. Infusion via this method further prevents rare apnea and laryngospasm most commonly observed with rapid and high intravenous bolus doses of ketamine. Dissociation by ketamine infusion usually requires less agent for longer procedures and greatly reduces recovery time.

Intramuscular method. This is usually dosed initially at 4 mg/kg (with a range of 0.5 to 17 mg/kg, reported in the literature, depending on procedural requirements). Analgesia alone is usually obtained with a dose of 1 mg/kg IM. Complete dissociation is usually obtained with a dose of 4 to 10 mg/kg IM. (Veterinarians routinely give 15 to 50 mg/kg IM to anesthetize animals for surgery.) Onset of action (glazed eyes and nystagmus) is usually within 5 minutes and lasts for up to 30 minutes, depending on the dose used. Before beginning any painful procedure, analgesic effect should be tested by pricking the patient with a needle. Booster doses of 2 to 5 mg/kg IM every 10 minutes (without additional antisialogogue) may be given if initial sedation is inadequate. The 100 mg/ml ketamine solution is preferred for intramuscular administration, to reduce the volume of injected solution.

Figure 23 *A child with severe burns who has been given ketamine 10 mg/kg IM. Note the semi-open eyes, total analgesia, and absence of need for an airway. Facial burns would have made inhalation induction of anesthesia painful and difficult. This child received ketamine on many subsequent occasions for grafting. Reprinted with permission from Pryor WJ: A manual of anaesthetic techniques (4th ed). Chicago: Year Book, 1973.*

Intravenous (IV) infusion method. Mix ketamine with saline or D5W to make a 1 milligram ketamine to 1 milliliter solution (500 mg ketamine in 500 ml fluid). To prevent inadvertent overdosage, the total amount of ketamine mixed can be limited to the maximum safe dosage (3 mg/kg IV). Using a regular non-microdrip IV chamber (15 drops/ml), the IV is opened to flow at a rapid drop rate (about 2 drops/kg/min). Onset of action (glazed eyes and nystagmus) is usually within 2 minutes and lasts until 10 minutes after the infusion is terminated. Before beginning any painful procedure, analgesic effect should be tested by pricking the patient with a needle. Once sedation is deep enough, the drip is turned down to approximately half of the induction rate (1 drop/kg/min). It is stopped 10 minutes prior to the end of the procedure.

Figure 24 *Sarcoma excision under ketamine drip anesthesia.*

IV bolus injection method. This is the most commonly used alternative to the two methods described above. IV bolus ketamine is usually dosed initially at 1-2 mg/kg. If ketamine is the only anesthetic to be used, slightly more is required than if it will be used for induction alone. An average adult dose for routine anesthesia is 100 mg, though 50 mg may be sufficient for small adults, and 200 mg may need required for patients with obesity or chronic alcoholism. This should be given slowly, over a minute or two. Onset of action (glazed eyes and nystagmus) is usually within a minute. Surgical anesthesia lasts about 15 minutes with full recovery in about 60 minutes. As above, before beginning any painful procedure, analgesic effect should be tested by pricking the patient with a needle. Booster doses of ½ to 1 mg/kg IV every 10 minutes (without additional antisialogogue) may be given if initial sedation is inadequate. The maximum dose for routine use, except in alcoholics who may require much more, is 3 mg/kg. The more dilute 10 to 50 mg/ml ketamine solutions are preferred for intravenous administration. Injection should be done slowly to avoid rarely observed ketamine-induced apnea.

IV drip with muscle relaxants. This is used to facilitate caesarean section and abdominal surgery when muscle relaxation is helpful and is has also been discussed previously.

If the only paralyzing agent available is succinylcholine, intubate with the minimum amount necessary for adequate paralysis (25 to 75 mg in average adults). Following intubation, ventilate with room air or low flow oxygen (1 liter/min).

Paralysis can be maintained with a long-acting nondepolarizing paralytic agent or with continuous succinylcholine infusion. In paralyzed patients, sedation can be maintained with half the normal ketamine infusion rate (half drop/kg/min). As mentioned previously, when succinylcholine infusion is used, paralysis should never exceed an hour and should ideally be restricted to procedures requiring 20 minutes or less to keep the total dose infused as low as possible.

Figure 25 *Amputation of gangrenous limb under ketamine drip anesthesia.*

Figure 26 *Appendectomy under ketamine IV bolus anesthesia.*

Recovery

The fear of the ketamine recovery experience should not preclude its use. Management of this period requires a certain finesse that separates the physician experienced in ketamine sedation from the novice. Because of the unique effects of dissociation, patients undergoing ketamine sedation experience a sense of semi-conscious bodily detachment as they awaken. During this period, imagination can be confused with actual environmental stimuli. Partially conducted stimuli may be interpreted as pleasant or noxious. Because of this, the physician has much control of the patient's recovery experience, and may positively direct this experience by simple and repeated suggestion, and by controlling the recovery environment. By the same mechanism, misinterpreted or noxious stimuli may cause patients to have a frightening recovery. During this period, physical contact, noise and stimulation should be minimized and caretakers should not to try to awaken the patient prematurely. Blood pressure monitoring during this period has been discouraged by some anesthesiologists, who note undue disruption of recovery from cuff stimulation. Recovery reactions are less frequently dramatic in pediatric and elderly patients. For patients who are recovering poorly, administration of any number of sleep-inducing agents during recovery is helpful. Patients at high risk for agitated recovery can be medicated prior to initiating the procedure. Such agents sedate the active but partially dissociated mind, blunting the confusion between imagination and reality. If such medication is used, promethazine is effective and provides antiemetic effects. Many developing world practitioners consider it the drug of choice. Benzodiazepines and haloperidol have demonstrated efficacy as well. Sedative agents are not essential for smooth recovery. Using reassurance alone, there were no unpleasant reactions in one series of adult ketamine sedation.

