



## Editorial

# Navigating the complexities of pediatric thoracic surgical malformations: An overview of management in developing countries

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## Abstract

Pediatric thoracic surgical malformations, including congenital pulmonary airway malformations (CPAM) and bronchopulmonary sequestration (BPS), represent complex developmental anomalies requiring specialized management. This editorial examines the evolution of diagnosis and treatment modalities in developing countries over the past decade, highlighting advances in imaging, surgical techniques, and improved outcomes. The integration of robotic-assisted thoracoscopic surgery (RATS) and enhanced prenatal diagnostics has revolutionized care delivery, though significant disparities persist between high-income and low- and middle-income countries.

**Keywords:** Congenital lung malformations, Pediatric thoracic surgery, Robotic surgery, CPAM, Bronchopulmonary sequestration, Developing countries

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## 1. Introduction

Congenital lung malformations (CLMs) encompass a spectrum of developmental anomalies that affect the lung parenchyma, airways, and vasculature, with an estimated incidence of 4 per 10,000 live births.<sup>1</sup> The most prevalent conditions include congenital pulmonary airway malformations (CPAM), bronchopulmonary sequestration (BPS), congenital lobar overinflation, and hybrid lesions. Over the past decade, significant advances in prenatal diagnosis, surgical techniques, and postoperative care have transformed the management landscape, particularly in developing nations where resource constraints historically limited optimal outcomes.

## 2. Evolution of Diagnostic Capabilities

The integration of advanced imaging modalities has revolutionized the early detection and characterization of thoracic malformations. Recent studies have demonstrated that fetal magnetic resonance imaging (MRI) combined with ultrasonography has improved diagnostic accuracy to 97.5% for conditions such as congenital diaphragmatic hernia.<sup>2</sup> Contemporary chest computed tomography

angiography (CTA) with multiplanar reformats and 3D/4D reconstructions has become the gold standard for postnatal evaluation, enabling precise anatomical delineation and surgical planning.<sup>3</sup>

The lung-to-head ratio (LHR) and CLM volume ratio (CVR) have emerged as crucial prognostic tools, with CVR >1.6 predicting fetal hydrops development and guiding perinatal management strategies.<sup>4</sup> These advances have facilitated earlier intervention and improved counseling for families facing these challenging diagnoses.

## 3. Transformation in Surgical Approaches

### 3.1. Minimally invasive surgery revolution

The adoption of video-assisted thoracoscopic surgery (VATS) has marked a paradigm shift in pediatric thoracic surgery. Recent multicenter data from India demonstrate that VATS procedures now comprise 60-80% of pediatric thoracic interventions at specialized centers, with significantly reduced morbidity compared to open thoracotomy.<sup>5</sup> A recent multicenter study, a survey from India, demonstrates

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significant variability in empyema management practices, with VATS procedures increasingly preferred by pediatric surgeons over conservative management, reflecting the growing adoption of minimally invasive techniques in specialized centers.<sup>6</sup> This also holds true for the management of other congenital malformations and thoracic tumors.

### 3.2. Robotic-Assisted Thoracoscopic Surgery (RATS)

The emergence of RATS represents the latest advancement in minimally invasive pediatric thoracic surgery. Comparative analysis of 93 patients of RATS and 77 patients of VATS revealed that RATS patients experienced lower chest tube indwelling rates (61.3% vs. 90.9%), fewer drainage days (1.0 vs. 2.0 days), and shorter hospital stays (5.0 vs. 6.0 days) compared to conventional VATS.<sup>7</sup> There is a need for a reviewed cohort or larger randomized study in the Indian literature on pediatric RATS for congenital malformations. We are currently limited to isolated case reports, case series, and conference presentations.

The three-dimensional visualization, tremor filtration, and articulating instruments of robotic systems offer particular advantages in complex procedures like posterior mediastinal mass excision and esophageal surgery. However, limitations include increased operative costs and the need for appropriately sized instruments for smaller children.

