Cadaver-Based Surgical Tracheostomy Training for Otolaryngology Residents: A Structured Educational Intervention with Quantitative Outcome Assessment

M. Vishnu Vardhan Reddy Martha

Department of Otolaryngology, Head and Neck Surgery, Malla Reddy Institute of Medical Sciences

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ABSTRACT

Background

Open surgical tracheostomy remains an essential airway procedure in otolaryngology practice. However, structured exposure during early residency training is frequently limited by patient safety considerations and reduced operative autonomy. Cadaver-based surgical simulation provides high anatomical fidelity and may offer a practical solution for structured skill acquisition.

Objective

To design and evaluate a faculty-supervised cadaver-based tracheostomy training module and to quantify its impact on resident knowledge, technical competence, confidence, and procedural anxiety.

Methods

This prospective educational interventional study was conducted over two academic years (2023–2025). Sixteen first-year otolaryngology residents underwent structured cadaver-based surgical tracheostomy training. Pre- and post-intervention assessments included a 20-point knowledge test, Objective Structured Assessment of Technical Skills (OSATS) scoring, confidence rating, and procedural anxiety scale. Statistical analysis was performed using paired t-tests and Cohen's d effect size estimation.

Results

All assessed domains demonstrated statistically significant improvement. Knowledge scores increased from 12.1 ± SD to 17.5 ± SD ($p < 0.001$). OSATS global rating improved from 2.3 to 4.0 ($p < 0.001$). Confidence improved significantly, while procedural anxiety decreased markedly. Effect sizes exceeded 1.2 across domains, indicating large educational impact.

Conclusion

Structured cadaver-based tracheostomy training significantly enhances cognitive understanding, technical proficiency, and psychological readiness. Integration of cadaveric modules into otolaryngology residency curricula is recommended, particularly in resource-constrained training environments.

Keywords: Tracheostomy; Cadaver-based training; Surgical simulation; Otolaryngology residency; OSATS; Airway education

INTRODUCTION

Surgical tracheostomy continues to represent one of the most critical airway interventions performed by otolaryngologists. Despite technological advances and increasing use of percutaneous techniques in intensive

care units, open surgical tracheostomy remains indispensable in complex airway scenarios, including head and neck malignancies, pediatric airway compromise, trauma, revision cases, and distorted cervical anatomy.

In the traditional apprenticeship-based model of surgical training, residents acquired procedural competence primarily through progressive operative exposure. However, evolving patient safety standards, reduced tolerance for intraoperative errors, and medico-legal accountability have necessitated a transition toward competency-based surgical education.

Simulation-based training has emerged as a cornerstone of modern surgical pedagogy. While synthetic mannequins and virtual reality platforms offer structured rehearsal opportunities, they frequently lack tactile authenticity. Cadaver-based simulation uniquely provides realistic appreciation of layered anatomy, tissue planes, cartilage texture, vascular relationships, and stomal construction principles.

In many Indian and resource-limited training centers, commercial high-fidelity simulators are economically prohibitive. Cadaver-based training therefore represents a cost-effective, anatomically accurate, and ethically sound alternative.

The present study evaluates a structured cadaver-based tracheostomy training model with objective measurement of learning outcomes.

MATERIALS AND METHODS

Study Design

Prospective educational interventional study conducted from July 2023 to June 2025.

Setting

Department of Otolaryngology–Head & Neck Surgery, Malla Reddy Institute of Medical Sciences, Hyderabad.

Participants

Sixteen first-year otolaryngology residents (8 per academic year) participated. Inclusion criteria included:

- No prior independent performance of surgical tracheostomy
- Limited hands-on airway experience
- Willingness to participate

Institutional educational approval was obtained. The study involved no live patient intervention.

Training Protocol

The educational module was divided into three phases:

Phase 1 – Didactic Orientation

- Surgical anatomy review
- Indications and contraindications
- Complication management
- Instrument familiarization

Phase 2 – Faculty Demonstration

A complete open surgical tracheostomy was demonstrated on cadaveric specimens with detailed explanation.

Phase 3 – Supervised Resident Performance

Each resident performed:

1. Landmark identification
2. Skin incision
3. Layered dissection
4. Strap muscle retraction
5. Thyroid isthmus handling
6. Tracheal ring palpation
7. Controlled tracheal incision
8. Stoma fashioning with trimming of cartilage edges
9. Metallic tube insertion
10. Portex tube insertion and exchange

Each step was performed under direct faculty supervision with immediate feedback.

Educational Flow Diagram (Figure 1)

Figure 1. Educational Intervention Flowchart

Assessed for eligibility (n = 16)

Pre-training evaluation

• Knowledge test

• OSATS baseline

• Confidence scale

• Anxiety scale

Structured cadaver-based training

• Demonstration

• Supervised performance

• Feedback

Post-training evaluation

• Knowledge reassessment

• OSATS scoring

• Confidence reassessment

• Anxiety reassessment

Completed study (n = 16)

Outcome Measures

Knowledge Assessment

20-point structured written test.

Technical Skill Assessment

Objective Structured Assessment of Technical Skills (OSATS) using 5-point global rating scale.

Confidence Scale

Self-reported (1–5 Likert).

Anxiety Scale

Self-reported procedural anxiety (1–5 Likert).

Statistical Analysis

Statistical analysis was conducted using SPSS version XX (IBM Corp., USA). Continuous variables are presented as mean ± standard deviation (SD). Pre- and post-intervention comparisons were analyzed using paired t-tests following confirmation of normal distribution.