Figure 27 *Quiet room recovery.*

Safety issues

Ketamine is suitable for most age groups provided the physician supervising its use is versed in its age-related effects and contraindications. Emergence phenomenon are less common and, when noted, less pronounced in pediatric and elderly patients. Apnea is more frequently observed in children under 3 months of age. Potential transient side effects of ketamine administration include hypersalivation, muscle hypertonicity, clonus, stridor, emesis, rash, and agitation.

Ketamine is relatively contraindicated in cases with (1) airway instability or tracheal pathology (unless used with endotracheal intubation to provide a higher margin of safety); (2) high predisposition to laryngospasm or apnea (active pulmonary infection or age under 3 months); (3) a full meal within 3 hours (due to a higher aspiration risk); (4) severe cardiovascular or disease (angina, heart failure, malignant hypertension, due to ketamine's cardiostimulant effects, though this is argued); (5) cerebrospinal fluid obstructive states (severe head injury, central congenital or mass lesions, though this is argued); (6) intraocular pressure pathology (glaucoma or acute globe injury, though this is argued); (7) previous psychotic illness (due to potential activation of psychoses); (8) hyperthyroidism or thyroid medication use (due to the possibility of severe tachycardia or hypertension); and (9) porphyria (due to the possibility of triggering a porphyric reaction).

These relative contraindications are mostly unconfirmed by formal studies. In cases necessitating emergency sedation, ketamine's benefits may outweigh the risks listed above, particularly if substituting other sedative agents will bring greater risks. The literature demonstrates that ketamine has a safety profile which outperforms many other sedative agents making it the agent of choice for many potentially difficult emergency situations.

Spinal Anesthesia

Introduction

In many developing world hospitals, all abdominal operations are performed with spinal anesthesia. Spinal anesthesia involves injection of lidocaine (or similar agents) directly into the spinal canal in order to anesthetize the nerves passing through the subarachnoid space. Solutions of lidocaine mixed with dextrose are heavier than cerebrospinal fluid (CSF) and are therefore termed hyperbaric solutions. This property allows control of the level of anesthesia, since gravity pulls the heavier anesthetic solution through the CSF toward the spinal nerves lying below the point of spinal injection. By positioning a patient properly (using a tilting table), choosing the level of injection into the spinal canal, and altering the amount of hyperbaric lidocaine injected, a skilled anesthetist can consistently provide anesthesia and muscle relaxation at predicted spinal levels.

Spinal anesthesia is reliable in experienced hands, but not as safe as ketamine. However, its risks are less than those of paralysis and intubation. In one common use, caesarean section, a proportion of patients will become hypotensive due to its sympatholytic effects. This can be avoided by preloading patients with saline prior to anesthesia. If this fails, hypotension can be treated with ephedrine or other alpha-agonist agents. Rarely, a patient will become both hypotensive and apneic if anesthesia ascends to block the intercostal high thoracic levels. If a high block is recognized early and steps are taken to support both vasodilation and respiratory depression, the patient is safe. However, this requires vigilance and preparation ahead of time; unrecognized, it will prove fatal. For these reasons, spinal anesthesia should never be used in patients who are in shock prior to operation or when intravenous fluid is unavailable.

Spinal anesthesia with lidocaine provides paralysis and paresthesia for approximately an hour. If bupivacaine is used, anesthesia is prolonged to 3 hours.

Equipment for spinal anesthesia must be sterilized, by either autoclaving or boiling. Boiling, however, is not safe at elevations above a thousand meters. At these altitudes, if an autoclave is not available another anesthetic method should be used instead. Chemical sterilization is dangerous due to inadequate removal of bacteria and previous cases of neurologic damage from inadvertent injection of the sterilizing fluid.

