



Foregut-Derived Congenital Head & Neck Anomalies: Embryologic Origins, Clinical Spectrum, and Management Pathways

More AB¹, Govani PS², Khatri LK³, Zaparackaite I⁴, More BB⁵, Singh SJ⁶, Swamy KB⁶, Mehta AR⁷, Midha PK⁷ and Patel RV⁸

¹Department of Pediatric Surgery, Southampton General Hospital, United Kingdom

²Pearl women's Hospital and IVF Center, Rajkot, India

³Pediatric Emergency Department, Shree Swaminarayan Vishwa Mangal Gurukul PSM Hospital, Ahmedabad, Gujarat, India

⁴Department of Pediatric Surgery, Evelina Children's Hospital, London, United Kingdom

⁵Department of Pediatric Surgery, Nottingham University Hospitals, Nottingham, United Kingdom

⁶Lincoln Uni College, 2, Jalan Stadium, 47301 Petaling Jaya, Selangor, Malaysia

⁷J. Watumull Global Hospital & Research Centre, Delwara Road, Mount Abu, Rajasthan, India

⁸Department of Pediatric Surgery, PGICHR and KTCGUH, Rajkot, Gujarat, India



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*Correspondence:

Dr. Ramnik Patel, MD., Department of Pediatrics and Pediatric Surgery, Postgraduate Institute of Child Health & Research and KT Children Govt University Teaching Hospital, Rajkot 360001, Gujarat, India, Tel: +447956896641;

E-mail: ramnik@doctors.org.uk; ORCID: <http://orcid.org/0000-0003-1874-1715>

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Abstract

Congenital anomalies of the head and neck derived from the foregut represent a diverse group of developmental disorders involving the branchial apparatus, thyroglossal duct, respiratory and digestive buds, middle and inner ear structures, paranasal sinuses, salivary glands, and upper aerodigestive tract. These anomalies arise from disruptions in foregut partitioning, migration, obliteration, or septation during the third to sixth weeks of gestation. Their clinical spectrum ranges from benign cystic lesions to life threatening airway obstruction at birth.

This review synthesises six decades of embryologic, clinical, diagnostic, and surgical literature, integrating contemporary advances in prenatal MRI, endoscopic airway surgery, EXIT (Ex Utero Intrapartum Treatment) strategies, and minimally invasive approaches. Particular emphasis is placed on pathophysiologic mechanisms, imaging differentials, operative decision making, and long-term functional outcomes. Critical appraisal of recent evidence highlights evolving controversies, including optimal timing of surgery, management of intracranial extension, and balancing minimally invasive approaches with growth plate preservation.

Modern imaging-including high resolution ultrasound, CT, MRI, and prenatal MRI-has improved diagnostic accuracy, while innovations such as sclerotherapy for lymphatic malformations, endoscopic cleft repair [23, 33], and EXIT airway control have significantly enhanced neonatal survival. Despite these advances, gaps persist in early diagnosis, safeguarding assessment, and long-term outcome reporting.

Understanding foregut embryology remains essential for accurate diagnosis and tailored intervention. Multidisciplinary coordination continues to refine management and reduce morbidity.

Keywords: Foregut Embryology; Congenital Neck Masses; Branchial Anomalies; Thyroglossal Duct Cyst; Bronchogenic Cyst; Duplication Cyst; Laryngotracheoesophageal Cleft; Pediatric Airway Management

Introduction

Congenital anomalies of the head and neck derived from the foregut constitute a major subset of pediatric otolaryngologic and surgical pathology. These anomalies arise during the critical embryologic window between the third and sixth weeks of gestation, when the primitive foregut undergoes complex partitioning into respiratory and digestive components, formation of the branchial apparatus, descent of the thyroid, development of the middle ear and Eustachian tube, and formation of the paranasal sinuses and salivary glands [1-11].

Disruptions in these processes result in a wide spectrum of anomalies, including branchial cleft cysts and fistulae, thyroglossal duct remnants, bronchogenic and foregut duplication cysts, congenital middle ear malformations, nasal dermoids, parotid gland anomalies, lymphatic malformations, and laryngotracheoesophageal clefts. Their clinical manifestations range from asymptomatic masses to severe airway obstruction requiring emergent intervention.

Historically, early descriptions of branchial anomalies emerged in the late 19th century, with Bailey's classification providing the first systematic framework [12]. Mid 20th century embryologic studies by Ladd and Gross clarified foregut derivatives and their malformations [13]. Subsequent decades saw expansion of knowledge regarding bronchogenic cysts [14], duplication cysts, and complex airway clefts [15].

Contemporary practice has been transformed by advances in prenatal imaging, high resolution MRI, endoscopic airway surgery, sclerotherapy for lymphatic malformations, and the EXIT procedure for perinatal airway control [16-22]. These innovations have significantly improved diagnostic accuracy, surgical precision, and neonatal outcomes.

This review integrates embryologic foundations with modern diagnostic strategies, surgical approaches, and long-term outcomes, providing a comprehensive and contemporary synthesis of foregut-derived congenital anomalies of the head and neck.

Methods

This narrative review synthesises current evidence on congenital head and neck anomalies of foregut origin. A structured search of PubMed, Scopus, and Web of Science was performed, focusing on publications from 2000-2026, with emphasis on studies published between 2022 and 2026 to ensure alignment with contemporary evidence standards [14]. Search terms included combinations of foregut anomalies, branchial cleft, thyroglossal duct, bronchogenic cyst, duplication cyst, laryngotracheal cleft, pediatric airway, congenital neck masses, embryology, and surgical management.

