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Tracheal Injury

Tracheal injuries in children are rare but potentially life-threatening. These injuries may arise due to traumatic events, iatrogenic causes such as intubation, or spontaneous occurrences linked to underlying conditions. The clinical presentation varies depending on the severity and mechanism of injury, making timely diagnosis and appropriate management crucial.

Pediatric tracheal trauma can be broadly categorized into blunt trauma, penetrating injuries, and iatrogenic injuries. Blunt trauma is often associated with motor vehicle accidents, falls, or sports-related impacts. The compliance and elasticity of a child's trachea make complete transections less common than in adults, yet injuries may be underdiagnosed due to their subtle presentation. Penetrating injuries, though less frequent, pose an immediate risk of airway compromise and often require surgical intervention. Iatrogenic injuries, particularly those due to endotracheal intubation, are a major concern in neonatal and pediatric intensive care units. The incidence of tracheal rupture following intubation varies but remains a critical issue, especially in cases requiring prolonged mechanical ventilation or repeated intubation attempts.

The clinical manifestations of tracheal injury often include respiratory distress, subcutaneous emphysema, stridor, pneumothorax, and pneumomediastinum. Some cases present with acute airway obstruction, necessitating emergency intervention. Imaging modalities such as plain radiographs, computed tomography, and bronchoscopy are vital in diagnosing tracheal injuries. Flexible or rigid bronchoscopy remains the gold standard for confirming injury and guiding management decisions.

Management strategies for tracheal injuries in children depend on the extent and location of the injury. Conservative management is gaining traction, particularly for minor injuries or stable patients. Reports suggest that in selected cases, spontaneous healing can be achieved with close monitoring, airway support, and judicious use of endotracheal tubes to bridge the injury. Stent placement has also been explored as an alternative to surgery, demonstrating promising outcomes in limited case series. However, when significant airway disruption or progressive respiratory compromise occurs, surgical intervention is warranted. Primary repair, end-to-end anastomosis, or tracheostomy may be required based on the severity and location of the injury.

The risk of complications such as tracheal stenosis, tracheoesophageal fistula, and mediastinitis underscores the need for long-term follow-up. Studies have indicated that while many pediatric patients recover well with appropriate intervention, delayed sequelae

can impact respiratory function. Conservative approaches often necessitate prolonged intubation or non-invasive ventilation to facilitate healing, though concerns remain regarding potential airway remodeling and stenotic changes.

Emerging research highlights the importance of prevention strategies, particularly in the context of iatrogenic injuries. Optimizing intubation techniques, using appropriately sized endotracheal tubes, and limiting repeated intubation attempts are key measures in reducing iatrogenic tracheal injuries. Advances in airway management, including video laryngoscopy and improved sedation protocols, aim to enhance safety and minimize complications.

Despite its rarity, tracheal injury in children demands heightened clinical awareness, early diagnostic intervention, and a multidisciplinary approach to management. The evolving preference for conservative management in selected cases represents a paradigm shift in treatment, though surgical intervention remains essential for severe injuries. Long-term surveillance is necessary to monitor for complications and ensure optimal respiratory outcomes in affected children.

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Achalasia

Achalasia in children is a rare primary motility disorder of the esophagus characterized by the failure of the lower esophageal sphincter (LES) to relax properly and the absence of normal peristalsis. The prevalence is low, with an estimated incidence of 0.11 to 0.18 cases per 100,000 children per year, and it is slightly more common in males. Although achalasia is more commonly diagnosed in adults, pediatric cases present unique diagnostic and management challenges.

The exact etiology of achalasia remains unknown, but the disorder is believed to result from the progressive degeneration of the inhibitory neurons in the esophageal myenteric plexus. This leads to an imbalance between excitatory and inhibitory neurotransmission, specifically a deficiency in nitric oxide-producing neurons that regulate LES relaxation. Some studies suggest an autoimmune mechanism involving CD3/CD8-positive cytotoxic T

cells, eosinophils, and mast cells, which could contribute to the destruction of ganglion cells. Familial cases have been reported, and achalasia has been associated with genetic syndromes such as Allgrove syndrome and Down syndrome. Additionally, Chagas disease, caused by Trypanosoma cruzi infection, can lead to secondary achalasia through the destruction of enteric neurons, mimicking idiopathic achalasia.

Children with achalasia often present with progressive dysphagia, initially to solids and later to liquids. Other symptoms include regurgitation of undigested food, nocturnal cough due to aspiration, chest pain, weight loss, and failure to thrive. Misdiagnosis is common, with many children being treated for gastroesophageal reflux disease or feeding disorders before the correct diagnosis is made. The delay in diagnosis often leads to significant esophageal dilation and the development of a sigmoid-shaped esophagus, also known as megaesophagus.