Figure 28 *Sterile safety sign.*

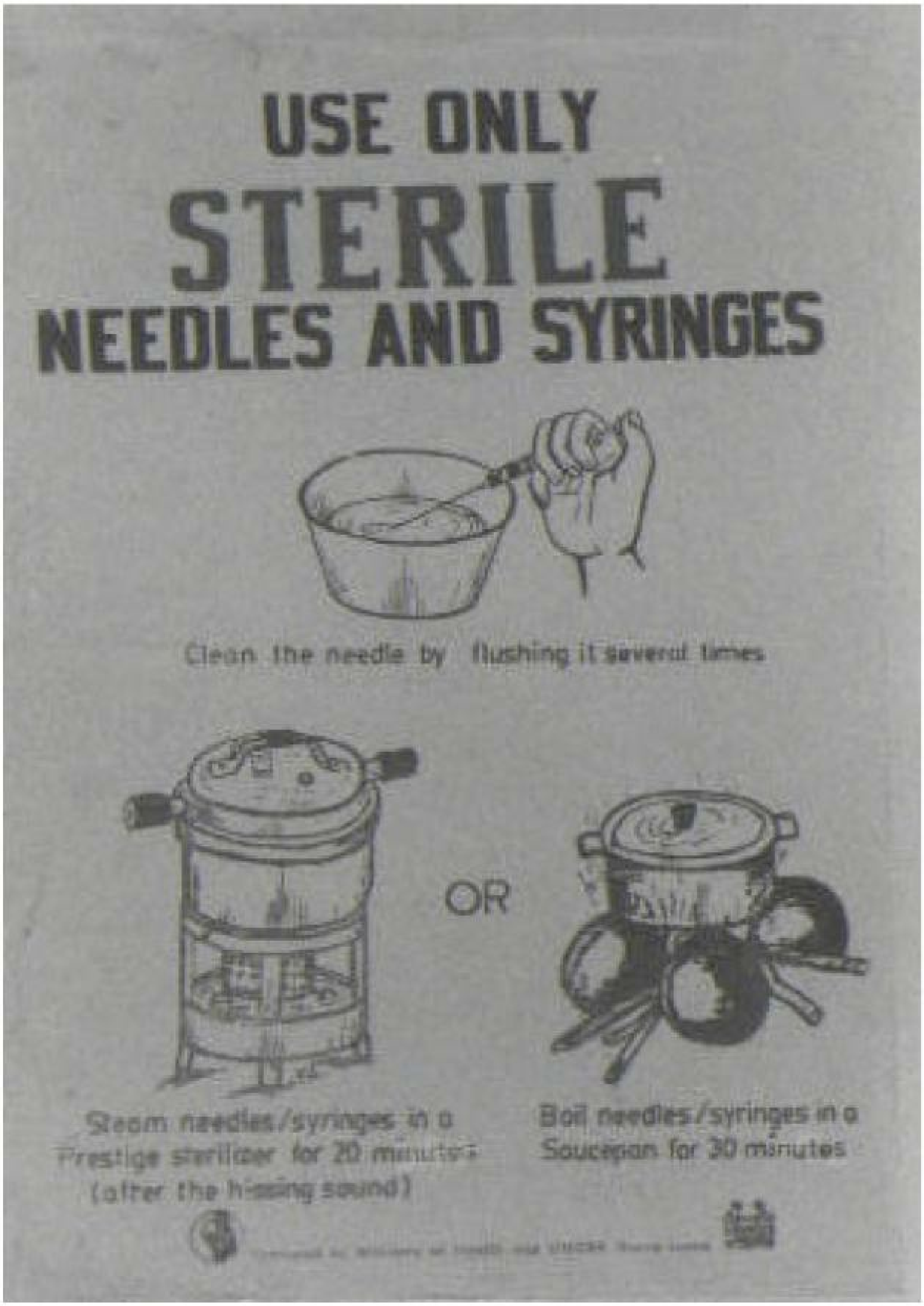


Figure 29 *"Heavy" lidocaine flow in CSF. With permission.*

HOW A HEAVY ANAESTHETIC SOLUTION FLOWS IN THE CSF

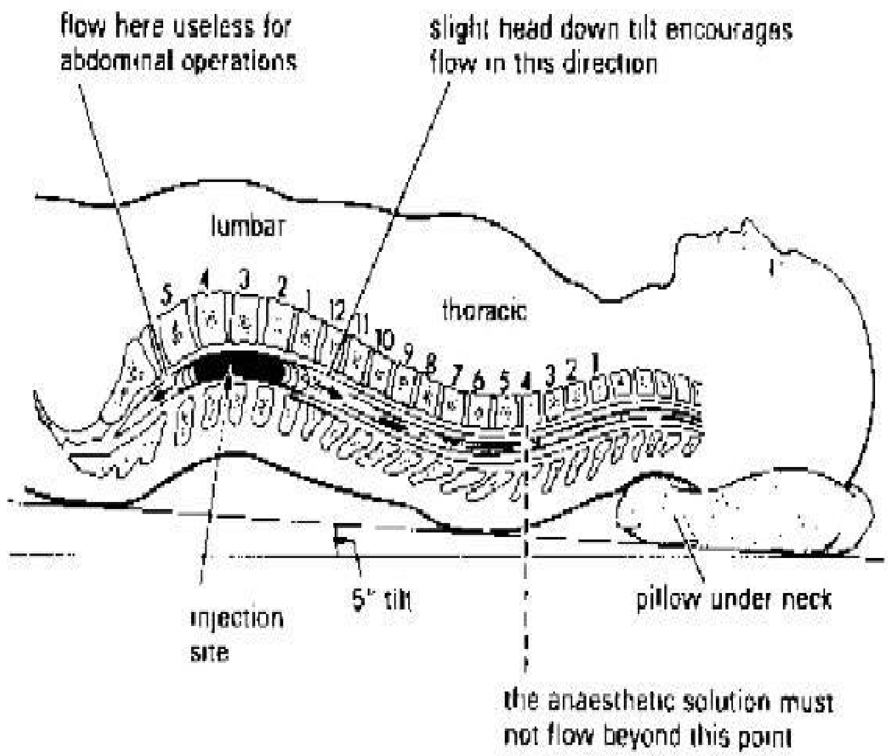


Fig. 7-6 HOW A HEAVY ANAESTHETIC SOLUTION FLOWS IN THE SUBARACHNOID SPACE. A heavy anaesthetic solution introduced at the summit of the lumbar curve will fall towards the patient's sacrum and his thorax. For abdominal operations the flow towards the sacrum is useless, so the table is given a slight head down tilt.

Indications: Spinal

Use spinal anesthesia for operations of the lower abdomen, pelvic, or extremities. Spinal anesthesia is safer than inhalation anesthesia for patients who cannot be intubated, such as those with severe asthma, pneumonia, or contorted airway anatomy. It is also safer than general anesthesia for patients in renal or cardiac failure.

It is not safe for operations lasting beyond the duration of the anesthetic solution (e.g. one hour with lidocaine), in children, for thoracic operations, for patients in shock, and for patients with cellulitis overlying the skin injection site.