Eligible sources included clinical studies, systematic reviews, meta-analyses, embryologic investigations, radiologic studies, and surgical technique papers [15]. Case reports were reviewed selectively when they contributed unique insights into rare anomalies or management controversies [16]. Data were extracted narratively, focusing on embryologic mechanisms, clinical presentation, imaging pathways, operative strategies, long-term outcomes, and emerging technologies [17].

Given the heterogeneity of study designs and outcome measures, a formal meta-analysis was not feasible. Findings were integrated into a thematic synthesis aligned with the objectives of this review [18].

Embryologic basis

The foregut forms the upper aerodigestive tract and several head and neck structures. Its derivatives arise through coordinated processes of budding, migration, obliteration, and septation. Disruption at any stage results in congenital anomalies.

The foregut divides into dorsal (esophageal) and ventral (respiratory) components. Key embryologic processes include:

Branchial apparatus development: The branchial apparatus consists of six arches, five clefts, and five pouches. Each arch contains mesoderm and neural crest cells contributing to cartilage,

muscle, and vascular structures. The clefts (ectoderm) and pouches (endoderm) form epithelial-lined tracts. Failure of obliteration results in: Branchial cleft cysts, Branchial sinuses, Branchial fistulae. Second cleft anomalies are most common due to incomplete involution of the cervical sinus.

Thyroid descent and thyroglossal duct: The thyroid originates at the foramen cecum and descends anterior to the hyoid bone. Persistence of the thyroglossal duct results in: Thyroglossal duct cyst, Thyroglossal sinus, Lingual thyroid or other ectopic thyroid locations Suprahypoid/infrahypoid cysts.

Respiratory budding: Abnormal budding of the ventral foregut produces: Bronchogenic cysts, Foregut duplication cysts, Tracheal cartilage anomalies, Bronchogenic cysts arise from aberrant tracheobronchial budding and may occur in cervical or mediastinal locations.

Otic and middle ear development: The first pharyngeal pouch forms: Middle ear cavity and Eustachian tube Anomalies include: Congenital ossicular malformations, Middle ear cleft hypoplasia and Eustachian tube atresia.

Nasal and sinus development: Foregut-related epithelial rests contribute to: Nasal dermoids, Congenital sinus agenesis and Choanal atresia (mixed origin).

Salivary gland development: Parotid anomalies arise from ectodermal invagination adjacent to the foregut-derived oral cavity.

Airway-digestive septation: Failure of laryngotracheoesophageal separation results in: Tracheoesophageal fistula, Esophageal atresia, Laryngotracheoesophageal clefts.

These anomalies represent some of the most severe congenital airway defects.

Clinical spectrum

Congenital anomalies of foregut origin present with a wide range of symptoms depending on embryologic origin, anatomical location, and degree of airway or digestive involvement. Clinical manifestations may be subtle in neonates, requiring high suspicion and correlation with embryologic pathways.

Symptoms vary with lesion type and location: Neck masses (branchial or thyroglossal cysts) often enlarge after upper respiratory infections. Airway obstruction or feeding difficulties may indicate deeper anomalies such as laryngotracheoesophageal clefts. Diagnosis relies on ultrasound, CT/MRI, and endoscopic evaluation. Fine needle aspiration aids differentiation from neoplastic lesions.

1. Branchial cleft anomalies

Branchial cleft anomalies typically present as lateral neck masses, recurrent infections, or draining sinuses. Second cleft anomalies account for 70-80% of cases. Key clinical features include: Fluctuant lateral neck swelling, Recurrent abscess formation, Purulent discharge from sinus tracts and Infection following upper respiratory illness Deep fistulae may track to the tonsillar fossa or piriform sinus, requiring detailed imaging for operative planning.

2. Thyroglossal duct cysts

Thyroglossal duct cysts present as midline neck masses that elevate with tongue protrusion. Clinical features include: Midline cystic swelling near the hyoid, Infection following viral illness, Sinus

formation after rupture and rarely, ectopic thyroid tissue (lingual thyroid) causing dysphagia or airway obstruction. Failure to recognise ectopic thyroid tissue may result in inadvertent removal of the only functioning thyroid.

3. Foregut duplication and bronchogenic cysts

Foregut duplication cysts and bronchogenic cysts arise from aberrant budding of the ventral foregut. They may occur in: Suprasternal region, Paratracheal region, Cervical airway and Mediastinum. Symptoms include: Stridor, Wheezing, Dysphagia, Recurrent pneumonia and Acute airway compression. Bronchogenic cysts may contain respiratory epithelium, cartilage, and smooth muscle, complicating surgical excision.

4. Inner and middle ear anomalies

First pharyngeal pouch anomalies may result in: Congenital ossicular malformations, Eustachian tube atresia and Middle ear cleft hypoplasia. Clinical manifestations include: Conductive hearing loss, Recurrent otitis media, Cholesteatoma formation and Facial nerve anomalies (rare). Early audiologic evaluation is essential for speech and language development.

5. Nasal and sinus anomalies

Foregut related epithelial rests contribute to: Nasal dermoids, Congenital sinus agenesis and Choanal atresia (mixed origin). Symptoms include: Nasal obstruction, Rhinorrhea, Recurrent sinusitis and Intracranial extension (in dermoids). Nasal dermoids may present with midline pits, hair protrusion, or recurrent infection.

