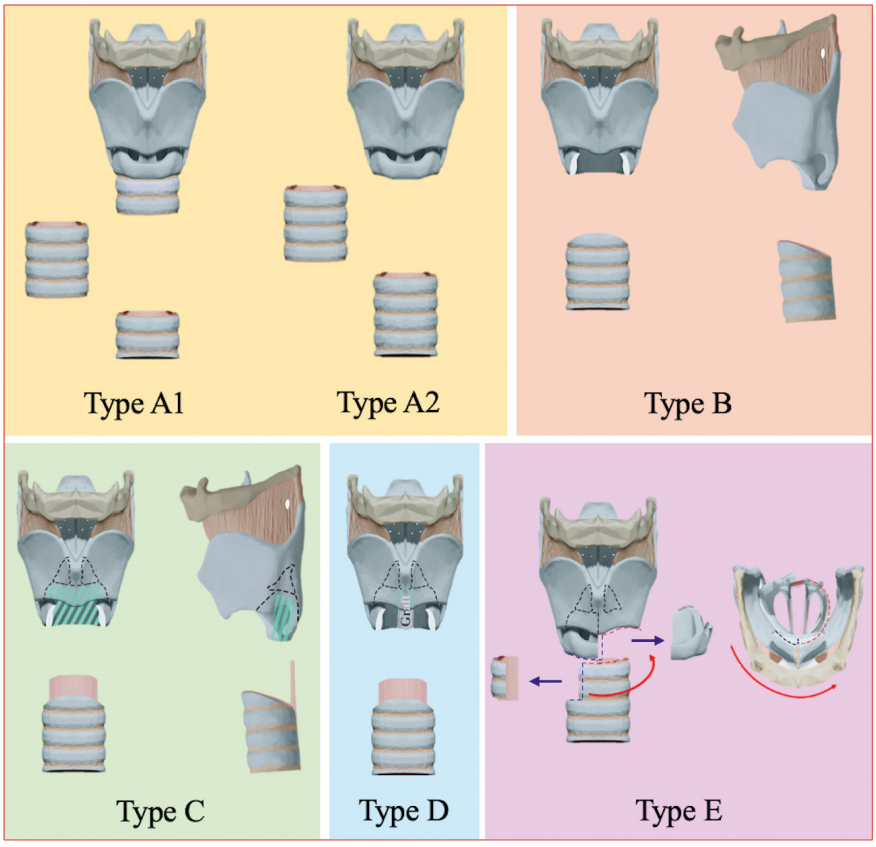
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Classification of tracheal and crico-tracheal resection and anastomosis: a proposal from the European Laryngological Society



Cover figure. Diagram representing the proposed European Laryngological Society classification for (crico-)tracheal resection and anastomosis.

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Summary

Objective. Tracheal (TRA) and crico-tracheal resection and anastomosis (CTRA) are highly effective surgical procedures for managing selected cases of laryngo-tracheal stenosis, although the absence of a standardised classification limits the use of a common language within the scientific community and hinders multicentre comparisons. We present the European Laryngological Society (ELS) proposal, categorising (C)TRA into 6 Types (A1, A2, B, C, D, and E) mainly based on their anatomical extension and type of anastomosis performed.

Methods. The classification was validated through a preliminary multicentre cohort of 390 patients treated between September 1996 and March 2026 in 4 European referral airway centres sharing a common protocol for definitions of (C)TRA. Primary outcomes included postoperative complications and airway patency in terms of tracheostomy-free rate.

Results. The cohort was distributed across (C)TRA Type A1 (24.9%), A2 (21%), B (19%), C (31%), D (1.5%), and E (2.6%). Overall and anastomosis-specific complication rates increased from Type A1 to Type C,

reflecting the technical burden of the procedure, while planned temporary tracheotomy in Types D and E effectively mitigated acute airway morbidity. Long-term functional success remained high across all (C)TRA Types, with tracheostomy-free rates ranging from 95.1% to 100% for all different kinds of (C)TRA procedures. **Conclusions**. The proposed ELS classification provides a standardised framework that correlates well with surgical complexity and complication profiles, enhancing data comparability and serving as a valuable didactic resource for the international airway community.