Spinal Methods

Preparation. Begin by starting an intravenous drip (18 gauge or larger) in the patient and preloading with a liter of saline solution, followed by a maintenance drip. Initial blood pressure and pulse should be recorded. Equipment for resuscitation, including extra intravenous fluid, ephedrine, intubation supplies, a bag-valve assembly, and suction, should be readied. If time allows, premedicate the patient with promethazine, diazepam, or a similar sedative.

Figure 30 *Preload patients with saline.*

Lumbar puncture. Placement of the patient, the spinal needle, and the volume of injection each affect the highest level reached by the anesthetic solution. Recognizing that many methods are used, the two with the greatest utility are described below.

For both, lumbar puncture is performed using the standard sterile technique in the L3/L4 interspinous space — the level of the iliac crests. (The L2/L3 space can also be used.) In order to ensure sterility and prevent inadvertent injection of preservative, anesthetic solution for spinal injection should always come from a single use ampoule rather than a multi-dose vial. As mentioned, all equipment used for spinal anesthesia should be sterilized by autoclave, or by boiling if autoclave is unavailable.

The first method, known as a low spinal block, provides anesthesia from the L1 dermatome downward. It is useful for operations of the pelvis and legs. The second method, known as a mid spinal block, provides anesthesia from T7 downward. For both methods, the patient should be lying laterally in preparation for lumbar puncture, with the table tilted exactly 5 head down. If difficulty is encountered entering the dural space, these blocks can also be performed with the patient sitting upright initially, though slightly more solution must be used to reach the same level of anesthesia.

Entrance into the dural space should be confirmed by the flow of CSF before injecting anesthetic.

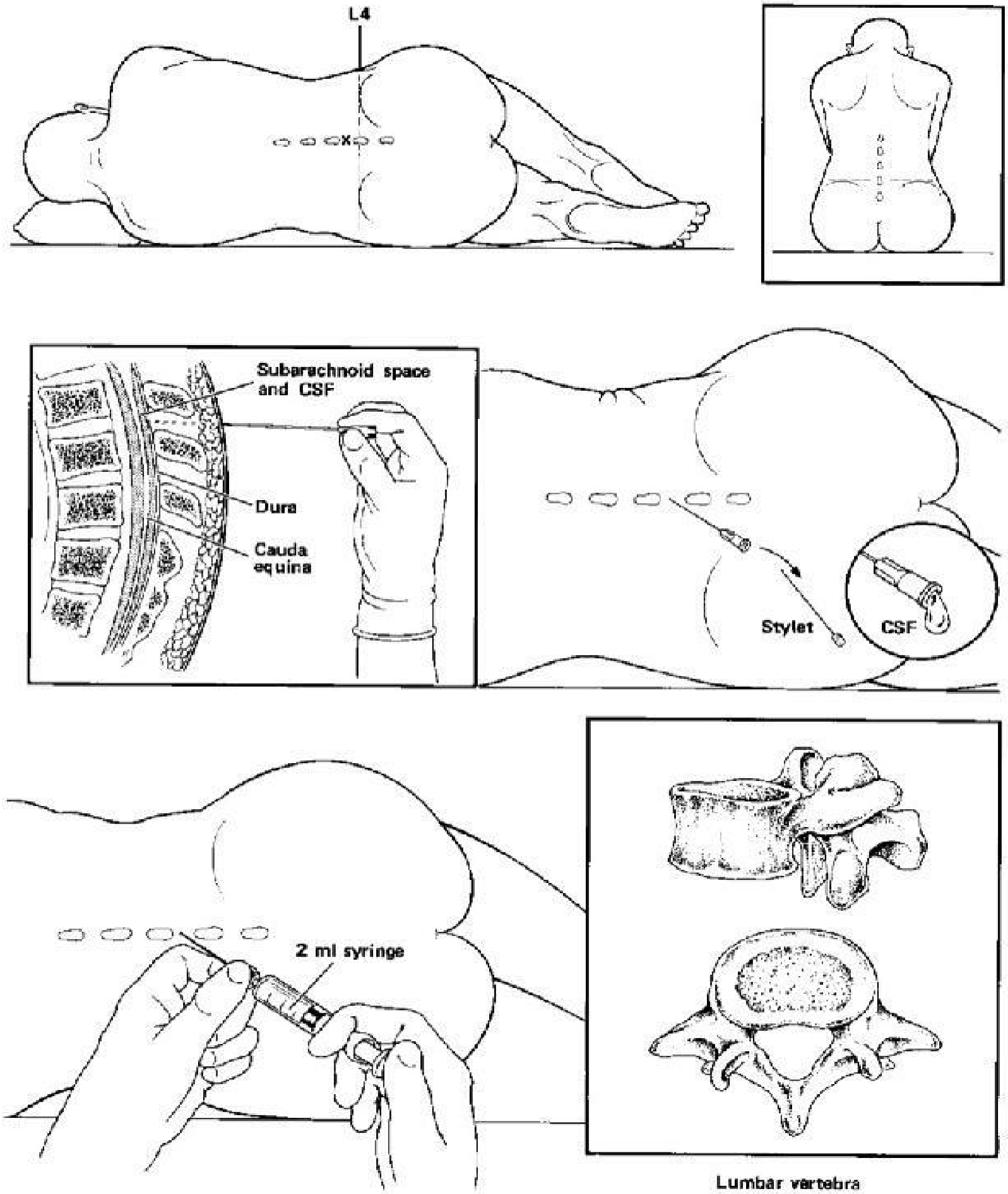
Low spinal block (L1 and below). For the low spinal block, 1.5 ml of hyperbaric lidocaine should be injected into the dural space and the patient immediately laid flat on his or her back, with the table returned to the 0 position.