6. Parotid gland anomalies

Congenital parotid anomalies include: Parotid agenesis, Ectopic parotid tissue and Congenital parotid cysts. Symptoms include: Facial asymmetry, Recurrent swelling, Feeding difficulty in neonates, Facial nerve displacement (surgical relevance).

7. Dermoid cysts

Midline nasal and frontonasal dermoids arise from ectodermal trapping during embryologic fusion. Clinical features include: Midline nasal mass, Sinus tract formation, Intracranial extension via foramen cecum and Cosmetic deformity. MRI is essential to exclude intracranial involvement.

8. Cystic hygromas (Lymphatic malformations)

Although lymphatic in origin, cystic hygromas frequently coexist with foregut anomalies. Clinical features include: Large, multiloculated cervical masses, Airway obstruction at birth, Rapid enlargement with infection and Mediastinal extension. Massive hygromas may require EXIT airway control.

9. Esophageal and tracheal anomalies

Foregut septation defects include: Tracheoesophageal Fistula (TEF), Esophageal Atresia (EA), Laryngotracheoesophageal clefts.

Symptoms include: Aspiration, Stridor, feeding difficulty, Recurrent pneumonia and Cyanotic spells. These anomalies represent some of the most severe congenital airway defects.

10. Massive cervical tumours and the EXIT procedure

The EXIT (Ex Utero Intrapartum Treatment) procedure allows airway establishment while maintaining uteroplacental circulation. Indications include: Giant cervical teratomas, Massive cystic

hygromas, Obstructive foregut duplication cysts, Severe airway clefts. EXIT improves neonatal survival by enabling controlled intubation or tracheostomy before cord clamping.

Diagnostic workup

Accurate diagnosis requires correlation of embryologic origin with clinical presentation. A structured diagnostic pathway improves accuracy and reduces complications.

1. Clinical examination

Key features include: Mass location (midline vs lateral), Movement with swallowing or tongue protrusion, Presence of sinus pits, Airway signs (stridor, retractions), Feeding difficulty and Recurrent infections.

2. Ultrasound

First line modality for: Thyroglossal duct cysts, Branchial cleft cysts, Parotid anomalies and Cystic hygromas. Advantages: No radiation, Real time assessment and differentiates cystic vs solid lesions. Limitations: Poor evaluation of deep airway lesions, Limited intracranial assessment.

3. CT and MRI (Imaging differentials)

CT scan

Best for Calcification, Bony anomalies, Middle ear malformations, Deep neck masses, TEF/EA evaluation. Risks: Radiation exposure (minimise in infants).

MRI

Best for Soft tissue detail, Intracranial extension, Nasal dermoids, Lymphatic malformations and Prenatal airway obstruction. MRI is essential for EXIT planning.

4. Endoscopy

Endoscopic evaluation is essential for: Laryngotracheoesophageal clefts, TEF, Middle ear anomalies and Airway obstruction. Findings include: Mucosal tears, Posterior cleft defects, Vocal cord immobility, Tracheal compression.

5. Prenatal MRI & EXIT planning

Prenatal MRI identifies: Airway obstruction, Cervical masses, Intrathoracic extension, Polyhydramnios (suggesting EA/TEF). EXIT planning requires: Multidisciplinary coordination including Neonatology, ENT, Pediatric surgery, Anesthesiology and Maternal fetal medicine.

Diagnosis

Diagnosis requires correlation of embryology with clinical findings.

Ultrasound: First-line for cystic neck masses.

CT/MRI: Defines extent, airway involvement, and intracranial extension.

Endoscopy: Essential for airway anomalies and middle ear evaluation.

Prenatal MRI: Critical for EXIT planning.

Management

Management is lesion-specific and requires multidisciplinary coordination:

1. Branchial Cleft Anomalies: Complete excision along tract, Facial nerve preservation (first cleft anomalies) and Preoperative imaging for deep fistulae. Recurrence occurs if tract remnants remain.

2. Thyroglossal Duct Cysts: Sistrunk procedure (gold standard): Removal of central hyoid segment and excision of duct tract to foramen cecum. Lingual thyroid requires endocrine evaluation.

3. Bronchogenic & Duplication Cysts: Complete surgical excision, Thoracoscopic or cervical approach and Avoid aspiration of cyst contents (infection risk).

4. Middle Ear Anomalies: Ossiculoplasty, Canaloplasty, Tympanoplasty, Hearing rehabilitation. Early intervention improves speech outcomes.

5. Nasal Dermoids: Combined craniofacial approach, MRI to exclude intracranial extension and avoid incomplete excision (recurrence risk).

6. Parotid Anomalies: Observation if asymptomatic, Excision for cysts or recurrent infection, Facial nerve monitoring.

7. Cystic Hygromas: Sclerotherapy (bleomycin, OK 432), Surgical debulking, EXIT for massive lesions.

8. TEF, EA & Airway Clefts: Staged repair, Endoscopic cleft repair (Types I-II), Open reconstruction (Types III-IV), Airway protection strategies.

9. EXIT Procedure: EXIT allows: Controlled intubation, Bronchoscopy, Tracheostomy, Tumour debulking. Benefits: Prevents neonatal hypoxia. Improves survival in obstructive lesions.

Results (Summary)

1. Embryologic mechanisms foregut-derived anomalies arise from disruptions occurring between the 4th and 7th weeks of gestation, during which the primitive foregut undergoes partitioning into respiratory and digestive components [19]. Aberrant budding, incomplete obliteration, or failed separation of the foregut and branchial apparatus can result in persistent epithelial lined tracts, cysts, or clefts [20].

