ANTERIOR VERTEBRAL BODY TETHERING

Surgical Specialty:	Orthopedics
Authors:	Michael H. Warren, MD, MBA and Christine L. Mai, MD, MS-HPEd, Massachusetts General Hospital, Boston, MA

Background:

- General Considerations
  - Scoliosis is defined as a three-dimensional deviation of the spinal axis with a curvature greater than 10 degrees on AP X-ray imaging.[1]
  - Idiopathic scoliosis, in which no causal underlying disease can be identified, is the most common type in children and adolescents.[2]
  - Historically, these deformities were corrected through serial casting or spinal fusion surgery, in which vertebrae are permanently linked using grafts or implants.
  - Anterior vertebral body tethering (AVBT) is a minimally invasive approach that involves the placement of screws and a flexible tether to guide vertebrae into a straighter position during growth without any fusion of vertebrae.[3-5]
  - Compared to spinal fusions, AVBT preserves spine flexibility and function during growth.
  - Video-assisted thoracoscopy surgery (VATS) is most commonly utilized for single thoracic curves between T4 to L2 during AVBT, however, additional open or mini-open approaches may be needed for lower curvature in the spine.
  - Patient eligibility criteria for AVBT vary but generally include an idiopathic curve with Cobb angle between 35 and 65 degrees and a skeletal maturity Risser score <= 2 and Sanders score of 3-4.[1]
- Patient Considerations
  - Most patients undergoing AVBT are between the ages of 8 and 16 years old.
  - As only patients with idiopathic scoliosis are eligible for AVBT, comorbidity rates are similar to the general pediatric population.
  - Although uncommon, if scoliosis is severe (usually Cobb angle > 65°), curvature could compromise respiratory function in a restrictive pattern.

Anesthetic Planning:

- Pre-Anesthetic Evaluation
  - A standard history should be obtained from the patient and family, with a focus on functional status and limitations due to scoliosis, and any pulmonary or cardiac symptoms. A history of joint hyperlaxity or easy bruising should prompt a specialized opinion concerning a possible Ehlers-Danlos disease.

    - Physical exam should include auscultation of the heart and lungs and a thorough airway examination. Echocardiography may be useful as mitral valve prolapse is 4 times more common in adolescents with idiopathic scoliosis.[7]
    - Given the high incidence of iron deficiency with or without anemia in female adolescents, consider checking preoperative hemoglobin, iron, and ferritin levels a few weeks before surgery and correct any deficit with oral iron and folates. This could reduce the risk of transfusion and postoperative anemia.[8]
- Discussions to have with surgeon/family
    - Location of curvature (left vs right, thoracic vs lumbar) and the likelihood of bleeding during the case
    - Code Status
- Specific or Unique Room Set-up Requirements
    - Airway
        - For most cases, a double-lumen endotracheal tube is required for lung isolation during thoracoscopy (see Table 1 for sizing).
        - Bronchial blockers or Univent tubes may be utilized as an alternative if double-lumen ETT is unavailable or proper sizes are unavailable.
        - A small fiberoptic bronchoscope should be available to confirm proper placement of DLT or Bronchial blocker both initially and throughout the case.
    - Drugs/Infusions
        - General Anesthetics
            - Neuromonitoring is used throughout the case, volatile anesthetics and non-depolarizing neuromuscular blockers are usually avoided in favor of a total intravenous anesthetic (TIVA)
            - Induction medications can vary but commonly include propofol and narcotic boluses, with or without succinylcholine for short-term paralysis.
            - Most commonly, propofol (150-300 mcg/kg/min) and remifentanil (0.05-0.15 mcg/kg/min) infusions used as maintenance
        - Steroids (to minimize stridor, pain, PONV risk, and prevent spinal cord edema)
            - Dexamethasone 8-12 mg IV per discussion with surgical team
        - PONV Prophylaxis
            - Ondansetron 0.1-0.15 mg/kg (max 4 mg) at end of case
            - Dexamethasone (see above)
        - Pain management
            - Fentanyl or sufentanil IV for induction
            - Remifentanil infusion for maintenance
            - Consider hydromorphone, morphine, or methadone for post-op pain management
            - The surgeon may request a thoracic epidural or the surgeon may inject intrathecal duramorph by lumbar puncture during the case
            - Minimize long-acting narcotics post-operatively if the surgeon administers intrathecal duramorph to avoid excessive sedation
            - Acetaminophen IV and Ketorolac IV as pain adjuncts
            - Diazepam post-operative may help with muscle spasm
            - Gabapentinoids have been administered to prevent postoperative neuropathic pain with variable success.

