**SUPPLEMENTAL DIGITAL CONTENT 1**

**SPINE PROTOCOL FOR PATIENTS UNDERGOING HIGH-RISK SPINE SURGERY**

**PREOPERATIVE MANAGEMENT**

**Before the day of Surgery**:

1. Identification of Spine Protocol patients prior to surgery1:
   1. Surgery involving > 6 spine levels
   2. Surgical timeline > 6 hours
   3. Predicted blood loss > 2 liters, or
      1. 1 or more vertebral column resection
      2. 2 or more pedicle subtraction osteotomy
      3. 3 or more Smith-Petersen osteotomy
   4. Combined anterior and posterior approach
   5. Staged procedure (not minimally invasive and/or one-two-level fusion procedures)
   6. Classified as high risk by the spine surgeon
   7. Patients who have significant co-morbidities and are of advanced age (coronary artery disease, pulmonary (disease causing functional impairment: severe COPD, Pulmonary fibrosis, impaired diffusion capacity), liver, end stage renal diseases, existing coagulopathy, age > 70)

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| PREOPERATIVE CHECK LIST |
| * Initial visit to surgeon’s office * Consult with clinical specialists * Consult with Preoperative Clinic with anesthesiologist * Additional consultation, if warranted * Discuss at multidisciplinary high-risk spine conference * Patient to the operating room |

1. Initial visit to surgeon’s office - the decision to proceed with surgery is made during this visit

Consult with clinical specialist(s) - the patient is sent to clinical specialists for an evaluation of co-morbidities, if necessary

Consult chronic pain specialist for opioid tapering in chronic pain patients2,3

1. Visit to Preoperative Clinic – should be scheduled three weeks prior to the scheduled operation
   1. History and Physical examination, laboratory orders –
      1. Complete Blood Count, Chemistry, Coagulation panel, Type and Screen/Type and Cross (depending on anticipated blood loss), and additional tests per patient’s co-morbidities
      2. If patient is deemed to be in poor nutritional status, Prealbumin level should be checked. If less than 15 mg/dL, consider delaying surgery and getting a nutrition consult (will be related to the surgeon)
      3. The following preoperative Hemoglobin (Hgb) goals
         1. <75-year-old, no cardiac history: Hgb > 11
         2. >75-year-old or history of cardiac disease: Hgb > 12
         3. If the Hgb is less than the goals, then
            1. A discussion by preoperative clinic with the surgical team will occur weighing the benefits/risks of delay
            2. Iron and/or Erythropoietin when indicated
   2. Additional anesthesiologist assessment – intubation (special attention should be made to cervical spine pathology), line placement, positioning challenges
   3. Preoperative discussion with the patient
      1. Prone positioned patients are informed of the increased risk for postoperative visual loss (associated with length of surgery and significant blood loss) and pressure sores secondary to positioning
      2. Patients are informed of high likelihood of blood transfusion
      3. Patients are informed of the potential for remaining intubated post-operatively
   4. Medication instructions to the patient
      1. Continue essential medication regimen until the morning of surgery, especially statins and beta-blockers (if normally taken by the patient in the morning)
      2. Discontinue anti-hyperglycemic medications the morning of surgery
      3. Discontinue ACE-inhibitors and angiotensin receptor blockers 1 day prior to surgery4
      4. Discontinue all medications that interfere with coagulation unless otherwise specified by a Clinical Specialists (ACCP Guidelines5)
      5. The patient is advised to discontinue smoking for at least 8 weeks (as soon as he/she is initially seen by the surgeon) and is educated with the risks associated with continued tobacco use
   5. Blood conserving strategies – preoperative embolization may be considered for hyper-vascularized lesions to reduce blood loss
2. Additional consultation if warranted - If the preoperative clinic warrants additional assessment/tests regarding new onset disease or chronic disease, the patient will be referred back to a Clinical Specialist for further testing
3. **Multidisciplinary High- Risk Spine Conference –** the case will be discussed to finalize assessment, make additional recommendations prior to the procedure, and agree to proceed or cancel

**Day of Surgery**:

1. Patients will have a carbohydrate fluid up to two hours prior to surgery
   1. “Pre-surgery Ensure” is given at the preoperative clinic
2. Blood glucose levels should be <180 mg/dL the day of surgery
   1. If preoperative blood glucose level is greater than 180 mg/dL please treat with Sub-cutaneous (SQ) injection of insulin
   2. If blood glucose level is greater than 300 mg/dL discuss delaying surgery until sugar is better controlled, with surgical team
3. If the patient is hemodynamically stable and surgery is urgent, then no delay for optimization of Hgb, nutrition, or physical activity should be done
4. The following medications may be administered to the patient in the preoperative holding area (at least one hour before induction):
   1. Acetaminophen 1 g PO (if no liver disease)
   2. Gabapentin 300-600mg PO depending on age, renal function, and patient naivety to the medication
   3. Celecoxib 200 mg PO – contraindicated in patients with sulfa and aspirin allergies (see drug insert)
   4. Chronic Pain Patients, requiring long-acting opioid pain management (including fentanyl patch, oxycontin, etc) and having pain for over 3 months6**,** should take their home pain medications the morning of surgery
   5. Opioids are NOT indicated preoperatively for opioid-naïve patients

