Guidelines for Anesthesia for Spinal Surgery with Evoked Potential Monitoring
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These guidelines are meant to provide a suggested general framework for providing anesthesia which provides for effective acquisition of Evoked Potential (EP) signals. There are many possible acceptable variations. Any drug which depresses the central nervous system or induces reduction in muscular activity will affect, to some degree, EP signals. In some patients, signals are strong enough that there is wide latitude in anesthetic technique, but in other patients with underlying neuropathy, signals may be weak and very sensitive to suppression, and choice of anesthetic can have a major impact on monitoring capability. Volatile anesthetics tend to be the most potent suppressors of evoked potentials, particularly motor evoked potentials (MEP), but in moderate doses (less than .5 "MAC") combined with narcotics and other agents such as propofol, they may still provide adequate monitoring capability in many patients. In some situations where the ability to provide very clear MEP is crucial to the surgeon, avoidance of volatile anesthetics will provide the optimum EP monitoring environment, and Total Intravenous Anesthesia ("TIVA") may be requested. In any case, the anesthesia team should be prepared to discontinue volatile anesthetic if EP signal acquisition is not adequate for monitoring.

Currently, the most common TIVA regimens involve propofol as the primary hypnotic agent, supplemented by relatively high levels of a potent narcotic. The choice of narcotic varies between practitioners. Used appropriately, virtually any narcotic can be effective. Most commonly, Sufentanil or Remifentanil are used, but Fentanyl can also be used. The advantage of Sufentanil is the quality of post-operative analgesia and relative stability for a long case. The disadvantage is the possibility of respiratory depression if the infusion is not discontinued early enough. The advantage of Remifentanil is the rapid elimination, but this results in the need for another opiod to provide post-operative analgesia, and the transition from remifentanil to other opioid can sometimes be unpredictable. Remifentanil is also expensive for a prolonged case, has been associated with a higher incidence of PONV, and may induce tolerance to other opiates. The advantage of Fentanyl is its familiarity for many practitioners. Whichever narcotic is chosen, it is best to try to establish a steady state by either using an infusion or frequent small doses rather than large boluses, which can affect the EP signals.

If monitoring MEP, neuromuscular blocking agents must be used very sparingly, if at all. Intubation is usually accomplished with succinylcholine to facilitate acquisition of baseline MEPS soon after induction. If a non-depolarizer is used in customary intubation doses, significant delay of the case may occur while waiting for neuromuscular blockade to fade enough for baseline MEP measurements. IF succinylcholine is contra-indicated (example burn, hemiplegia, hyperkalemia, etc.) then either intubation without neuromuscular blockers, or a very reduced dose of neuromuscular blocker may be considered. The surgeon may request small doses during portions of the case where MEP monitoring is less critical, but doses need to be small enough to allow return of activity after only a few minutes. This is typically rocuronium 5-10 mg increments as requested by the surgeon.

BIS monitoring is desirable as it serves as the best index of hypnotic effect. Generally, BIS of 40 +/- 10 indicates a reasonable hypnotic (i.e. propofol) effect. Depending on other indicators of overall anesthetic effects, if BIS is less than 30, reduction in propofol should be considered. If BIS is over 50, either additional narcotic or propofol may be considered.

There are an infinite number of combinations and "recipes" for TIVA. Following, I have described some examples which I am familiar with:

Propofol/Sufenta: Induce with 0.3-0.6 ug/kg of Sufenta and propofol 100-150 mg. If immediate MEP baselines will be done, use Succinylcholine (or no muscle relaxant) for intubation. Start propofol infusion at ~ 100 ug/kg/min within 5 minutes, and be prepared to give additional boluses of propofol as needed while getting positioned, etc. If patient seems "light", additional Sufenta in ~ 10ug increments can also be given, up to a total of 1 ug/kg. When stable, begin Sufenta infusion 0.2-0.5 ug/kg/hr **(NOTE!!!! Sufenta dosing in ug/kg/HOUR, NOT ug/kg/MINUTE!!!). For a normal adult, this works out to between 15-35 ug per hour of Sufenta. Beware of dose confusion with the dosing described in some infusion pump settings (ug/kg/MIN)!** To avoid confusion with case turnover and multiple personnel, we usually mix the infusion solution at 1ug/cc.

Titrate propofol between 50 and 175 ug/kg/min using BIS as guidance. Adjust Sufenta rate depending on signs of sympathetic reactivity, particularly heart rate. Usually, an adequate level of Sufenta results in a relatively slow heart rate (often bradycardia). Sudden increases in heart rate in response to surgical stimulation would suggest need for additional Sufenta (or increased propofol).

If Desflurane is used, we usually keep it between 0.4-0.6 "MAC", and propofol and Sufenta dosages may often be reduced by 30-45% (approximately the low end of the ranges described above).