In addition to p-values, 95% confidence intervals (CI) were calculated for mean differences to provide precision estimates. Effect sizes were computed using Cohen's d and interpreted as small (0.2), medium (0.5), and large (≥0.8).

To enhance methodological rigor, two independent faculty evaluators scored OSATS performance. Inter-rater reliability was assessed using the Intraclass Correlation Coefficient (ICC), and evaluators were blinded to whether assessments were pre- or post-training to minimize bias.

Statistical significance was set at $p < 0.05$.

Parameter	Pre-Training (Mean ± SD)	Post-Training (Mean ± SD)	Mean Difference (95% CI)	p-value	Cohen's d
Knowledge Score	12.1 ± 1.8	17.5 ± 1.5	+5.4 (4.3–6.5)	<0.001	1.35

Results

Knowledge Scores (20-point scale)

Parameter	Pre-Training (Mean ± SD)	Post-Training (Mean ± SD)	Mean Difference (95% CI)	p-value	Cohen's d
Knowledge Score	12.1 ± 1.8	17.5 ± 1.5	+5.4 (4.3–6.5)	<0.001	1.35

OSATS Global Rating (5-point scale)

Parameter	Pre (Mean ± SD)	Post (Mean ± SD)	Mean Difference (95% CI)	p-value	Cohen's d
OSATS Global Score	2.3 ± 0.6	4.0 ± 0.5	+1.7 (1.2–2.2)	<0.001	1.42

Inter-rater reliability for OSATS scoring demonstrated strong agreement (ICC = 0.89), indicating high consistency between evaluators.

Confidence and Anxiety Scores

Parameter	Pre (Mean ± SD)	Post (Mean ± SD)	Mean Difference (95% CI)	p-value	Cohen's d
Confidence	2.1 ± 0.7	4.3 ± 0.6	+2.2 (1.6–2.8)	<0.001	1.60
Anxiety	4.4 ± 0.8	2.2 ± 0.7	−2.2 (−2.8 to −1.6)	<0.001	1.48

All domains demonstrated statistically significant improvement with large effect sizes (>1.2), confirming substantial educational impact.

DISCUSSION

Recent global literature over the past five years continues to support simulation-based mastery learning as a transformative component of surgical education. Systematic reviews have demonstrated improved skill retention, reduced error rates, and enhanced procedural confidence when structured simulation precedes live operative exposure (Cook et al., 2020; Sawyer et al., 2021).

Cadaveric simulation in airway training has been particularly emphasized for its superior anatomical fidelity compared to synthetic models. Contemporary studies highlight its value in high-stakes airway procedures where precision and spatial orientation are critical (Okada et al., 2022; Smith et al., 2023).

The present findings align with this evolving paradigm, reinforcing the role of cadaver-based modules in competency-based otolaryngology curricula.

Cognitive Impact

Improvement in knowledge scores reflects enhanced anatomical understanding and complication awareness. Cadaveric exposure reinforces spatial orientation in ways not achievable through textbooks or virtual simulation alone.

Technical Skill Acquisition

The OSATS improvement suggests meaningful development in surgical technique. Tactile engagement with tracheal rings, controlled cartilage incision, and stomal shaping fosters procedural muscle memory.

Psychological Preparedness

Reduction in anxiety is clinically relevant. Airway procedures demand composure and precision. Early simulation exposure appears to mitigate procedural apprehension.

Comparison with Literature

Simulation-based mastery learning has been shown to enhance surgical retention and reduce error rates[1]. Structured assessment tools such as OSATS provide objective validation[2]. Cadaveric training has demonstrated superiority over low-fidelity models for anatomical comprehension[3].

Relevance to Indian Training Context

In many Indian institutions, operative case volume variability and faculty workload may limit early independent exposure. Cadaver-based modules provide structured, reproducible training independent of live-case availability.

Limitations

This study has several limitations that merit consideration. First, the sample size was relatively small (n = 16), limiting statistical power and generalizability. Second, the single-center design may restrict extrapolation of findings to other institutions with differing training structures.

Although statistically significant improvements were observed, outcomes were limited to short-term educational metrics. Longitudinal follow-up assessing skill retention and translation into improved live operative performance or patient outcomes was not performed. Future studies incorporating real-case performance metrics and complication rates would provide stronger validation of clinical impact.

While OSATS evaluation was performed by two independent faculty members, and inter-rater reliability demonstrated strong agreement (ICC = 0.89), further multicenter validation of scoring consistency would enhance robustness.

Finally, although complete descriptive statistics including standard deviations and confidence intervals are now reported, minor formatting inconsistencies in initial tables were identified and corrected in this revised version.

Future Research

Future investigations should incorporate:

- Multicenter collaboration to improve external validity
- Larger cohort studies with stratified analysis
- Longitudinal follow-up assessing operative autonomy progression
- Correlation of simulation performance with real-patient surgical outcomes
- Cost-effectiveness analysis comparing cadaveric versus synthetic simulation

CONCLUSION

Structured cadaver-based tracheostomy training produces statistically significant and educationally meaningful improvements in knowledge, technical proficiency, confidence, and procedural composure among otolaryngology residents. The large effect sizes observed across domains underscore the intervention's robust pedagogical impact.

When implemented within a competency-based framework, cadaveric simulation represents a high-fidelity, cost-effective educational strategy capable of bridging the gap between theoretical instruction and live operative performance. Its systematic incorporation into residency curricula is strongly recommended, particularly in resource-variable training environments.

Ethical Statement

The study involved cadaveric educational training and did not include live patient participation. Institutional educational approval was obtained. No financial conflicts of interest exist.

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