**INTRAOPERATIVE MANAGEMENT1,7,8,9**

1. Communication
   1. The surgeon/anesthesia provider and neuro-monitoring team communicate frequently including status and any pertinent changes in patient condition
   2. The anesthesia provider must inform the neurophysiological team with changes in anesthetic management (change in inhalation agent, bolus medication, non-depolarizing muscle relaxants administration, temperature perturbations)
2. **Anesthetic10**
   1. **Induction**: High-risk spinal surgery requires general anesthesia and endotracheal intubation. Considerations during the induction phase include:
      1. IF patient has cervical pathology THEN avoiding cervical spine manipulation during airway access
      2. Hemodynamic stability and avoidance of hypotension especially in myelopathic patients/spinal cord in jeopardy
      3. Induction technique should not interfere with electrophysiologic monitoring (EP)
         1. WHEN baseline Motor Evoked Potentials (MEP) or Somatosensory Evoked Potentials (SSEP) are warranted, THEN a depolarizing neuromuscular agent is preferred.
         2. Small dose of nondepolarizing blocking agent can be used to facilitate intubation and positioning BUT excessive or residual paralysis can interfere with EP
      4. Once the endotracheal tube is secure, a soft (but firm) bite block is placed between the molars and visible to facilitate easy removal at the end of the case
   2. **Maintenance**
      1. All cases require first antibiotic administration within one hour of the incision. If an inpatient is already receiving an antibiotic therapy or wound culture should be obtained by the surgeon prior to antibiotic administration in the operating room (OR), the decision on antibiotic regimen should be made according to hospital guidelines
      2. Most cases require total intravenous anesthesia (TIVA) - Propofol with Remifentanil or Sufentanil, Ketamine on a case by case basis
      3. If patient has severe cervical stenosis or cervical cord compression, THEN keep mean arterial pressure (MAP) > 85 mmHg
         1. Verify and document preferred MAP with surgeon for all cases
      4. If the patient is on long term opioid therapy for uncontrolled pain, THEN:
         1. Methadone 10-20 mg
         2. Magnesium Sulfate 2 gm
         3. Lidocaine infusion, if not contraindicated: 1-2mg/kg/hr intraoperatively and possibly continue infusion at 0.5-1mg/kg/hr until postoperative day (POD) 211,12
         4. Ketamine infusion (if not contraindicated): 0.5mg/kg administered pre-incision, then 0.25mg/kg/hr has been shown to decrease opioid use in the perioperative period13,14
         5. Intrathecal injection of morphine may be administered by the surgeon
      5. If the patient is high cardiac risk, THEN consider inhalations agent at ½ monitored anesthesia care (MAC) with TIVA
3. **Monitoring**
   1. Standard American Society of Anesthesiology (ASA) monitoring
   2. All patients require arterial line and most of the patients require central line
      1. IF central venous catheter is inserted, THEN monitoring is recommended
   3. Consider FloTrak or Lidco for dynamic cardiovascular monitoring15
   4. Patient’s temperature must be 36-37 degrees Celsius. The operating room temperature must be maintained at 70 degrees Fahrenheit. All warmers, forced air blankets, and humidifiers must be initiated
   5. Urinary catheter is required, preferably with the temperature probe
   6. Glucose monitoring is required. It is highly recommended to keep glucose level bellow 180 mg/dL throughout the surgery. The blood glucose on diabetic patients should be checked hourly. If blood glucose after two hours of treatment remains above 200 mg/dL – consider using insulin drip
4. **Positioning**
   1. All patients are positioned in collaboration WITH the surgical team
   2. Specialty tables are used (all inflatable pads should be inflated prior to positioning)
      1. Proaxis Jackson table: inflatable pads are located at the anterior superior iliac spines only
      2. Axis Jackson table: inflatable pads are located at chest, below axillae, and at the level of the anterior superior iliac spines
      3. Wilson Frame
      4. The surgical table is maintained in horizontal or slight reverse Trendelenburg position unless otherwise indicated
   3. **Anatomic position**
      1. Eyes are lubricated closed, protected, and free from external pressure
         1. Head and neck must be in neutral position
         2. IF Prone View headrest is used, THEN eyes and nose must be visible
         3. IF the Mayfield head fixator is used, THEN the patient’s head should *not* be extremely flexed or extended, and the chin must be free
         4. Soft padding is applied to the chin and forehead area
      2. The surgical team is responsible for proper patient positioning
         1. Arms abducted no more than 90 degrees, slight internal rotation, and arms lie in the front of the plane of the body to reduce brachial plexus injury
         2. Place soft pads in the axillae area, ulnar nerve at the elbow.
         3. IF the arms are tucked, THEN thumbs should be positioned pointing down to avoid over pronation
         4. All pressure points should be assessed EVERY 60 MINUTES (eyes, nose, lips and chin, elbows, arms and hands, breasts and genitalia