The diagnosis of achalasia relies on a combination of clinical presentation, radiologic imaging, endoscopic evaluation, and esophageal motility studies. A barium esophagogram typically reveals a dilated esophagus with a classic "bird-beak" appearance at the LES. High-resolution manometry (HRM) remains the gold standard for diagnosis, demonstrating the absence of peristalsis and elevated LES pressure with incomplete relaxation. Upper endoscopy is performed to exclude other conditions, such as strictures or malignancies, although its findings in achalasia are often nonspecific. Newer diagnostic tools, such as EndoFLIP (endoscopic functional luminal imaging probe), have been introduced to measure esophagogastric junction distensibility, aiding in diagnosis and treatment evaluation.

High-resolution manometry has also allowed for the classification of achalasia into three subtypes based on the Chicago Classification criteria. Type I achalasia is characterized by the complete absence of esophageal peristalsis. Type II achalasia presents with panesophageal pressurization in more than 20% of swallows, and these patients are more likely to experience significant weight loss. Type III achalasia is marked by peristaltic fragmented or spastic contractions and is often associated with chest pain. Histological findings reveal aganglionosis and neuronal loss in Type I and Type II achalasia, while Type III achalasia exhibits impaired inhibitory postganglionic neuron function but no neuronal loss. Some evidence suggests that untreated Type II achalasia may progress to Type I over time.

Management of achalasia in children focuses on relieving symptoms by reducing LES pressure to improve esophageal emptying. Pharmacological treatments, including calcium channel blockers and nitrates, have been largely ineffective. Botulinum toxin injection into the LES can provide temporary relief but has limited long-term efficacy, making it a less favored option. Pneumatic balloon dilation (PBD) has been used in children, with success rates varying between 50% and 80%, but repeated dilations are often required, and the risk of esophageal perforation remains a concern.

Heller myotomy, particularly the laparoscopic approach (LHM), is considered the standard surgical treatment for pediatric achalasia. This procedure involves cutting the muscle fibers of the LES to alleviate obstruction, often combined with an anti-reflux procedure such as Dor or Toupet fundoplication. LHM has demonstrated superior long-term outcomes compared to PBD, with lower recurrence rates and improved symptom control. A growing body of evidence supports the use of robotic-assisted Heller myotomy, which offers enhanced precision and dexterity, reducing intraoperative complications.

Peroral endoscopic myotomy (POEM) has emerged as a minimally invasive alternative to LHM, showing promising results in pediatric patients. POEM involves creating a submucosal tunnel to perform myotomy endoscopically without external incisions. Studies indicate that POEM achieves similar success rates to LHM, with fewer complications and shorter hospital stays. However, concerns about long-term reflux complications remain, as POEM does not include a concurrent anti-reflux procedure.

Comparative studies between PBD, LHM, and POEM have suggested that LHM provides the most durable symptom relief, whereas PBD is associated with higher recurrence rates requiring repeat interventions. A recent multicenter study comparing endoscopic dilation and myotomy in children confirmed that LHM had a significantly higher success rate with fewer retreatments. However, in select cases where surgical intervention is contraindicated, PBD or POEM may be viable alternatives.

Advancements in diagnostic techniques and treatment modalities continue to improve the management of pediatric achalasia. The use of EndoFLIP during surgical and endoscopic procedures allows for real-time assessment of esophageal distensibility, potentially guiding the extent of myotomy. Additionally, high-resolution manometry enables better subclassification of achalasia into types I, II, and III, which may influence treatment selection. Ongoing randomized controlled trials aim to further clarify the optimal management strategies, particularly comparing POEM and LHM in children.

Despite these advancements, the rarity of pediatric achalasia necessitates a multidisciplinary approach involving pediatric gastroenterologists, surgeons, and dietitians to ensure optimal outcomes. Early recognition and intervention are crucial in preventing disease progression and minimizing complications. Long-term follow-up is essential, as some children may require additional interventions for symptom recurrence or complications such as gastroesophageal reflux. Continued research and collaboration among specialized centers will further enhance the understanding and treatment of this challenging disorder.

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Venous Insufficiency

Pediatric venous insufficiency (PVI) is a condition that has historically been overlooked due to its perceived rarity and the assumption that it primarily affects adults. However, recent studies have challenged this view, revealing that children and adolescents can present with a wide range of venous disorders, some of which mirror adult presentations while others are distinct due to congenital or developmental vascular anomalies. The lack of standardized pediatric-specific diagnostic criteria and treatment guidelines complicates clinical management and long-term care.