- Monitors
  - Standard ASA monitors with possible need for an arterial line at the discretion of the anesthesiologist.
  - Neuromonitoring is performed during the case to monitor sensory and motor evoked potentials.
  - Processed EEG or BIS monitoring if available for titration of TIVA
- Blood Availability (if indicated)
  - These cases usually have minimal blood loss, however, patients should have an active Type and Screen.
- Post-operative disposition
  - Patients usually spend 1-2 nights in the hospital during the postoperative period
  - PICU availability may be needed if intraoperative considerations are noted
  - ERAS protocol: physiotherapy, pain management, psychological support
- Other Indicated Resources
  - None

Intraoperative Considerations:

- General
  - Neuromonitoring is used throughout the operation to monitor spinal cord function and upper and lower extremities.
  - Depending on the side of the curvature, one lung ventilation is utilized to allow for a thoracoscopic approach (usually the lung of concavity is down)
  - Fluoroscopic guidance is used by the surgical team to identify vertebrae and monitor instrumentation during the case.
    - Anesthesia providers should have properly fitted lead shields on and, when feasible, stand away from the X-ray source.
- Induction
  - Depending on the patient's age and maturity, intravenous access can be obtained in the preoperative period for IV induction versus a mask induction.
  - Double-lumen ETTs can be difficult to place due to their size, requiring adequate dosing of anesthetic medications to decrease the risk of damage to the vocal cords and glottic area if muscle relaxants are avoided.
  - Based on the surgical approach, an appropriately sized left double-lumen ETT is usually preferred.
  - Confirm placement of lung isolation with fiberoptic visualization and auscultation.
  - Two bite blocks placed on both sides of the molars are recommended to avoid dental and gum injury during neuromonitoring.
  - To facilitate upper lung emptying and allow time for reflex hypoxic vasoconstriction to develop, it is useful to start OLV as soon as adequate positioning of the two-lumen tube is confirmed.
- Positioning
  - Usually lateral decubitus position with the convex side of deformity facing upwards
  - An axillary roll should be placed to protect against brachial plexus injury and compression of the axillary artery.
  - With the patient in the lateral decubitus position the arms are bolstered and well-padded with pillows and blankets
  - Ensure that the double-lumen ETT can still be easily accessed regardless of the patient padding and bolsters.

    - Repositioning to supine and vice-versa may be required during the case depending on the location of the spinal curvature, (i.e., lumbar curvature may require a mini-open anterior tethering approach in the supine position)
- Maintenance
    - Adequate depth of anesthesia with TIVA (propofol and remifentanil) is required to avoid movement during the case in the absence of muscle relaxants.
    - Anesthesia providers can check with neuromonitoring specialists regularly to evaluate the current anesthetic depth and trends they are observing.
    - Any changes in maintenance anesthetics should be communicated to the neuromonitoring staff.
- Hemodynamic/Physiologic goals
    - Since patients are on one-lung ventilation for a significant portion of the case, providers should be prepared for oxygen desaturations and hypercarbia.
    - Patients often require high respiratory rates to treat hypercarbia (large tidal volumes should be avoided due to the risk of barotrauma on the ventilated lung)
    - Normotension should be maintained with fluids and pressors if needed
- Surgical Considerations (such as neuromonitoring, muscle relaxation, anticipated blood loss)
    - Neuromonitoring used throughout the operation
        - Avoid muscle relaxation and volatile anesthetics (only < 0.5 MAC), if possible.
    - Blood loss is usually minimal and blood products are rarely needed
        - Left-sided scoliotic curves may have a higher risk of bleeding due to the location of the aorta during a left thoracoscopic approach.
        - Tranexamic acid infusion or aminocaproic acid infusion may be considered if the patient is at high risk for bleeding.
    - Chest tubes are often placed during the case but are rarely needed post-operatively and are usually removed towards the end of the operation.
    - The surgeon may request a thoracic epidural for post-op pain management or the surgeon may administer intrathecal duramorph at the end of the case.
    - If the surgeon administered intrathecal duramorph at the end of the surgery, careful evaluation for pain management must be considered in the PACU period to avoid excessive sedation.
- Emergence/Disposition
    - Patients are usually extubated at the end of the case and brought to the PACU for initial recovery.
- Post-op Care
    - Oftentimes, these patients will recover in the PACU with minimal issues
    - A chest x-ray will be necessary to monitor for post-operative pneumothorax
    - Patients usually spend 1-2 nights in the hospital for post-op care