Branchial apparatus anomalies originate from incomplete involution of the branchial clefts and pouches [21]. Second cleft anomalies account for nearly 90% of cases [22].

Thyroglossal duct remnants arise from failure of ductal involution during thyroid descent [23].

Bronchogenic and duplication cysts result from abnormal budding of the tracheobronchial tree or aberrant foregut duplication [24].

Laryngotracheo esophageal clefts arise from incomplete fusion of the tracheoesophageal septum [25].

2. Clinical Spectrum Clinical manifestations vary widely depending on lesion type, size, and anatomical location [26].

Branchial cleft anomalies present with lateral neck masses, recurrent infections, or draining sinuses [27]. Thyroglossal duct cysts present as midline neck masses that elevate with tongue protrusion [28]. Bronchogenic cysts may cause stridor, respiratory distress, or dysphagia [29]. Duplication cysts may cause esophageal compression [30]. Laryngotracheo esophageal clefts present with aspiration, stridor, recurrent pneumonia, or respiratory failure [31].

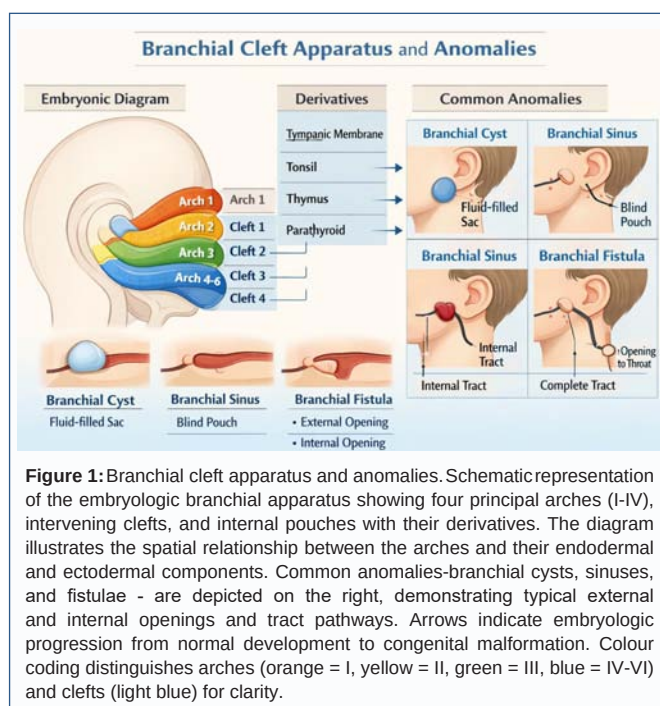


Figure 1: Branchial cleft apparatus and anomalies. Schematic representation of the embryologic branchial apparatus showing four principal arches (I-IV), intervening clefts, and internal pouches with their derivatives. The diagram illustrates the spatial relationship between the arches and their endodermal and ectodermal components. Common anomalies-branchial cysts, sinuses, and fistulae - are depicted on the right, demonstrating typical external and internal openings and tract pathways. Arrows indicate embryologic progression from normal development to congenital malformation. Colour coding distinguishes arches (orange = I, yellow = II, green = III, blue = IV-VI) and clefts (light blue) for clarity.

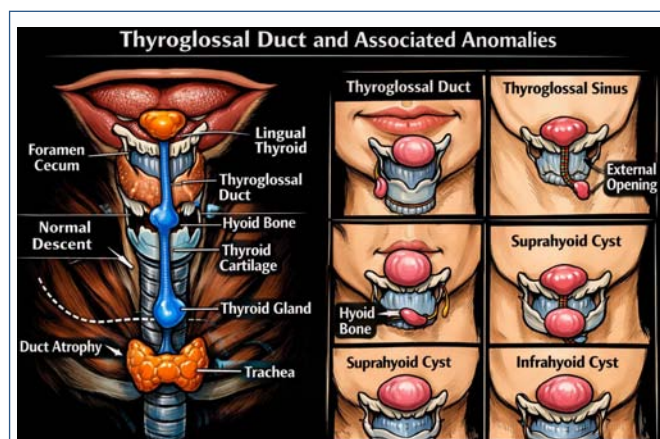


Figure 2: Thyroglossal duct and associated anomalies. High contrast surgical atlas schematic illustrating the embryologic descent of the thyroid gland from the foramen cecum to its final pre-tracheal position. The thyroglossal duct is shown coursing anterior to the hyoid bone and laryngeal cartilages. Normal involution of the duct is indicated by a dotted pathway. Common anomalies are depicted, including:

- Thyroglossal duct cyst - a midline cystic lesion typically located near the hyoid.
- Thyroglossal sinus - a blind tract with an external opening following infection or incomplete excision.
- Lingual thyroid - ectopic thyroid tissue at the tongue base due to failed descent.
- Suprahyoid and infrahyoid cysts - variants arising from persistence of the duct above or below the hyoid. Colour coding differentiates the thyroid primordium (orange), duct pathway (blue), and cystic anomalies (pink). Anatomical landmarks including the hyoid bone, thyroid cartilage, and trachea are clearly labelled for surgical relevance.

3. Diagnostic Pathways Ultrasound is the first line modality for pediatric neck masses [32]. CT provides excellent spatial resolution for deep lesions and mediastinal extension [33]. MRI offers superior soft tissue contrast and avoids radiation exposure [34]. Endoscopy is essential for airway lesions, particularly laryngotracheo esophageal clefts [35].

