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# Waking up is hard to do. Considerations for longer surgeries

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The modern anesthesiologist is often challenged with the need for intraoperative safety and rapid emergence from surgeries lasting more than 8 hours. In this presentation we will review the major anesthetic considerations for these procedures including: pharmacokinetics and pharmacodynamics of commonly used anesthetics, management of patient temperature, and positioning related concerns. Using the basic principles from these three areas the anesthesiologist can safely balance surgeon preferences with patient concerns to produce the best possible outcomes.

Emergence: If the patient is to awaken in a timely fashion at the end of the procedure, it is extremely important that the anesthesiologist is aware of the pharmacokinetics of the drugs that they are using to maintain anesthesia.

The basic principles governing elimination of intravenous drugs include distribution, biotransformation, and excretion. For longer surgeries using intravenous anesthetics to maintain anesthesia often context sensitive half-life is the most important issue. In the case of inhalational anesthetics context sensitive half-life of the drugs they are using to maintain amnesia. Distribution is the major determinant of end-organ drug concentration and depends on organ perfusion, protein binding, and lipid solubility. Highly perfused organs take up more drugs compared to less perfused organs. If a drug is bound to a plasma protein, it is not available for uptake; the main proteins which bind drugs are albumin and $\alpha_1$-acid glycoprotein. When the level of proteins are low, the amount of free drug available for tissue is increased. Examples of conditions which case low protein levels include renal disease, liver disease, chronic congestive heart failure, malignancy, trauma, infection, myocardial infarction, and chronic pain.

When plasma concentration of a drug falls, drug leaves the effect site and highly perfused organs to maintain equilibrium. This redistribution is can be responsible for termination of effect. Regarding longer surgeries, if the less perfused organs are saturated from repeated doses of drug, redistribution is lessened and emergence depends to a greater extent on drug elimination. For example, rapid-acting drugs such as propofol and fentanyl will become longer acting after repeated administration or when a large single dose is given.

Biotransformation is the alteration of a substance by metabolic processes and mainly occurs in the liver often producing a water soluble by product which is excreted by the kidney. Some of the byproducts are active and may have physiologic effects of their own until they are eliminated. Renal failure changes the pharmacokinetics of many drugs by altering protein binding, volumes of distribution, and clearance rates. There are a few drugs which depend on biliary excretion and these may accumulate in the case of hepatic failure.

Context sensitive half-life is the time for the plasma concentration to decrease by 50% from an infusion that maintains a constant concentration; context refers to the duration of the infusion. Time to 50% decrease in plasma concentration was chosen because a 50% reduction in drug concentration appears to be necessary for recovery after the administration of most intravenous hypnotics. In cases where total intravenous anesthesia is necessary for the procedure (e.g. spine surgery) the anesthesiologist must aggressively taper the intravenous anesthetic at the appropriate time, often more than 40 minutes prior to surgical finish. Fortunately, often during closure of the incision, the neuromonitoring team will stop monitoring and inhalational gas can be added if necessary.

Processed EEG monitoring: may be somewhat helpful to determine when infusions can be tapered, although it is not an index of immobility. Studies have shown that sevoflurane and propofol effect movement to noxious stimuli differently[1].

At an equivalent depression of BIS, sevoflurane suppresses the blink reflex more than propofol, indicating different pharmacodynamic properties of these anesthetics at brainstem level. The differential level of immobility at similar levels of hypnosis makes titration of TIVA during spine surgery, without use of paralytic drugs, somewhat complex.

## RECOVERY FROM INHALATIONAL AGENTS

Recovery from inhalational anesthesia occurs as the concentration of anesthetic in brain tissue decreases and redistributes to other tissues and/or is eliminated mostly by exhalation. After longer procedures significant absorption has occurred in adipose tissues which limit redistribution. Hence, the speed of recovery from inhalational anesthesia also depends on the length of time the anesthetic has been administered.

## RECOVERY FROM PARALYTIC DRUGS

The termination of action of nondepolarizing muscle relaxants occurs via redistribution, metabolism (slower), and excretion. Vecuronium and rocuronium are metabolized by the liver, so repeated administration in these patients may cause prolonged emergence. Pancuronium and vecuronium are partially excreted by the kidneys, and therefore their action can be prolonged in patients with renal failure. Liver disease and renal failure result in an increased volume of distribution and a lower plasma concentration for water-soluble muscle relaxants. However, these may demonstrate prolonged clearance therefore a greater loading dose but smaller maintenance dose is indicated for longer procedures.

Maintenance of physiologic homeostasis is important for patients undergoing longer procedures to avoid prolonged neuromuscular blockade. The most important factors include: temperature, acid-base status, electrolyte abnormalities. Hypothermia can prolong neuromuscular blockade by decreasing metabolism which in turn delays excretion. Acidosis can potentiate blockade and antagonize reversal. Hypokalemia, hypocalcemia, and hypermagnesemia augment blockade. The effect of hypercalcemia is unpredictable.

The anesthesiologist should also be aware of interaction of neuromuscular blockade with other drugs administered in the perioperative period which can potentiate blockade. These include but are not limited to: aminoglycoside antibiotics, clindamycin, phenytoin, calcium channel blockers, neostigmine, dantrolene, inhalational anesthetics, and magnesium sulfate (e.g. as used for preeclamptic patients).