Low spinal for caesarean section. For women about to undergo caesarean section, a flat position may induce hypotension from uterine compression of the inferior vena cava. Therefore, they should receive spinal injections sitting up, while held by an assistant. Following injection, the mother should remain sitting up for 5 minutes, in order for the anesthesia to take effect. She should be supported during this time, or she may faint and fall off the table. After 5 minutes, she can be laid on the table, with a pillow placed under her right flank to tilt her uterus leftward off the vena cava. This method reliably provides anesthesia to the uterus, perineum, and abdominal wall but sometimes requires local anesthetic supplementation of the proposed skin incision site from the level of the umbilicus (T10) to the level of the inguinal ligaments (L1).

Mid spinal block (T7 and below). For mid spinal block, 2.0 ml of hyperbaric lidocaine should be injected into the dural space and the patient immediately placed on his or her back, leaving the table in the 5 head-down position. This method is not appropriate for caesarean section due to hypotensive effects of the supine position as well as from higher level sympathetic spinal blockade.

Onset. Spinal anesthesia takes approximately 10 minutes to take effect. Before beginning the operation, the anesthetic level should be tested by gently pinching the patient with forceps or checking for cold sensation paresthesia with a wet towel. If the block is above the T8 level, be prepared to treat complications of a high spinal blockade.

Figure 31 *Low and mid spinal anesthesia methods. Reprinted with permission from Dobson M: Anaesthesia at the district hospital. Geneva, World Health Organization, 1993.*



Recovery. When the operation is complete, move the patient carefully to a recovery stretcher maintaining a supine position. Rapid movement, sitting upright in particular, often causes sudden hypotension and syncope. Allow the patient to recover while supine until the spinal block has completely disappeared.

Complications. If hypotension occurs, administer isotonic fluids intravenously at the maximal rate. If hypotension is associated with bradycardia, give atropine. Some anesthetists routinely premedicate with atropine mothers who are undergoing spinal anesthesia for caesarean section, due to the vagal effects of the gravid uterus on heart rate as well as bradycardia primarily caused by hyperbaric lidocaine.

If the patient is bleeding heavily, consider giving blood shortly if isotonic volume expansion does not immediately correct shock. This is particularly important for the woman with a ruptured ectopic pregnancy, or who is bleeding rapidly from a difficult caesarean section.

If hypotension is not corrected with fluid, give 10-20 mg of intravenous ephedrine, which will counter the vasodilatory effect of spinal anesthesia produced by sympathetic nerve blockade. This may be repeated as needed. Other alpha-agonistic agents may be used instead of ephedrine if available.

Remember that hypotension should not be treated by placing the patient in a head down position, since this may cause a high level spinal block, resulting in worsening shock and apnea.

If a patient has difficulty speaking or breathing, he or she probably has experienced high spinal blockade. Give supplemental oxygen and if necessary intubate the trachea in order to assist ventilation and prevent aspiration. Due to the hypotensive effects of high spinal anesthesia, sedation for intubation should be performed with ketamine or other agents that will not exacerbate shock.

Figure 32 *Spinal anesthesia.*

Muscle Relaxants

Additional complexity

Muscle relaxants should only be used by those who are skilled in intubation and who are experienced with both relaxant contraindications and measures needed in the event of paralysis-related complications. Mishaps with relaxant use lead rapidly to death for the patient. Patients who are paralyzed require continuous bedside monitoring by an anesthetist dedicated to this task, particularly in hospitals with little monitoring equipment. Since the paralyzed patient neither breathes or moves, there is little outward change to indicate that a patient has died until the skin grows cold. Thus, at the first sign that something has gone wrong, the patient may already be past rescue.

Muscle relaxants must be used with proper sedation, since the paralyzed patient may appear sedated even when wide awake.

Intubation

Patients who are paralyzed must be intubated so that they do not aspirate and so ventilation can be adequately assisted. In most third world hospitals, ventilation after intubation must proceed by hand using a bag-valve assembly. Automatic ventilators and inhalation anesthetic machines are uncommon and when present, require some expertise in their operation. Before paralysis, a plan for prolonged sedation with relays of bag-ventilation should be made in the event that paralytic reversal fails. With such a plan, all patients will recover eventually.

Succinylcholine

Brief operations requiring muscle relaxation can be performed using a sedative and succinylcholine paralysis alone. Since succinylcholine effects last only minutes, either a continuous infusion or intermittent supplemental boluses of this agent are needed to maintain longer paralysis. The dose of succinylcholine should never exceed 4 mg/kg, or 300 mg total for an average adult. Ideally, use should be reserved for operations that can be completed within 20 minutes but use up to 60 minutes is permitted provided the maximum dose is not exceeded.

The principle danger of using succinylcholine for prolonged paralysis is the conversion from a short-lived depolarizing to a long-lasting nondepolarizing blockade that does not reverse immediately once the infusion is stopped. Further, about one patient in two thousand lacks the enzyme, pseudocholinesterase, needed to break down succinylcholine for reversal of paralysis, and will have prolonged paralysis even after a single dose for rapid-sequence intubation. Patients at particular risk for this complication include those on antimalarial drugs, those with liver disease, anemia, or malnutrition, those poisoned by organophosphates (or who have received neostigmine on purpose), and pregnant women.

Succinylcholine should be used with atropine, particularly in children in whom profound vagal effects of paralysis may lead to frank asystole. The dose is 0.02 mg/kg for children, with a usual adult dose of 0.6 mg. For prolonged succinylcholine use, atropine should be redosed at 0.2-0.6 mg intravenously every 20 minutes as needed when the patient’s pulse drops to 60 or below.