Keywords: tracheal resection, crico-tracheal resection, laryngo-tracheal resection, sleeve resection, end-to-end anastomosis, airway stenosis, laryngo-tracheal stenosis, classification

Introduction

Tracheal (TRA) and crico-tracheal resection and anastomosis (CTRA) involve complete separation and circumferential rejoining of the airway, and are well-known surgical procedures for treating a wide array of situations determining laryngo-tracheal stenosis (LTS) [1-15]. While minimally-invasive techniques [16-24] have long been established and are now the recommended first-line treatment for LTS [25], (C)TRA remains the only viable option in a subset of patients with crico-tracheal benign or malignant tumours, and for those with benign conditions following failure of less invasive approaches. As such, (C)TRAs form a sizeable workload in every tertiary referral airway unit.

When focusing on the entire gamut of conditions causing LTS and possibly amenable of (C)TRA, one should consider both iatrogenic issues (endotracheal intubation, tracheostomy, traumatic airway manoeuvres), external injuries (blunt trauma, caustic ingestion, fire burns, attempted suicide, or consequences of interpersonal violence), autoimmune conditions (Wegener's granulomatosis, idiopathic subglottic stenosis, relapsing polychondritis), primary or secondary tumours (chondrosarcomas, fibrosarcomas, minor salivary gland tumours, squamous cell carcinomas, thyroid cancers infiltrating the airway), and a number of rarer miscellaneous scenarios (amyloidosis, tracheocele, and tracheo-oesophageal fistula). All these conditions constitute potential challenging situations for anaesthesiologists, bronchoscopists, laryngologists, airway, and head and neck as well as thoracic surgeons, since no precise guidelines exist for management of every specific clinical setting and a multidisciplinary effort must be established to successfully pass through each of the different critical steps of pre-, intra-, and postoperative management of these patients.

The key challenge with (C)TRA is that, uniquely among LTS operations, it carries the risk of causing laryngo-tracheal separation due to anastomosis dehiscence, which is a devastating and potentially fatal complication. The risk of anastomotic dehiscence is directly linked to the patient's underlying wound-healing conditions and related comorbidities like diabetes and cardiovascular/pulmonary diseases, as well as to the length and location of airway resected, all variables that may greatly impact on the ability to construct a well-healing tension-free anastomosis. Furthermore, (C)TRA encompass a wide range of different surgical procedures with variable degrees of proximal extension, possible resection of cricoid arch, plate, and crico-arytenoid joint(s). While subtypes of (C)TRA have been already individually described in seminal works [26-42], the exact location of the resected airway has not been described within a common classification system to enable risk-stratification, safety, and functional comparisons. These variables, according to different studies, together with the total length and subsites of airway resected, play a key role in determining the success and complications rates of (C)TRA both in terms of preventing postoperative anastomosis dehiscence and achieving a tracheotomy-free airway in the long term [43-51].

The present European Laryngological Society (ELS) proposal for (C)TRA classification aims at building a homogeneous framework to render patients submitted to various procedures or different series comparable. In a realm of rare and variegated diseases, often treated in a heterogenous way, the lack of a common classification may represent a further layer of confusion and difficulty in sharing multicentric outcomes. On the other hand, no attempt will be made herein to detail specific indications of every type of (C)TRA or those fundamental surgical steps (such as preoperative work-up including scrupulous measurement of length of airway to be excised, type of endotracheal tube, modality of intraoperative oxygenation, number, size, and type of anastomotic stitches used, sequence of their knotting, policy of postoperative airway management by immediate/delayed tube removal or upfront temporary tracheotomy, staged procedures, combination with various types of stenting, use of specific medications) that every airway team has frequently evolved in a different way and still represent technical variations within a common framework.

ELS proposal of (C)TRA classification

We herein propose to classify (C)TRA into 6 Types as schematically illustrated in the Cover figure:

- Type A1: tracheal resection with preservation of at least the first 2 tracheal rings, and ensuing tracheo-tracheal

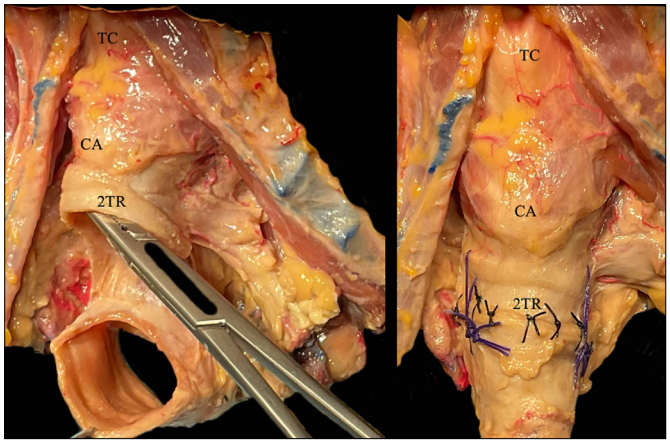


Figure 1. Type A1 TRA. Tracheal resection with preservation of the first 2 tracheal rings and tracheo-tracheal anastomosis. CA: cricoid arch; 2TR: second tracheal ring; TC: thyroid cartilage.