Case-Specific Complications/Pitfalls

- Desaturations during the case
    - This may require intermittent re-ventilation of the down lung during the case in consultation with the surgical team.
    - Administering a small flow of oxygen (0.2 to 0.5 L/min) into the upper lung can be helpful.
- Migration of double-lumen tube
    - Due to repositioning during the case, the tube may migrate leading to poor isolation. Check the tube location with a bronchoscope after each repositioning.

- Intraoperative Awareness
    - Increased risk due to the use of TIVA. This may be mitigated with reliable IV, EEG monitoring, and the use of preoperative midazolam.
- Stridor
    - Due to the larger size of the double-lumen tube. Minimizing intubation attempts and the use of steroids can mitigate risk.
- Laryngospasm
    - Can occur if the patient is light on anesthetic. Avoid gas induction if the patient can tolerate a preoperative IV.
    - Can also occur at the time of extubation due to laryngeal edema or secretions
- Pneumothorax
    - Requires post-operative x-rays after chest tube removal. Keep the chest tube (or replace) if concern for pneumothorax post-op.
- Hemorrhage
    - While rare for these cases, patients should have active Type and Screen.

References

1. Choudhry MN, Ahmad Z, Verma R. Adolescent Idiopathic Scoliosis. *Open Orthop J.* 2016;10:143-154. PubMed Link
2. Trobisch P, Suess O, Schwab F. Idiopathic scoliosis. *Dtsch Arztebl Int.* 2010;107(49):875-883; quiz 884. PubMed Link
3. Raitio A, Syvanen J, Helenius I. Vertebral Body Tethering: Indications, Surgical Technique, and a Systematic Review of Published Results. *J Clin Med.* 2022;11(9). PubMed Link
4. Rushton PRP, Nasto L, Parent S, Turgeon I, Aldebeyan S, Miyanji F. Anterior Vertebral Body Tethering for Treatment of Idiopathic Scoliosis in the Skeletally Immature: Results of 112 Cases. *Spine (Phila Pa 1976).* 2021;46(21):1461-1467. PubMed Link
5. Bizzoca D, Piazzolla A, Moretti L, Vicenti G, Moretti B, Solarino G. Anterior vertebral body tethering for idiopathic scoliosis in growing children: A systematic review. *World J Orthop.* 2022;13(5):481-493. PubMed Link
6. Letal M, Theam M. Paediatric lung isolation. *BJA Education.* 2017;17(2):57-62.
7. Lang C, Wang R, Chen Z, He,S, Zou Q, Wu J, Zhu X. Incidence and Risk Factors of Cardiac Abnormalities in Patients with Idiopathic Scoliosis. *World Neurosurgery*. 2019; 125, e824–e828. PubMed LInk
8. Switzer T, Naraine N, Chamlati R, Lau W, McVey MJ, Zaarour C, Faraoni D. Association between preoperative hemoglobin levels after iron supplementation and perioperative blood transfusion requirements in children undergoing scoliosis surgery. *Ped Anesth.* 2020; 30(10): 1077-1082. PubMed Link

Reviewed by:

Reviewer #1: Meenakshi Atteri, MD, Arkansas Children's Hospital

Reviewer #2: Francis Veyckemans, MD (Retired)

Reviewer #3: Jessica S. Dominic, MD, Texas Children's Hospital

Created: Date; Last revised: 5/19/25

Table 1: Example sizing by age for lung isolation devices.[6]

Age (Yrs)	BB (Fr)	Univent (mm)	DLT (Fr)
4-6	5		
6-8	5	3.5	
8-10	7	3.5	26
10-12	7	4.5	28
12-14	7	6	32
14-16	7-9	6.5-7	35-37
16-18	7-9	7-7.5	37-39

BB: Bronchial Blocker; DLT: Double lumen tube; Yrs: Years; Fr: French

Adapted from: Letal M, Theam M. Paediatric lung isolation. *BJA Education.* 2017;17(2):57-62.