A descriptive study published in 2015 by Andraska and colleagues examined 20 pediatric patients under 18 years old who underwent venous reflux studies. The most common indications for referral were limb swelling, varicose veins, and rubor or acrocyanosis. Duplex ultrasound revealed venous reflux in 90% of cases. Interestingly, one-third of the patients were ultimately diagnosed with conditions other than primary venous insufficiency, including vascular malformations, lymphedema, and complex regional pain syndrome (CRPS). This highlights the diagnostic complexity in pediatric populations, where reflux may be present but not pathologic, or may be secondary to another vascular condition. Moreover, the study found that superficial valve closure time was significantly prolonged in patients with primary chronic venous insufficiency (CVI) and Klippel-Trenaunay syndrome (KTS), distinguishing them from those with alternative diagnoses.

A 2016 follow-up study from the same group reinforced these findings. Among a similar cohort, superficial reflux time was again significantly elevated in those with primary chronic venous disease (CVD) and KTS. In 44% of cases, an alternative diagnosis was made despite ultrasound evidence of reflux. The absence of typical signs like hyperpigmentation or ulceration suggests a milder, yet clinically relevant, disease course. These results emphasized the value of adjunct imaging such as magnetic resonance venography and lymphoscintigraphy in confirming or ruling out CVI, especially in patients with ambiguous symptoms.

In children with KTS—a congenital vascular disorder characterized by capillary

malformations, limb overgrowth, and venous abnormalities—venous insufficiency is common and often more severe. Persistent embryonic veins (PEVs), including lateral marginal veins (LMVs) and persistent sciatic veins (PSVs), contribute to chronic reflux. A 2021 clinical study evaluated the feasibility and safety of mechanochemical ablation (MOCA) in 11 pediatric patients with KTS. MOCA, which uses a combination of mechanical endothelial injury and chemical sclerotherapy, achieved 100% technical success and primary vein occlusion. Two patients experienced partial recanalization after over a year but responded well to repeat treatment. No major complications were reported. The study highlighted MOCA's value in avoiding heat-related risks associated with thermal ablation—particularly important in pediatric patients with delicate vascular structures.

A 2025 retrospective review of a rural pediatric population added broader insight into the practical management of venous insufficiency. Thirty-four adolescents were included, with the majority presenting with bilateral symptoms. After evaluation, 13 patients underwent treatment including radiofrequency ablation (RFA), endovenous laser ablation (EVLA), ultrasound-guided sclerotherapy, or microphlebectomy. RFA and EVLA were associated with 100% vein occlusion and no significant complications. Patients resumed normal activity within 48 hours, and cosmetic outcomes were favorable—an important factor in treating adolescents. Notably, female patients were more likely to present with bilateral disease, while male patients were more likely to undergo treatment. The study also found no significant associations between disease severity and age, body mass index (BMI), or vein diameter.

Across all studies, a consistent theme emerged: pediatric venous reflux is common, but not always clinically significant. Physiologic reflux has been observed in up to 13% of healthy adolescents, suggesting that adult diagnostic thresholds may not be appropriate for children. Nevertheless, in symptomatic patients with confirmed reflux and failure of conservative management (e.g., compression therapy), minimally invasive procedures such as RFA, EVLA, or MOCA are increasingly preferred over traditional surgical options.

The differential diagnosis for pediatric lower extremity symptoms remains broad. Venous insufficiency may mimic or coexist with conditions such as lymphedema, vascular malformations, CRPS, or postural orthostatic tachycardia syndrome (POTS). A multidisciplinary evaluation, including advanced imaging and vascular expertise, is often necessary for accurate diagnosis and targeted treatment.

The natural history of pediatric CVI is still not well understood. It remains unclear whether early intervention changes disease trajectory or prevents complications like venous ulcers later in life. However, the current evidence supports that early diagnosis and treatment—when indicated—can improve symptoms, functional outcomes, and quality of life. Minimally invasive techniques, with low risk and strong cosmetic outcomes, are especially suitable for this age group.

In conclusion, pediatric venous insufficiency is more prevalent than previously assumed and requires careful diagnostic evaluation to differentiate true pathology from physiologic

variants. Emerging treatments such as MOCA, RFA, and EVLA have shown to be safe and effective when used appropriately. Further prospective studies are needed to refine diagnostic criteria, validate treatment thresholds, and establish long-term outcomes in this unique population.

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