If Remifentanil is used, dosage recommendations are quite variable. A wide range of 0.05-2.0 ug/kg/MIN is provided in the manufacturer's dosing guidelines. Respected colleagues have suggested that a range of 0.25 - 0.7 ug/kg/MIN is common for healthy patients (i.e. young scoliosis patients), and 0.1-0.2 ug/kg/MIN for elderly patients, used with propofol and/or Desflurane. Fentanyl 100-250 ug is often used at induction. Some additional analgesic such as Morphine, Dilaudid, or Fentanyl must be used for post-operative analgesia.

If Fentanyl is chosen for intra-op, I would expect a dose range of 1-5 ug/kg/Hour.

A few comments about Ketamine are offered: There is good data, (Loftus et al, *Anesthesiology* Sept 2010, Vol 113, pp 639-46) that ketamine is very helpful for postoperative analgesia in opoid tolerant patients undergoing spine surgery. Many spine patients have chronic pain and are opiod dependant, and I do recommend consideration of

ketamine for these patients. The dose used in the study cited is about .5mg/kg/hour beginning at either induction or incision and continued until about one hour before the end of the case. It can be given by infusion, but can also be easily given incrementally. Beware that mixing ketamine in propofol may result in the ketamine separating out of solution with erratic administration. I find it easiest to give it incrementally, at 0.25mg/kg every 30 minutes. At this low dose range, emergence may be slightly delayed, but it is rarely problematic. The MEP technician will encourage ketamine as well, because it often enhances MEP signals, but I do not routinely use it for this indication if the patient is not opiod tolerant, unless MEP signal acquisition is difficult. In difficult MEP signal cases, I start with 0.5 mg/kg ketamine. Larger doses up to 1-2 mg/kg/hour can be tried, but the higher doses may result in emergence delay or delirium. Ketamine can have a variable effect on BIS values, usually increasing values 10-15 units. I usually try to note BIS value prior to giving ketamine and then note the effect (if any), and take this into account when evaluating BIS data. Rarely, BIS values as high as 70-80 may be seen with ketamine, usually at higher ketamine dosages.

Dexmetatomidine in the dose range of .2-1.0 mg/kg/hr is used as an adjunct to propofol/narcotic TIVA in some centers, but I have limited experience with this. Note that is an adjunct to propofol/narcotic; it is not potent enough to be the primary agent for TIVA!

For spinal surgery, blood pressure should be maintained to optimize perfusion to spinal cord and retina. In general, MAP of 80, or near the patient's baseline. It is common to need a low-dose vasopressor such as phenylephrine or dopamine to counteract the effects of the propofol and narcotic. Be wary that if vasopressor requirements seem high, or are increasing as the case progresses, the patient may be hypovolemic. Blood loss can be difficult to track, but be wary that it is often underestimated. Use of the Masimo Pulse Oximeter with Hgb estimation and Pulse Pressure variability can be helpful. I frequently give albumin to avoid excessive crystalloid. My general guideline is Albumin equivalent to blood loss, up to a maximum of 750 cc Albumin, and I try to limit crystalloid to no more than 1-2 liters over maintenance requirements and other blood loss. Hemoglobin should be checked regularly, and probably maintained above 7.5-9.0 depending on patient cardiovascular status. Be aware that recent data shows a strong correlation between blood product administration and surgical infection in spine surgery, so avoidance of transfusion when feasible is recommended. This needs to be balanced according to cardiovascular risk factors and the fact that anemia is a potential risk factor for ocular injury in prone patients. The decision to give blood products is often difficult. I routinely involve the surgeon in this decision. They usually have a good idea of how much post-op bleeding is likely. If the surgeon is likely to have a low threshold to give blood products post-operatively, then I would be more likely to start them intra-op, but if he prefers avoidance of blood products, I might delay or limit blood products within reason. For example, a young healthy scoliosis patient with a starting Hgb over 12 may tolerate a liter or more of blood loss, with a Hgb as low as 8 intra-op.

Sufenta infusion should usually be discontinued at least one hour before the end of the procedure. For long procedures, I consider stopping Sufenta two hours before the

end, and waiting for any sign of narcotic deficiency (heart rate, respiratory effort, etc.). I often do a "ventilation test" 90-120 minutes before the end of the case, reducing minute ventilation to allow ETCO2 to rise and waiting to see if the patient begins spontaneous ventilation. If they resume ventilatory effort at ET CO2 less than 50, I consider that they *may* receive more sufenta, but if they do not begin to breathe after several minutes of ETCO2 over 50, I would be reluctant to give any more sufenta. It is easier to give more Sufenta if needed than to get rid of it if you left it on too long!