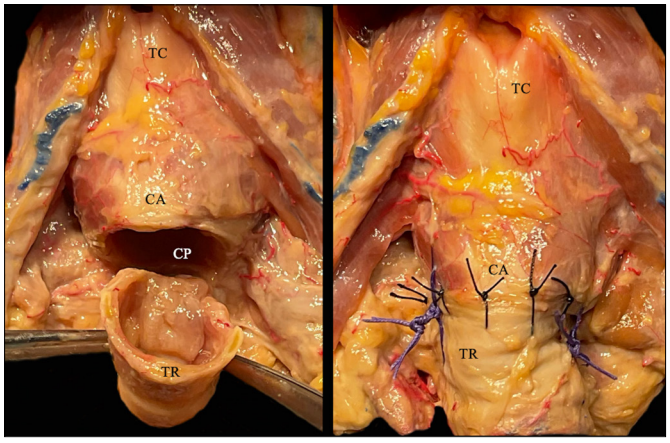


Figure 2. Type A2 CTRA. Tracheal resection of the first tracheal rings and crico-tracheal anastomosis. CA: cricoid arch; CP: cricoid plate; TC: thyroid cartilage; TR: trachea.

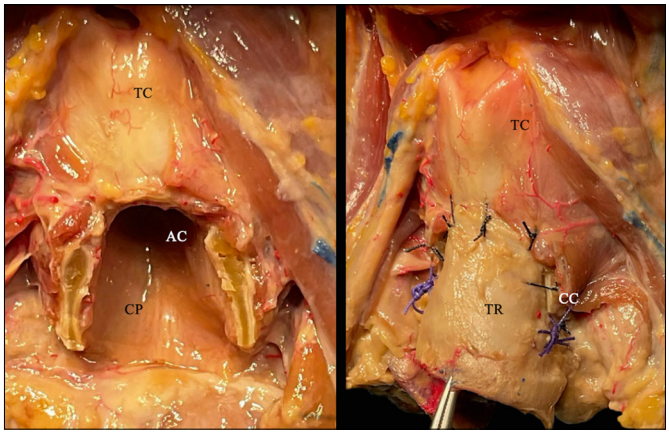


Figure 3. Type B CTRA. Removal of the first tracheal rings together with the anterior portion of the cricoid arch and thyro-crico-tracheal anastomosis. AC: arytenoid cartilage; CC: cricoid cartilage; CP: cricoid plate; TC: thyroid cartilage; TR: trachea.

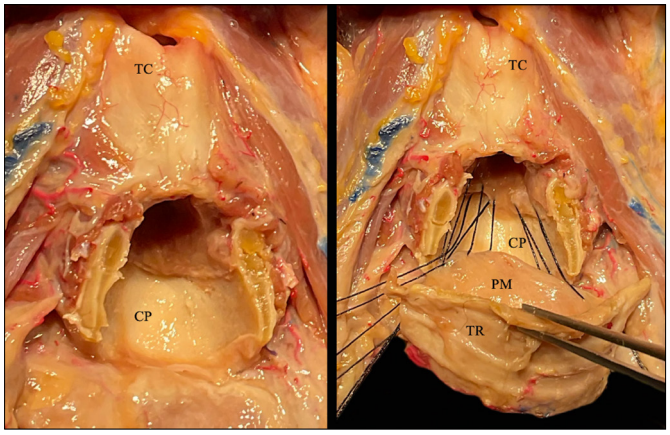


Figure 4. Type C CTRA. Removal of the first tracheal rings, anterior cricoid arch, and inner part of the cricoid plate, covering the bare cricoid plate by a pedicled flap of posterior tracheal wall. CP: cricoid plate; PM: pars membranacea; TC: thyroid cartilage; TR: trachea.

anastomosis (Fig. 1). This is mainly indicated in tracheal stenosis without extension to the first tracheal rings and cricoid.