To use succinylcholine by infusion, mix 150 mg of succinylcholine in 500 ml saline or dextrose in water, to make a 0.03% solution. Intubate using a rapid-sequence technique that minimizes the bolus dose of succinylcholine (25-75 mg for adults), so that the overall dose used during the operation is also minimized. After intubation, run the drip at 2.5 mg/minute, about 140 drops/minute using a non-microdrip (15 drops/ml) intravenous set. Keep a clock nearby and periodically inform the surgeon about the period left before the drip must be stopped.

Succinylcholine may also be administered in intermittent boluses of 10-20 mg. This may be mixed in the same syringe with atropine, to give 0.2-0.6 mg with each intermittent dose. Without it, the second or third dose usually causes bradycardia.

In the setting of resource-scarce practices, succinylcholine is often combined with ketamine infusion to provide sedation with paralysis. This combination has advantages over inhalation anesthesia with paralysis, as neither supplemental oxygen nor a vaporizing apparatus is needed. In practices using ether inhalation anesthesia, the combination has advantages when electrical or heated cautery is required, due to the explosive potential of ether.

Pancuronium

When available, nondepolarizing paralyzing agents are safer and easier to use than succinylcholine for prolonged paralysis. Many agents are available and principles of use are similar for them all. Pancuronium is chosen as a prototypical agent, and has advantages for third world use, due to availability, inexpense, and medium duration (about 30 minutes).

To use pancuronium, intubate the patient using a rapid-sequence technique with succinylcholine. Wait until the succinylcholine begins to wear off before giving a longer acting paralyzing agent. Next, administer pancuronium in a dose of 0.05 mg/kg (about 5 mg in average adults). This can be supplemented as needed with boluses at half the initial dose. Note that time to effect for all nondepolarizing agents is much longer than for succinylcholine, so be patient before giving additional doses. As soon as a long-acting agent is given, sedate the patient again if induction was performed with a short-acting sedative. Be prepared to redose sedative agents if a patient gives any sign of waking. If paralyzed, the only indication of a wakeful state may be an increase in the patient's blood pressure, pulse, or degree of skin diaphoresis. For most operations, ketamine by infusion is an ideal sedative for combination with longer-acting muscle relaxants.

When the operation is complete, nondepolarizing paralysis must be reversed with neostigmine and atropine. This should not be performed until at least 20 minutes following the initial dose, or 10 minutes following the last dose, of pancuronium. Reversal is necessary even if a patient appears to be breathing normally, since he or she still may be unable to cough. Peak effect of neostigmine takes approximately 5 minutes.

Give neostigmine mixed with atropine in the same syringe, in doses of 0.04 mg/kg and 0.02 mg/kg, respectively. A standard adult dosing is 2.5 mg and 0.6 mg, respectively. Atropine is necessary to counter bradycardia due to direct vagal effects of neostigmine. Both agents should be given slowly and atropine should be repeated if the patient has persistent bradycardia. If reversal is ineffective, do not give more neostigmine.

A patient should remain intubated until paralysis has completely worn off. The endotracheal tube is ready to be removed once the patient can lift his or her head off the pillow, open his eyes, and breathe normally. Have the patient inspire deeply and cough as the tube is rapidly removed. Suction his airway immediately following extubation.

Special Considerations: Pediatrics

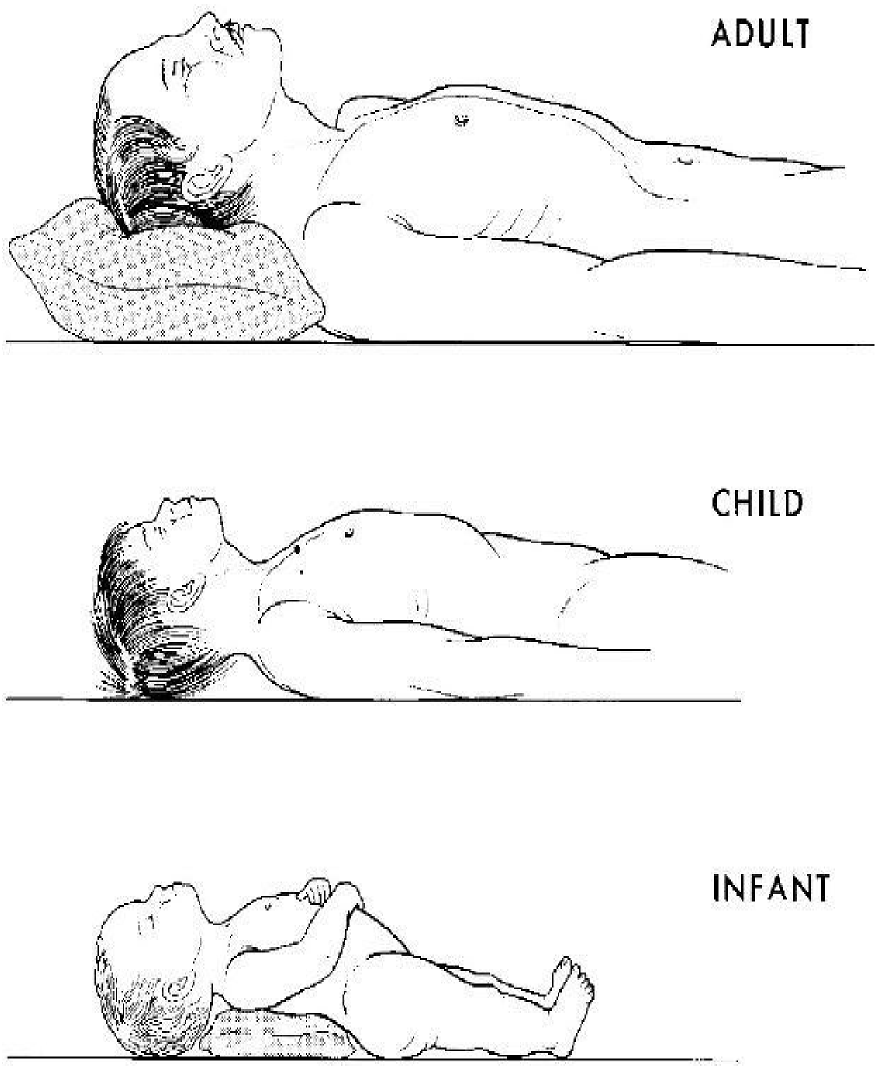
Metabolism, energy, and heat. Glycogen is more rapidly depleted in children than adults. Thus, children should be allowed to drink milk until 6 hours prior and 3% dextrose in water until 2 hours prior to operation. IV fluids during operation should contain dextrose, and children should be allowed to feed immediately on waking. Moreover, if respiration fails during operation, a child's high metabolic rate results in hypoxia much more rapidly than in an adult. Children also lose heat more rapidly than adults, and may therefore become hypothermic during operation, particularly if paralyzed.