## 4. Improved Outcomes in Specific Malformations

### 4.1. Congenital Pulmonary Airway Malformations (CPAM)

The molecular understanding of CPAM pathogenesis, including identification of key signaling pathways (SHH, WNT, BMP, FGF) and genetic alterations (KRAS, DICER), has facilitated risk stratification and personalized treatment approaches.<sup>1</sup>

Management controversies persist regarding asymptomatic lesions. A recent single-center study of 45 cases had 18% cases with histology suggestive of ongoing inflammation, and one-third of patients overall with inflammation. This may result in alveolar fibrosis and therefore supports early malformation excision, irrespective of symptoms.<sup>8</sup> Recent evidence also suggests that even seemingly benign lesions may progress over time, with a subset demonstrating malignant transformation potential. This has led to an evolving consensus favoring surgical intervention for most diagnosed CPAMs, particularly given the excellent outcomes achieved with contemporary techniques. CPAM management has yielded remarkable improvements in outcomes. A contemporary series reports survival rates exceeding 94% for symptomatic cases undergoing surgical resection.<sup>9</sup>

### 4.2. Bronchopulmonary Sequestration (BPS)

BPS management has similarly benefited from technological advances. Recent international surveys reveal increasing preference for surgical resection over percutaneous

embolization, driven by superior long-term outcomes and reduced recurrence rates.<sup>10</sup> Intralobar sequestration, comprising 75-86% of all sequestrations, demonstrates excellent surgical outcomes with contemporary approaches, particularly when diagnosed early and managed at specialized centers.

### 4.3. Congenital Diaphragmatic Hernia (CDH)

CDH outcomes in developing countries have shown steady improvement, with recurrence rates improving with time. In a larger series of 151 infant the initial recurrence rates was 7.9% as compared to 2.7% in open procedure.<sup>11</sup> Study from Varanasi reported overall recurrence of 28.5% which was quite high compare to other series. The basic reason is learning curve, which improves with number of cases and recurrence rates fall. Survival rates are increasing from 45% in 2015 to 76% in 2025. A recent Indian study reported overall survival of 73.4% in their cohort, with thoracoscopic repair emerging as a viable alternative to open procedures.<sup>12</sup>

### 4.4. Tracheo-Oesophageal Fistula (TOF)

Minimally invasive approaches to TOF repair are being explored at leading Indian centers like PGIMER Chandigarh, with presentations indicating high success rates and rapid recovery. A larger prospective peer reviewed randomized trial or larger case series comparing the outcomes of thoracoscopic TOF repair versus the conventional Open thoracotomy approach is currently awaited from India. However, a 16-case study from Chandigarh had concluded that outcomes in both were comparable. They highlighted integrating inanimate models into the curriculum to navigate the steep learning curve, ensuring the delivery of safe and effective patient care in the era of minimally invasive surgery.<sup>13,14</sup>

## 5. Centers of Excellence and Infrastructure Development

The landscape of pediatric thoracic surgery in developing countries has expanded dramatically. Premier institutions, including AIIMS New Delhi, PGIMER Chandigarh, JIPMER Puducherry, CMC Vellore, and SGPGI Lucknow, have established comprehensive programs encompassing prenatal diagnosis, advanced surgical techniques including RATS, and long-term follow-up protocols. Other centers, in corporate sector too have established state of art centers for pediatric thoracic surgery.

This expansion has been facilitated by governmental initiatives, international collaborations, and increased recognition of pediatric surgical subspecialties. Among the Pediatric surgical fraternity in India, the basic and advanced thoracic surgery procedures were performed for more than a decade. But this fraternity lacked a platform or a dedicated forum to share its outcomes. A section of the Indian Association of Pediatric Surgeons (IAPS), known as the Society of Pediatric Thoracic Surgery (SPTS), was reborn in 2024 with the objectives of collaborative learning and research in the field of pediatric thoracic surgery.

That was a landmark event in the field to give further boost to the existing level of pediatric thoracic surgery in India. The National Medical Commission's mandate for pediatric surgical services in medical colleges has further accelerated this growth.

## 6. Challenges and Future Directions

Despite remarkable progress, significant challenges persist. Equipment maintenance, cost considerations, and the need for specialized training remain barriers to universal access. The development of 3-mm robotic instruments specifically designed for pediatric applications represents a promising advance for younger patients and neonates.

Future directions include enhanced integration of artificial intelligence in surgical planning, expansion of prenatal intervention capabilities, and development of standardized outcome registries to facilitate continuous quality improvement and multicenter collaborative research.

## 7. Conclusion

The past decade has witnessed transformative advances in pediatric thoracic surgical malformation management in developing countries. The integration of sophisticated diagnostic modalities, minimally invasive and robotic surgical techniques, and specialized centers of excellence has dramatically improved outcomes for children with these complex conditions. While disparities with high-income countries persist, the trajectory of progress suggests continued evolution toward optimal care delivery for all children, regardless of geographic location. Sustained investment in infrastructure, training, and technology will be essential to maintain this momentum.

## 8. Source of Funding

None.

## 9. Conflict of Interest

None.

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