- Type A2: tracheal resection including the first tracheal rings but without cricoid excision, with subsequent crico-tracheal anastomosis (Fig. 2). This procedure is indicated in pure tracheal stenosis extended to the first tracheal rings, without involvement of the cricoid.
- Type B: removal of the first tracheal rings, anterior cricoid arch, medial to the crico-thyroid joints, with subsequent thyro-crico-tracheal anastomosis (Fig. 3). This is indicated in LTS involving the first tracheal rings and the anterior part of the cricoid, while sparing the posterior cricoid plate.
- Type C: removal of the first tracheal rings, anterior cricoid arch, and the inner part of the cricoid plate (potentially up to the crico-arytenoid joints), with ensuing thyro-crico-tracheal anastomosis and covering of the bare cricoid plate with a pedicled flap of posterior tracheal wall (Fig. 4). This procedure is indicated in LTS with posterior involvement of the mucosa and cartilage forming the cricoid plate.
- Type D: removal of the first tracheal rings and the anterior cricoid arch, midline thyrotomy (laryngofissure),

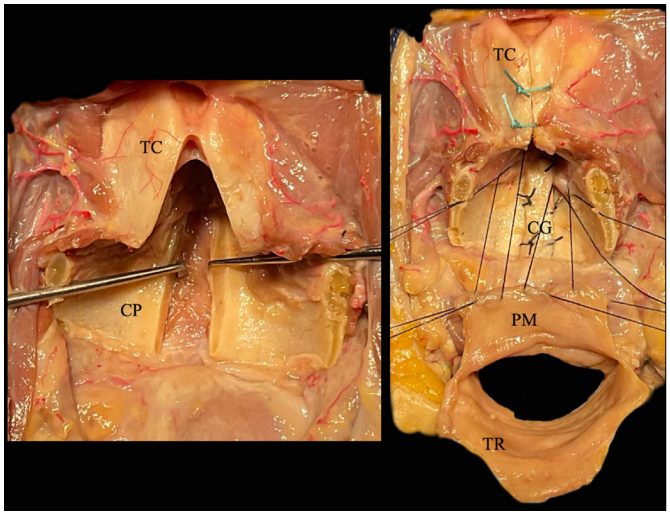


Figure 5. Type D CTRA. Removal of the anterior cricoid arch, midline thyrotomy, and posterior midline cricoid split. Fixation of a costal cartilage graft between the 2 hemicricoid halves, with coverage of the bare cricoid plate by a pedicled flap of the pars membranacea. CG: cartilaginous graft; CP: cricoid plate; PM: pars membranacea; TC: thyroid cartilage; TR: trachea.



Figure 6. Type E CTRA. Removal of one hemicricoid including half of the anterior arch and corresponding half of the cricoid plate with rotational thyro-crico-tracheal anastomosis obtained by cutting in an asymmetrical fashion the distal airway stump used to sustain the preserved arytenoid. AC: arytenoid cartilage; CC: cricoid cartilage; CP: cricoid plate; ICTC: inferior cornu of the thyroid cartilage; PM: pars membranacea; TC: thyroid cartilage; TR: trachea (reproduced with permission from: Piazza C, Lancini D, Zigliani G, et al. Hemicricoidectomy with modified rotational thyro-crico-tracheal anastomosis: a newborn in the family of crico-tracheal resection and anastomosis techniques. Acta Otorhinolaryngol Ital 2023;43:382-389).

posterior median cricoid split with or without removal of part of the cricoid plate up to the inter-arytenoid area, with placement and fixation of a costal cartilage graft between the 2 hemicricoid halves, with thyro-crico-tracheal anastomosis and covering of the cricoid plate with a posterior tracheal wall flap (Fig. 5). The main indication is LTS involving the first tracheal rings, subglottis, and glottis in presence of posterior glottic stenosis or cicatricial fusion of the vocal folds.

- Type E: removal of one hemicricoid including half of the anterior arch and the corresponding half of the cricoid plate, disarticulating the ipsilateral inferior thyroid cornu and arytenoid, then bridging the gap by a rotational thyro-crico-tracheal anastomosis obtained by cutting in an asymmetrical fashion the distal airway stump used to sustain the preserved (but denervated and disarticulated) arytenoid cartilage (Fig. 6). This procedure is indicated in selected oncological cases such as non-squamous cell subglottic tumours or unilateral cricoid infiltration by well-differentiated thyroid carcinoma, with complete preservation of one functioning crico-arytenoid unit.