Positioning: There is significant concern that longer procedures can contribute to injury due to prolonged positions and immobility. Peripheral nerve injury is a relatively common complication and not altogether avoidable.

The most common peripheral nerve injury is ulnar neuropathy. Risk factors included: gender, hospital stay > 14 days, and extremes of body habitus. Anesthetic technique was not implicated as a risk factor, in fact one quarter of patients received monitored care or lower extremity regional technique which casts doubt that a stretch or compression mechanism caused the injury[2]. In fact, the onset of symptoms is generally delayed and occurred despite extra padding over the elbow area injury.

Other peripheral nerve injuries are more closely associated with positioning or surgical procedure these include the peroneal nerve, the brachial plexus, or the femoral and sciatic nerves. Lower extremity neuropathies, e.g. involving the peroneal nerve are associated with extreme and prolonged lithotomy positioning. Risk factors for include; hypotension, weight, age, vascular disease, diabetes, or smoking. Brachial plexus injuries during lateral decubitus positioning may be related to improper positioning of the axillary roll. Axillary rolls should be caudal to the axilla and large enough to relieve pressure from the mattress on the lower shoulder. Shoulder braces to support patients in Trendelenburg should be avoided, and shoulder abduction and lateral rotation should be minimized to reduce the chance of brachial plexus injury. The upper extremities should not be extended greater than 90° at any joint and should be supinated to protect the ulnar tunnel. Pronation of the forearm can compress the ulnar nerve in the cubital tunnel. Lower extremities should not have any obvious pressure points; additional padding may be helpful in vulnerable areas.

The prone position has several anesthetic implications, the position itself is not necessarily harmful, and may be improved ventilation. However, malpositioning in prone position may lead to significant morbidity. In osteoporotic patients and those with cervical instability, attention should be given to the positioning process. Prior to induction the patient should be allowed to position themselves for comfort in a supine position. After induction and intubation it is important to safely log roll the patient with in-line stabilization of the neck. There are many commercially available tables and frames, and it is also possible to use improvised bolsters and padding on a standard table. The overall goals are the same to maintain the patient's neck in a neutral position with a foam headrest or with a cervical traction device. Horseshoe head rests have routinely fallen out of favor for prone positioning as they may be associated with postoperative blindness when they impinge on the lateral can thus of the eye. The anesthesiologist should avoid positioning the patient with the face turned to one side or another since this is associated with postoperative blindness and stroke.

Care must be taken to avoid over aggressive traction on the shoulders and brachial plexus as this can lead do neurologic issues post operatively. Shoulders occasionally need to be un-

tapped or released from any traction when there are changes in neurophysiologic monitoring suggesting undue stretch on the brachial plexus. Patients undergoing lumbar surgery will have their arms positioned at 90 degrees in all planes, supported by armboards. Typically the shoulder is abducted, with minimal shoulder flexion and 5-10 degrees of internal rotation. Neuromonitoring can help to assess the position of the neck and brachial plexus throughout the surgery.

Finally, bolsters should support the patient at the tips of the shoulders and upper chest and iliac crests allowing the abdomen to hang freely. This allows venous return and diaphragm excursion during ventilation. Legs should be bent at the knees. The hips may be extended to create lordosis of the lumbar spine for fusion or flexed for more decompression procedures without fusion. All pressure points and areas peripheral nerves are subject to compression (i.e. ulnar nerve at elbow, peroneal nerve at fibular head and neutral positioning of the wrist for median nerve) should be padded with foam.

## TEMPERATURE

Maintenance of patient temperature during longer surgeries can be challenging, especially for surgeries which require large areas of body surface to be exposed. Hypothermia may be associated with cardiac dysrhythmias, increased myocardial oxygen consumption, coagulopathy, altered mental status, decreased drug metabolism (which could lead to prolonged emergence), and an increased risk of poor wound healing and infection. Therefore, it is extremely important that the anesthesiologist be aware of the likelihood of hypothermia in prolonged surgery.

During general anesthesia, the patient's core temperature decreases 1 to 2 degrees C during the first hour secondary to redistribution from the core to the periphery. This phenomenon is due to anesthetic induced vasodilation. After the first hour the patient's temperature decreases secondary to heat loss to the environment. These changes in temperature cannot be compensated by the usual hypothalamic mechanisms (vasoconstriction, shivering) because they are inhibited by anesthetics.

Strategies which may be employed by anesthesiologists to maintain patient body temperature can include: prewarming with forced air blankets prior to induction (blunting the initial redistribution temperature loss), raising the operating room temperature, warming intravenous fluids, using forced air warming blanket. Passive heating with warmed blankets is generally ineffective.

In summary, lengthy procedures are increasingly common in anesthetic practice. Anesthesiologists must use their knowledge of pharmacology to select and use drugs which will allow for rapid emergence when desirable. Careful attention must be paid to proper positioning during the surgery, although it is likely that a significant proportion of the injury is not preventable. Maintenance of patient temperature is very important to avoid prolonged action of anesthetic drugs and physiologic derangement leading to perioperative complications.

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