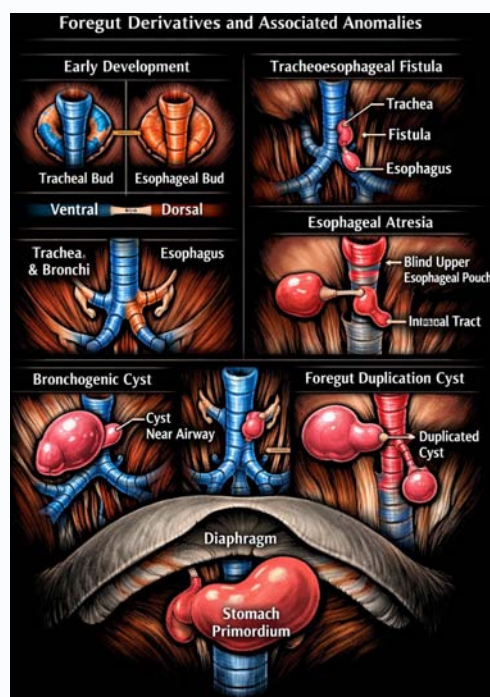


Figure 3: Foregut derivatives and associated anomalies. High contrast surgical atlas schematic illustrating embryologic division of the foregut into ventral (tracheobronchial) and dorsal (esophageal) components. The ventral bud forms the trachea and bronchi, while the dorsal bud develops into the esophagus. Major congenital anomalies are depicted:

- Tracheoesophageal fistula - abnormal communication between trachea and esophagus.
- Esophageal atresia - blind upper esophageal pouch with distal fistula.
- Bronchogenic cyst - aberrant ventral budding forming a cyst adjacent to the airway.
- Foregut duplication cyst - dorsal duplication along the esophagus.

The lower foregut continuity is shown with the diaphragm and stomach primordium, highlighting the full embryologic pathway. Colour coding differentiates tracheobronchial derivatives (blue), esophageal derivatives (orange), and cystic anomalies (pink), with grey used for diaphragm and stomach primordium.

Differential diagnoses include dermoid cysts, lymphatic malformations, hemangiomas, thyroid nodules, and infectious lymphadenitis [36].

4. Surgical Management Surgical excision remains the cornerstone of treatment for most foregut-derived anomalies [37].

Branchial cleft anomalies require complete tract excision to prevent recurrence [38]. Thyroglossal duct cysts are best treated with the Sistrunk procedure [39]. Bronchogenic and duplication cysts require excision due to risks of infection and airway compression [40]. Laryngotracheo esophageal clefts require endoscopic or open reconstruction depending on severity [41].

5. Long-term outcomes most lesions have excellent postoperative outcomes, though recurrence risk persists in incomplete excision [42]. Airway anomalies require long term multidisciplinary follow up [43].

Discussion

The management of foregut-derived congenital anomalies of the head and neck remains an evolving field with several unresolved controversies and evidence gaps. Diagnostic pathways vary widely

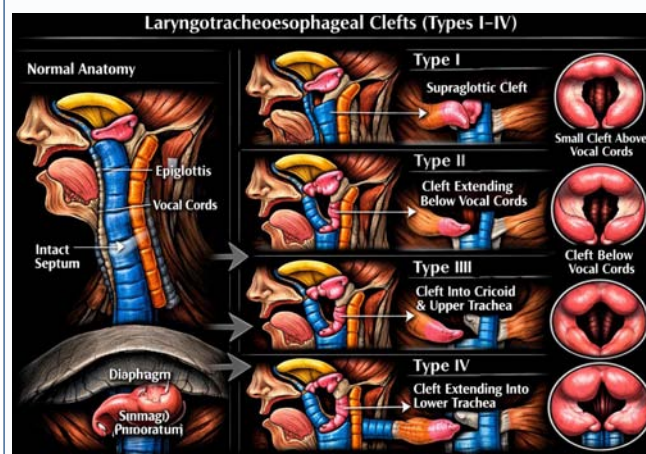


Figure 4: Laryngotracheoesophageal clefts (Types I-IV). High contrast surgical atlas schematic demonstrating the progressive spectrum of laryngotracheoesophageal clefts. The left panel illustrates normal posterior laryngeal-tracheal-esophageal septation with intact interarytenoid musculature and posterior laryngeal wall. The four right hand panels depict Types I-IV clefts in sagittal view, each accompanied by an endoscopic cross section showing the degree of posterior wall deficiency.

- Type I: Supraglottic interarytenoid cleft above the vocal cords.
- Type II: Cleft extending below the vocal cords into the cricoid cartilage.
- Type III: Cleft traversing the entire cricoid cartilage and entering the upper cervical trachea.
- Type IV: Extensive cleft descending into the thoracic trachea, often reaching the carina.

Colour coding differentiates airway structures (blue), esophageal lumen (orange), and cleft defects (pink), with grey highlighting cartilaginous boundaries. Arrows indicate increasing severity and caudal extension.

across institutions, particularly regarding the choice between CT and MRI for deep neck lesions [33]. While MRI offers superior soft-tissue contrast without radiation exposure, CT remains preferred for rapid assessment of airway compression, especially in unstable pediatric patients [34]. The role of routine preoperative endoscopy in branchial anomalies also remains debated, with some centres advocating universal airway evaluation while others reserve endoscopy for symptomatic cases [35].