Validation of the present proposal in a multicentre series

To validate the proposed ELS classification system, rates of postoperative complications and functional airway patency were selected as primary outcome measures, since they directly reflect the surgical complexity of the procedures. Overall complications encompassed anastomotic-related events, postoperative haemorrhage, unintended recurrent laryngeal nerve(s) palsy, pneumothorax, and severe laryngeal oedema requiring unplanned tracheostomy. Anastomotic-specific complications, including dehiscence, obstructive granulomas or fibrin flaps, and tracheal stump intussusception, were evaluated as a predefined specific subgroup of postoperative complications. Additionally, the functional airway patency rate (defined as the proportion of patients not requiring a tracheostomy at last follow-up, including both those never tracheotomised and those successfully decannulated) was assessed to measure morbidity and long-term functional success. No effort was directed toward quantification of unavoidable functional sequelae observed after some types of CTRA (for example lowering of voice pitch after cricoid arch and crico-thyroid muscle resection after Type B to E procedures).

This multicentric study analysed a cohort of 390 patients treated between September 1996 and March 2026 at the Units of Otorhinolaryngology - Head and Neck Surgery,

ASST Spedali Civili of Brescia, Comprehensive Cancer Center, University of Brescia, Italy (n = 211), Klinikum Stuttgart, Germany (n = 66), IRCCS Policlinico San Martino Hospital, Genoa, Italy (n = 65), and University Hospital of Modena, Italy (n = 48).

The proposed classification for (C)TRA was applied using standardised criteria shared across all centres to ensure consistency, resulting in the following distribution: 24.9% Type A1 (n = 97), 21% Type A2 (n = 82), 19% Type B (n = 74), 31% Type C (n = 121), 1.5% Type D (n = 6), and 2.6% Type E (n = 10).

The overall complication rates varied across groups, with values of 18.6%, 26.8%, 41.9%, 44.6%, 33.3%, and 20% from Types A1 to E, respectively. A progressive increase in complications was observed from Types A1 through C, mirroring the escalating procedural complexity, whereas this trend was less evident in Types D and E. In these latter subgroups, in fact, a planned tracheostomy is systematically performed at the end of the procedure and maintained until the subsidence of oedema, effectively bypassing complications related to acute airway obstruction; furthermore, the limited sample size for Types D and E CTRA restricts the statistical power and reliability of percentage-based comparisons. Focusing on anastomosis-related complications, which may more accurately represent the technical burden than overall morbidity, a clear upward trend was noted from Type A1 to E (9.3%, 14.6%, 17.6%, 19%, 33.3%, and 20%, respectively). Of note, the relatively low anastomosis-related complication rates observed in Types D and E are likely attributable to the routine use of postoperative temporary tracheotomy and nasogastric feeding tube, which mitigates mechanical stress on the anastomosis (Type E) and the use of endotracheal stent for some weeks after surgery (Type D). Finally, the tracheotomy-free functional airway rate at last follow-up remained high across all kinds of (C)TRA (Type A1 97.9%, Type A2 95.1%, Type B 97.3%, Type C 97.5%, Type D 100%, and Type E 100%), underscoring the safety and robust functional profile of these surgical techniques across the proposed ELS classification spectrum.

On the other hand, no attempt was made in this preliminary work to evaluate other essential variables for prediction of (C)TRA success other than the type of end-to-end anastomosis performed, and mainly related to the length of airway resected (with a well-known increase in terms of risk of anastomotic dehiscence for airway resections exceeding 4 cm) [43], use of 2-staged or multi-steps procedure with endoluminal stenting and temporary tracheostomy, and presence of associated comorbidities or congenital malformations [44].

Conclusions

The aim of the present ELS proposal is to standardise a common (C)TRA classification, thus enabling a meaningful comparison of outcomes and providing a reproducible framework for didactic purposes, ensuring consistency in both clinical research and surgical training. The distribution of overall complication rates, and particularly the pattern of anastomosis-related issues, supports the internal reliability of the proposed classification, reflecting a stratification of surgical burden and airway management requirements. The present preliminary multicentre analysis also demonstrates the reproducibility of this classification, showing its applicability across different surgical settings.

Conflict of interest statement

The authors declare no conflict of interest.

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Author contributions

CP, GP, DL, MF, JCK, FM, CM, CS: data acquisition; CP: study conception and design; CP, DL, CM: article drafting; DL, CM: data analysis; CP, GP, DL, KS, MF, JCK, FM, CM, CA, CS, RN: critical revision of the article and final approval of the version to be published.

Ethical consideration

This study was approved by the Institutional Ethics Committee of the University of Brescia (protocol number: 4268). The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association's Declaration of Helsinki.

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