Falsely secure vital signs. Children with lifethreatening bleeding often do not exhibit hypotension and other signs of hemorrhagic shock until they are nearly dead. Pay attention to children with declining vital signs who are undergoing surgery. Once vital signs decline, full shock will rapidly ensue unless immediate therapy is undertaken. For this reason, all children undergoing major operations should be monitored with a monaural stethoscope taped to the left chest, by which breath sounds, pulse, and pulse intensity can be continuously monitored.

Vagal effects of medication. Children have more sudden swings in heart rate due to vagal sensitivity. Atropine, for example, should always be used as premedication for succinylcholine paralysis in children ten years and younger due to the possibility of cardiac standstill due to vagal effects of depolarizing paralysis. (It should also be considered for older children, and kept on hand for potential resuscitation of any patient undergoing rapid paralysis.) Atropine, however, is dangerous if the ambient temperature is over 30 C, as it may raise a child's core temperature, producing hyperpyrexia and seizures.

Intubation concerns. Airway anatomy in children is different than in adults. Intubation in small children can be facilitated by placement of towels under the neck and shoulders simultaneously to lift these anteriorly without hyperflexion of the neck.

Figure 33 *Anatomy of adult and pediatric airways showing correct towel placement to facilitate intubation. Reprinted with permission from Dobson M: Anaesthesia at the district hospital. Geneva, World Health Organization, 1993.*



Special Considerations: Obstetrics

Dilation and curettage

This can be safely performed with conscious sedation, using a benzodiazepine and opiate combination such as morphine and diazepam. Be cautious, however, not to over-sedate the patient, as respiratory depression and hypoxia will result. The procedure can also be performed with ketamine, but the patient should be placed in operating position first, as she will be unable to cooperate once dissociated.

Figure 34 *Dilation and curettage under diazepam and meperidine sedation.*

Caesarean section

Surgical technique. In the developing world, most childbirth occurs outside a medical setting. Women who have had prior caesarean sections are at high risk of uterine rupture if subsequent pregnancies result in obstructed labor. Thus, the technique for caesarian sections generally favors a midline vertical incision rather than the low horizontal Pfannensteil incision – as a visible scar itself may communicate lifesaving information to a physician if an unresponsive woman is brought to the hospital with obstructed labor. This event is not simply theoretical, as this author (a nonsurgeon) has successfully operated on many women in shock from uterine rupture while working as a general practitioner in Africa. The actual technique is beyond the scope of this book, but is not beyond the learning ability of motivated physicians who are able to learn from mentors skilled in the medical practice techniques of the developing world. The following link opens a 23-minute teaching video demonstrating a standard caesarian section (under spinal anesthesia) performed by the author in a rural hospital in Ethiopia: YouTube CS.

Spinal anesthesia. Several methods have already been discussed briefly. The simplest and perhaps most commonly used method is spinal anesthesia. This reliably provides anesthesia and muscle relaxation, is simple to perform, and allows the mother to stay awake following delivery if desired, in order for her to immediately bond with her newborn. The major disadvantage is the possibility of hypotension from blockade of the spinal sympathetic nerves. However, this is both avoidable and treatable with saline preloading and alpha-agonist pressor agents.