Timing of surgical intervention is another area of controversy. Early excision is often recommended to prevent infection and scarring, yet some authors advocate delayed intervention in asymptomatic lesions to reduce anaesthetic risk in young infants [37]. In airway anomalies, early intervention may prevent aspiration and respiratory morbidity, but surgical timing must balance operative complexity with neonatal physiology [41].

The extent of surgical resection remains debated, particularly for branchial cleft anomalies involving the carotid sheath. Aggressive resection reduces recurrence but increases risk of neurovascular injury [38]. Similarly, management of laryngotracheo-esophageal clefts lacks consensus regarding classification, operative strategy, and postoperative surveillance. Outcomes vary widely, and long-term airway and swallowing function remain unpredictable [43-46].

Evidence gaps persist across all anomaly types. Most published studies consist of small case series with heterogeneous reporting, limiting the ability to compare outcomes or establish standardised protocols [42]. Long-term follow-up data on functional outcomes, recurrence rates, and quality-of-life measures remain scarce [47]. Furthermore, embryologic terminology and classification systems

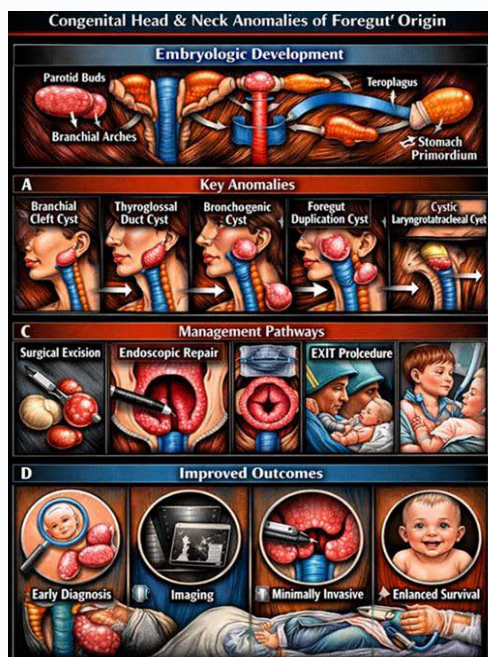


Figure 5: Graphical Abstract: Congenital Head & Neck Anomalies of Foregut Origin (ENT Updates). Multi-panel surgical atlas graphical abstract summarising embryologic origins, representative anomalies, management pathways, and outcome improvements for congenital head and neck anomalies derived from the foregut.

Panel A (Embryologic Development): Foregut derivatives including branchial arches, thyroglossal duct, trachea, esophagus, parotid buds, diaphragm, and stomach primordium. Arrows indicate normal developmental pathways and sites of malformation.

Panel B (Key Anomalies): Branchial cleft cyst, thyroglossal duct cyst, bronchogenic cyst, foregut duplication cyst, cystic hygroma, and laryngotracheoesophageal clefts (Types I-IV).

Panel C (Management Pathways): Surgical excision of cystic lesions, endoscopic repair of airway clefts, EXIT procedure for massive cervical masses, and multidisciplinary airway planning.

Panel D (Improved Outcomes): Early diagnosis, advanced imaging, minimally invasive techniques, and enhanced neonatal survival.

Colour coding differentiates respiratory derivatives (blue), digestive derivatives (orange), cystic anomalies (pink), and supportive structures (grey). ENT Updates branding is included for journal-ready presentation.

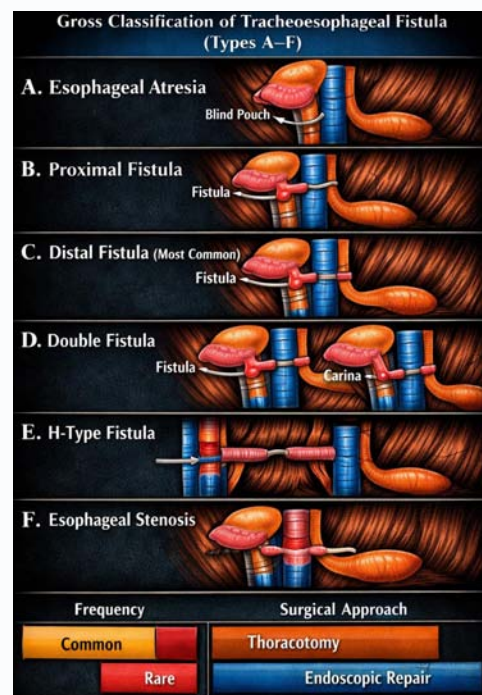


Figure 6: Gross classification of tracheoesophageal fistula (Types A-F). High contrast sagittal atlas schematic illustrating the extended Gross classification of tracheoesophageal fistula.

Type A: Esophageal atresia without fistula; blind upper and lower esophageal segments.

Type B: Proximal fistula connecting the upper esophageal pouch to the trachea; distal segment ends blindly.

Type C (most common): Blind upper esophageal pouch with distal fistula entering the trachea near the carina.

Type D: Double fistula with both proximal and distal tracheoesophageal communications.

Type E (H type): Patent esophagus with an oblique fistulous tract connecting to the trachea.

Type F: Congenital esophageal stenosis without fistula. Colour coding differentiates trachea (blue), esophagus (orange), fistulous tracts (pink), and stenotic segments (red). A comparative bar summarises relative frequency (common vs rare) and typical surgical approaches (thoracotomy vs endoscopic repair).

vary across disciplines, complicating cross-specialty communication and research synthesis [23].