5. **Neurophysiological Monitoring**
   1. Neurophysiological monitoring is used on a routine basis: SSEP/MEP
   2. Baseline neurophysiological baseline is recorded pre-incision
      1. IF there is concern regarding spinal integrity, THEN monitoring is assessed pre AND post positioning
   3. SSEP is assessed continuously and MEP is assessed at the surgeons’ request, and following any critical surgical interventions (spinal instrumentation, osteotomy, or scoliosis correction)
   4. Free run electromyography (EMG) is performed to monitor nerve root irritation and/or injury
6. **Fluid Management**
   1. Initial assessment of the intravascular volume must be assessed, and resuscitation is warranted BEFORE bleeding occurs. Continual assessment of:
      1. Clinical status
      2. Vital signs
      3. CVP measurements
      4. ABG results
      5. Stroke Volume Variation Plethysmography
   2. Use balanced salt solutions with low chloride content (Plasma-lyte/Lactated Ringers)16 (20)
      1. For maintenance, *nil per os* (NPO) deficit and insensible loss should be considered
      2. Intra-operative losses volume replacement should be administered according to goal directed therapy
   3. 5% albumin is acceptable for fluid resuscitation
      1. Consider minimal use of crystalloid solutions in favor of 5% albumin to decrease facial swelling in prone position for cases > 6 hours in length
   4. IF the patient fails to respond to fluid resuscitation, THEN vasoactive medications should be initiated
   5. Fluid status is assessed continuously and adjusted with the final target of end organ perfusion and tissue oxygenation17
7. **Blood Loss** 
   1. Preparation for significant blood loss
      1. Cell salvage (exception: patients with spinal oncological disease, infection, or the concern for dissemination of malignant cells)
      2. Acute normovolemic hemodilution
      3. Rapid transport infusion systems must be available
      4. Blood components must be in the operating room (ice in the cooler must be replaced in timely matter according to the blood bank refrigeration policy). Cryoprecipitate (Cryo) ordered when decision is made to transfuse it
      5. Ensure the availability of coagulation factors - Cryo and fresh frozen plasma (FFP), and platelets (Plt) prior to incision
      6. Ensure laboratory tubes in cart in the event chemistry/coagulation profile is warranted
   2. Expected Massive Transfusion
      1. Prophylactic18,19
         1. Antifibrinolytic therapy (if not contraindicated)
            1. Tansexamic acid (TXA): infusion is initiated at the BEGINNING of surgery as a 10 mg/kg bolus over 10 minutes then 1mg/kg/hr infusion throughout the procedure
         2. Fibrinogen complex, 1 gm/kg at the beginning of the procedure, if indicated. Desmopressin acetate (DDAVP) should be considered in patients with Von Willebrand factor (VWF) deficiency or platelet dysfunction
         3. Prothrombin Complex Concentrate (PCC), if indicated
         4. Routine cell salvage in all cases with anticipated significant blood loss (more than 500cc), if not contraindicated
         5. Acute normovolemic hemodilution for Jehovah’s Witness (JW) patients
      2. Laboratory
         1. Assess coagulation panel, fibrinogen level
         2. Arterial blood gas (ABG) on a regular basis - every hour, and every 30 minutes for acute bleeding
      3. Protocol for massive transfusion - 1U blood loss = 1U packed red blood cells (PRBC)transfused - initiate if expected blood loss will be more than 1500 ml whole blood (Supplemental Digital Content. Appendix B)
         1. 6U PRBC/2U FFP/2U Cryo/1U Plt (6:2:2:1) as previously discussed with surgeons
         2. IF the patient has a history of left ventricular dysfunction or heart failure, THEN infuse more cryoprecipitate and less FFP to lessen volume load1
8. **Wake-up Test**
   1. On rare occasions a wake-up test is used when neurophysiological monitoring raises a concern while obtaining baselines, during positioning, or following critical portions of the surgery
      1. IF the decision to perform a wake-up test prior to the start of the surgery, THEN the patient must be informed during the preoperative evaluation
      2. IF the surgeon anticipates an intraoperative wake-up, THEN the surgeon gives adequate warning so that the anesthetic can be discontinued in a timely manner
      3. Short acting opioids or a less soluble inhalation agent are preferred if a wake-up test is anticipated
   2. The wake-up test
      1. The anesthetic is discontinued, and the patient awakens
      2. The surgeon performs neurological examination (assessment of corticospinal track injury and if assessed timely the injury may be reversible)
      3. IF the incision was not made, a wake test is required, and the decision is made to proceed, THEN the patient is reassured and re-anesthetized
9. **Transfer to the Intensive Care Unit (ICU)**
   1. At the completion of surgery, the patient is transferred to the ICU with Standard ASA monitors and invasive arterial line monitoring
   2. The patient handoff report is given from the anesthesiologist to the ICU attending or fellow (if attending is not available), and to the registered nurse (RN)
   3. Hgb goal: Hgb>10 mg/dL

**POSTOPERATIVE MANAGEMENT**

None

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