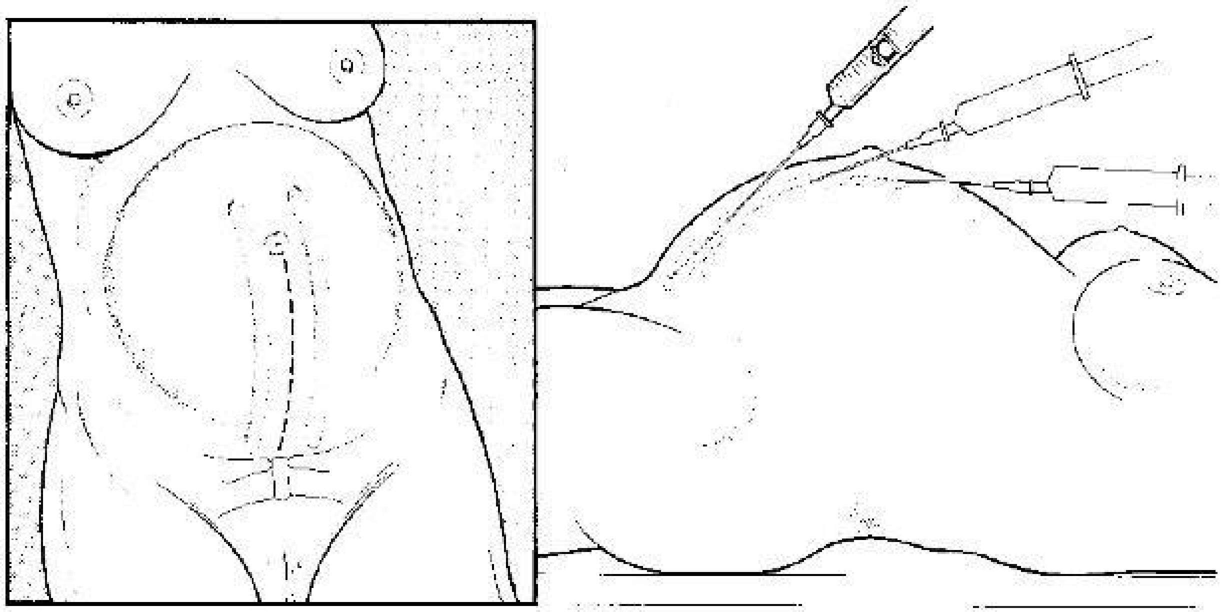
Figure 35 *Caesarian section under spinal anesthesia.*

Ketamine anesthesia. Ketamine is also simple, particularly for the sort of crisis where a mother will die without operation and the only operator available has little experience with anesthesia or caesarean section. The major difficulty with ketamine, however, is complete lack of muscle relaxation. In fact, abdominal muscles are often contracted as the patient moves during the dissociative state, making it more difficult to deliver or replace the uterus through the rectus incision.

Rectus muscle infiltration assists muscle relaxation. Muscle contraction from the rectus segments accounts for most of the difficulty in performing caesarean section in unrelaxed patients. Such contraction can be relieved by directly injecting the rectus muscle in eight segments (four on each side of the incision) once the skin is incised and the rectus is directly visualized. When each segment is visualized, inject in the center of each segment with 5 ml of 0.4% epinephrine-supplemented lidocaine. After pushing the needle through the anterior rectus sheath, use the needle tip to feel for the posterior sheath. Once this is felt, raise the needle slightly so that the injection occurs in the body of the muscle toward the middle part of the sheath. Recall that the posterior sheath ends halfway between the umbilicus and symphysis pubis at the arcuate line, so this applies only to the upper two-thirds of the rectus muscles.

Local anesthesia. This method is the safest for mothers, but is more difficult for inexperienced surgeons due to the increase in patient discomfort and lack of adequate muscle relaxation. Approximately 100 ml of 0.4% epinephrine-supplemented lidocaine is used to anesthetize the skin, where the patient would feel the most pain of incision. (Some surgeons prefer 0.5% procaine which is metabolized so rapidly that there is no upper limit to the safe dose. However, procaine has both a longer latent period and is less effective when compared to lidocaine.) This solution is then used to paralyze the rectus muscles, as described above. It is also necessary to anesthetize the parietal and visceral peritoneal membranes, to prevent further pain and discomfort when incised and manipulated. The advantage to this method lies its safety. However, local anesthesia is usually incomplete, particularly when intraabdominal structures are manipulated.

Figure 36 Local infiltration methods for caesarian section. Reprinted with permission from Dobson M: Anaesthesia at the district hospital. Geneva, World Health Organization, 1993.



Following each injection, a latent period of 5 minutes is needed for the anesthetic solution to act. The method of local anesthesia may be supplemented with analgesic or anxiolytic agents such as ketamine, diazepam, and morphine. This is safest once the baby is delivered, but sometimes necessary prior in order to allow the operation to proceed further.

Local anesthesia method. When possible, premedicate a mother with promethazine and keep her tilted to the left to prevent uterine pressure on her inferior vena cava. If available, supplemental oxygen should be administered until the delivery is complete.

Prepare 100 ml of epinephrine-supplemented 0.4% lidocaine. (Preparation of 0.4% lidocaine solution is discussed previously in the section Local and Regional Anesthesia: General methods.) Using a long infiltration needle (100 mm), inject two large intradermal and subcutaneous bands of the solution from the pubis to a point 5 cm above the umbilicus, on either side of the pending incision. (Alternatively, some surgeons inject one wide band in the midline and cut directly through it.)

The injection must always be parallel to the skin. Otherwise it may pass through the thin abdominal wall and puncture the uterus. The needle may be bent to facilitate this method. As with field blocks, the solution should be injected continuously without need to check for intravascular needle placement, while the needle is both pushed forward and withdrawn through the skin.

After the skin incision is performed, inject 10 ml of the solution immediately beneath the linea alba, in order to anesthetize the parietal peritoneum. Then inject the rectus segments as described. Remember to wait for the anesthetic solution to take effect.

On reaching the uterus, inject another 5 ml of the solution under the loose visceral peritoneum where the lower uterine segment will be incised. This only anesthetizes the visceral peritoneum in the region of the uterine incision, so be careful not to disturb the rest of the abdominal cavity during the remainder of the operation.

Supplemental intravenous agents are best avoided until the cord is clamped, to reduce transfer to the baby. However, be generous with them once delivery is complete. If the operation cannot be continued due to patient discomfort, use ketamine to supplement local anesthesia.

Figure 37 *Unexpected twins! These were delivered under spinal caesarian section.*

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