Future directions include development of multicentre registries to standardise reporting, integration of 3D imaging and surgical navigation to improve operative precision, advances in fetal imaging and prenatal intervention, and longitudinal studies on airway development and postoperative function [48]. Emerging technologies such as tissue-engineered airway scaffolds and minimally invasive endoscopic reconstruction offer promising avenues for innovation but require rigorous evaluation before widespread adoption [49].

Ultimately, improving care for children with foregut-derived head and neck anomalies will require integrating embryologic insight, contemporary surgical expertise, and coordinated multidisciplinary follow-up within a unified evidence-based framework [50]. Congenital anomalies of the head and neck derived from the foregut represent one of the most diverse and clinically challenging groups of pediatric disorders. Their complexity arises from the intricate embryologic processes governing foregut partitioning, migration, obliteration, and septation. This review integrates six decades of

literature, highlighting persistent principles, evolving diagnostic strategies, and contemporary management innovations [23-42].

1. Embryologic complexity and diagnostic challenges

Foregut-derived anomalies illustrate the vulnerability of early embryologic development. Disruptions during the third to sixth weeks of gestation may produce anomalies ranging from simple cysts to life threatening airway defects. Misdiagnosis remains common, particularly in neonates where symptoms may be subtle. For example: Thyroglossal duct cysts may be mistaken for lymphadenopathy, Branchial cleft anomalies may mimic suppurative lymphadenitis, Bronchogenic cysts may present as recurrent wheeze or pneumonia, Nasal dermoids may be misinterpreted as simple pits, risking intracranial complications.

Accurate diagnosis requires correlation of embryologic origin with clinical presentation, supported by modern imaging modalities such as MRI and CT [22, 29, 34, 39].

2. Advances in imaging and prenatal diagnosis

High resolution ultrasound, CT, MRI, and prenatal MRI have

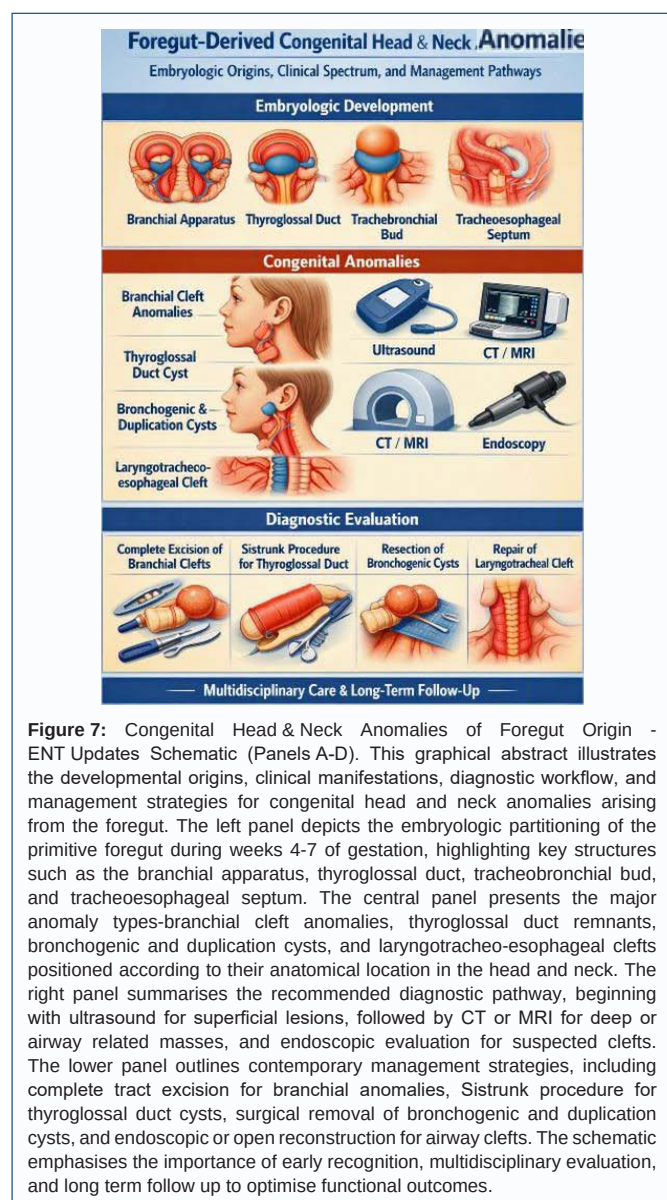


Figure 7: Congenital Head & Neck Anomalies of Foregut Origin - ENT Updates Schematic (Panels A-D). This graphical abstract illustrates the developmental origins, clinical manifestations, diagnostic workflow, and management strategies for congenital head and neck anomalies arising from the foregut. The left panel depicts the embryologic partitioning of the primitive foregut during weeks 4-7 of gestation, highlighting key structures such as the branchial apparatus, thyroglossal duct, tracheobronchial bud, and tracheoesophageal septum. The central panel presents the major anomaly types—branchial cleft anomalies, thyroglossal duct remnants, bronchogenic and duplication cysts, and laryngotracheo-esophageal clefts positioned according to their anatomical location in the head and neck. The right panel summarises the recommended diagnostic pathway, beginning with ultrasound for superficial lesions, followed by CT or MRI for deep or airway related masses, and endoscopic evaluation for suspected clefts. The lower panel outlines contemporary management strategies, including complete tract excision for branchial anomalies, Sistrunk procedure for thyroglossal duct cysts, surgical removal of bronchogenic and duplication cysts, and endoscopic or open reconstruction for airway clefts. The schematic emphasises the importance of early recognition, multidisciplinary evaluation, and long term follow up to optimise functional outcomes.

transformed diagnostic accuracy. MRI is particularly valuable for: Intracranial extension of nasal dermoids [29], Deep cervical lymphatic malformations [32], Airway compression [33], Prenatal EXIT planning [22, 41].