As soon as closure begins, ask the surgeon if he has finished MEP monitoring – if so, you can then begin or increase Desflurane, which will allow you to turn off the propofol in order to give it time to wear off. (Be careful of the transition – let Desflurane concentration rise for a few minutes before cutting propofol). For a long procedure (>6 hours), it may take 30 minutes or more for propofol to wear off, so take advantage of the opportunity to turn it off early and switch to Desflurane if possible. I usually keep Desflurane at .7-1.0 MAC during closure, and do not turn it off until surgery is finished and patient is ready to turn if prone, or when the dressing is applied for supine cervical surgery. Turning it off prematurely risks premature coughing and moving, which can be dangerous in spine surgery. Most patients will not have received neuromuscular blockers for several hours before emergence, and reversal is usually not necessary or indicated, but this is a decision to be made carefully based on good monitoring.

If the patient is spontaneously breathing, most patients will awaken within 7-10 minutes of stopping Desflurane, and a slightly slow emergence is better than rapid, rocky emergence. Optimally, the patient emerges smoothly and is extubated at the first sign of purposeful movement, taking into consideration any airway issues. Long cases in the prone position, particularly with cervical surgery, can lead to precarious airways. Assess the patient carefully for edema of the tongue and airway, cervical alignment, etc. Discuss with surgeon, and if in doubt, leaving the patient intubated should be considered. In borderline cases, extubation over an airway exchange catheter, which can be left in until the patient is fully awake and stable, is an option which facilitated re-intubation if needed.

Hopefully, the patient soon follows directions and moves extremities to command. Ketamine use sometimes slows this phase, and may require a few minutes of patience. Brief stimulation of the extremities with a nerve stimulator may elicit enough of a withdrawal response to satisfy the surgeon that the patient can leave the OR, but this should be done sparingly.

I hope these suggestions are helpful. My technique constantly evolves, and I welcome input or critique.

Step-by-step Suggestions:

Room Set-up: Basic GETA set-up, with Succinylcholine, Propofol, etc. (I recommend having a second syringe of propofol drawn up – it is likely to be needed during initial phase). Phenylephrine infusion ready, propofol and narcotic infusions ready

to plug in. It is likely that extensions will be needed on infusions from the pumps. Depending on IV arrangement, the three-port extension for the IV may simplify plugging in multiple infusions. Gather additional airway tools if needed.

Patient prep: 2 IVs for cervical cases due to limited access. Usually A-line (but not mandatory in healthy patient for lumbar or anterior cervical). Standard monitors, BIS.

Induction: Propofol/Narcotic and either Succinylcholine or no muscle relaxant (NO Rocuronium, Vecuronium, or Cisatracurium!)

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Airway: For cervical cases I usually use a technique that does not require any neck extension, such as VideoLaryngoscope (Storz/Glidescope/McGrath) or intubating LMA. Direct Laryngoscopy is my last choice, only if other techniques fail. After ETT placed and secured, a soft bite block must be used to prevent tongue damage with jaw closure during MEP stimulation. I use a folded gauze "pillow" between the incisors, taped securely.

After induction, a foley will usually be placed, and the EP monitoring technician will finish placing scalp leads and do baseline MEP. IF doing full TIVA, DO NOT TURN ON DESFLURANE! If doing a low dose Desflurane technique, keep the Desflurane below ~ .5 MAC. The propofol infusion will need to be plugged in and started ASAP, otherwise additional boluses of Propofol will be needed. Try to get a stable plane of anesthesia for the baseline MEP. If signals are good quality, discuss with EP tech and surgeon and consider low dose Desflurane. IF signals are poor, consider stopping Desflurane if it has been on.

Turning Prone: Always a difficult process due to multiple IVs, monitor leads, etc. NOTE – anything that needs to get plugged into IV must be done before the arms get wrapped! You will not be able to get to the proximal ports after turning. Confirm that all IVs run well after arm wrap. DON'T give muscle relaxant "to hold them still for the turn" unless you have confirmed that post-turn MEP won't be needed! Usually, another set of MEP is done ASAP after positioning. NOTE – we have seen several cases where positioning caused loss of MEP and led to case cancellation or need for "wake up test", so be careful with doses of long acting drugs.

Maintenance: Propofol/Narcotic +/- low dose Desflurane, ketamine, etc. Muscle relaxation may be requested by surgeon for a brief period during exposure, but use small, incremental doses (e.g. Rocuronium 5-10 mg) so that MEPs may be obtained soon afterward. BIS usually 30-50, possibly higher if ketamine used. BP MAP >80. Fluids as discussed above:

One hour before emergence: Turn off Sufenta or adjust other narcotic as needed. Consider "ventilation test" to assess depth of narcotic respiratory suppression. When surgeon satisfied with fixation (usually just prior to starting closure) ask whether he is satisfied with MEP and if so, turn on Desflurane (~0 .7-1.1 MAC) and wean propofol.

Adjust ventilation to establish spontaneous ventilation during last few minutes of closure. Keep Desflurane on until incision closed and drapes come off.

Turn Supine, usually incline head up, extubate when patient meets extubation criteria. (If the patient is not a difficult airway, I do not insist on movement of hands and feet prior to extubation. I extubate when appropriate, then let patient wake up enough to follow commands and move extremities before leaving room).