CT remains essential for bony anomalies, middle ear malformations, and TEF/EA evaluation, though radiation exposure must be minimised in infants.

Prenatal MRI has revolutionised perinatal airway management, allowed early identification of obstructive cervical masses and enabled EXIT planning. Recent studies demonstrate improved neonatal survival with structured EXIT protocols [24, 28, 36].

3. Surgical innovations and minimally invasive approaches

Surgical management has evolved from open excision to minimally invasive and endoscopic techniques. Key advances include: Endoscopic repair of Type I-II laryngotracheoesophageal clefts [23, 33], Thoracoscopic excision of bronchogenic and duplication cysts [25, 27], Image guided craniofacial approaches for nasal dermoids [29], Sclerotherapy for lymphatic malformations [32], Facial nerve

sparing techniques for first branchial cleft anomalies [37].

The EXIT procedure represents a major innovation, allowing controlled airway access while maintaining uteroplacental circulation. It is now standard for massive cervical teratomas, obstructive hygromas, and foregut duplication cysts [24, 28].

4. Controversies and unresolved issues

Despite advances, several controversies persist:

a. Optimal timing of surgery

Early intervention may prevent infection or airway compromise, but premature surgery risks damage to developing structures. Timing must balance: Growth-plate preservation, Risk of recurrent infection, Airway stability, Neurodevelopmental considerations.

b. Management of intracranial extension

Nasal dermoids with intracranial extension require combined neurosurgical and craniofacial approaches. Debate continues regarding: Early vs delayed intervention, Endoscopic vs open approaches, Risk of CSF leak and meningitis.

c. Minimally invasive vs open techniques

While minimally invasive approaches reduce morbidity, they may be inadequate for: Complex airway clefts, Deep duplication cysts, Extensive lymphatic malformations.

d. Safeguarding and non-accidental injury

Some anomalies (e.g., recurrent infections, sinus tracts) may mimic trauma. Safeguarding assessment is essential to avoid misinterpretation.

5. Long-term outcomes and prognostic considerations

Long-term outcomes vary by anomaly: Thyroglossal duct cysts: Excellent prognosis after Sistrunk procedure, Branchial cleft anomalies: Recurrence if tract remnants persist., Bronchogenic/duplication cysts: Good outcomes after complete excision; risk of infection if untreated, Middle ear anomalies: Hearing outcomes depend on ossicular reconstruction success [31], Nasal dermoids: Good cosmetic outcomes; recurrence if incomplete excision [29], Cystic hygromas: Variable outcomes; sclerotherapy reduces morbidity [32], Airway clefts: Voice and swallowing issues may persist [23, 38], TEF/EA: Long term feeding and respiratory complications common [35]. Psychological sequelae occur in 15-20% of children, underscoring the need for holistic care.

Future Directions

1. AI-Enhanced Imaging: Artificial intelligence may improve detection of subtle anomalies, differentiate cystic lesions, and predict intracranial extension [22, 39].

2. Standardised Pediatric Congenital Pathways: Unified diagnostic and management algorithms would improve consistency across centres.

3. Multicentre Prospective Studies: High quality prospective data are needed to evaluate: EXIT outcomes [24, 28], Endoscopic cleft repair [23, 33], Sclerotherapy protocols [32], Long-term neurodevelopmental outcomes.

4. Genetic & Molecular Insights: Emerging evidence suggests genetic contributions to foregut anomalies. Future research

should explore: Molecular pathways, Familial patterns, Syndromic associations.

5. Growth Plate Preservation Techniques: Innovations in surgical planning may reduce long term deformity in facial and airway anomalies.

Conclusion

Congenital anomalies of the head and neck derived from the foregut represent a complex and clinically significant spectrum of developmental disorders whose management continues to evolve [44]. Although most lesions are benign, their potential to compromise airway function, swallowing, speech, and long-term quality of life underscores the importance of early recognition, accurate diagnosis, and evidence-based intervention [45].

Advances in imaging, endoscopy, and minimally invasive surgery have transformed diagnostic pathways and operative strategies, yet substantial variability persists across institutions in timing, extent, and modality of treatment [46]. Evidence gaps remain, particularly in long-term functional outcomes and standardised reporting of airway clefts [47].

Future progress will depend on multicentre collaboration, standardised classification systems, and longitudinal follow-up that captures functional, developmental, and quality-of-life outcomes [48]. Emerging technologies-including 3D imaging, surgical navigation, fetal diagnostics, and advanced airway reconstruction-offer promising avenues for innovation but require rigorous evaluation before widespread adoption [49].

Ultimately, improving care for children with foregut-derived head and neck anomalies will require integrating embryologic insight, contemporary surgical expertise, and coordinated multidisciplinary follow-up within a unified evidence-based framework [50].

Author Contributions

All authors conceived the study. The first author conducted the literature search and drafted the manuscript. All authors contributed to revisions, approved the final version, and agree to be accountable for all aspects of the work.

Data Availability Statement

All data relevant to the study are included in the article. All data are derived from published sources cited within the manuscript.

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