

A Proposed Classification System of Central Airway Stenosis

Lutz Freitag⁺, Armin Ernst⁺⁺, Michael Unger^{*}, Kevin Kovitz[∴], Charles Hugo Marquette^{""},

⁺ Lungenklinik Hemer, Hemer, Germany

⁺⁺ Beth Israel Deaconess Medical Center, Boston, USA

^{*} Fox Chase Cancer Center, Philadelphia, Pennsylvania, USA

[∴] Tulane University Medical Center, New Orleans, Louisiana, USA

^{""} Hopital A. Calmette, CHRU de Lille, France

Address for correspondence:

Lutz Freitag, MD

Lungenklinik, Hemer

58675 Hemer, Germany

Tel. --49-2372 9080

Fax. --49-2372-914945

freitag-hemer@t-online.de

The authors gratefully acknowledge the assistance of Michelle Secic with the statistical analysis.

Abstract

Tracheobronchial stenosis, a serious problem of adults and children, has multiple causes and has been treated in many ways. While developing an international multicenter study to evaluate efficacy of airway stents, we realized that no adequate description of central airway stenosis, regarding type, location and degree has been published. Thus, comparing results of different treatment modalities in different centers has been difficult due to a lack of uniformity of classification. Reports are typically descriptive and precise classification schemes have not adequately addressed either the trachea or the main bronchi. We propose a standardized classification scheme with descriptive pictures and diagrams for rapid and uniform classification of central airway stenosis. Our system divides stenoses into structural and dynamic and further classifies them by degree of stenosis, location and transition zone. Multiple sites can be described and each is transformed into a simple numerical scoring system prompted by a diagram that can be easily captured for subsequent uniform analysis across sites. A pilot validation of the system with 18 Pulmonologists of varying training background showed strong precision and agreement between observers. Such a system will enhance our ability to study the effectiveness of treatment modalities for central airway stenosis.

Introduction

Tracheobronchial stenosis, a serious problem of adults and children, has multiple causes and has been treated in many ways. Interventional endoscopic procedures compete with surgical approaches and various new treatment modalities are currently tested for efficacy and safety. While developing an international multicenter study to evaluate efficacy of airway stents, we realized that no adequate description of central airway stenosis, regarding type, location and degree has been published. Thus, comparing results of different treatment modalities in different centers has been difficult due to a lack of uniformity of classification. Reports are typically descriptive and precise classification schemes have not adequately addressed either the trachea or the main bronchi. We propose a standardized classification scheme with descriptive pictures and diagrams for rapid and uniform classification of central airway stenosis.

Earlier systems

Cotton (1) classified laryngotracheal stenosis (LTS) in pediatric patients. The classification is based on the cross-sectional area of the stenosis and divided into four grades. Location and length are noted but these do not affect the grade of stenosis. This classification does not apply to the lower trachea or bronchi. It was designed for a group of patients who typically had scarring after prolonged intubation. Grundfast (2) and colleagues retrospectively looked at a pediatric population for factors predictive of outcome in patients treated for subglottic stenosis. They opted for a more descriptive form of classification. Like Cotton, the authors addressed the airway opening by measuring diameter at the narrowest point. They added to this measurement of length and four types of consistency: soft, hard, cartilaginous, and mixed.

More recently, MacCaffrey (3) retrospectively reviewed the treatment of 72 cases of LTS. Although diameter and length were factors, the predominant predictor of outcome was location. Locations were confined to the glottis, subglottic area and upper trachea. Four stages were defined. Stage 1 in the subglottis or trachea, less than 1 centimeter in length. Stage 2 in the subglottis, greater than 1 centimeter in length. Stage 3 in the subglottis and upper trachea and stage 4 in the glottis with vocal cord fixation and paralysis. Outcomes were worse with each advancing stage. Grillo (4) and colleagues reviewed their experiences with LTS confined to the upper trachea and subglottic larynx. The stenoses are descriptively characterized and three types are diagrammed. These are in the upper trachea, the subglottis with a space below vocal cords for a possible anastomosis, and the subglottis without an adequate space for an anastomosis.

Anand (5) and colleagues also looked at surgical approaches. Specifically, reviewing the treatment of tracheal stenosis, most post intubation, they characterized stenosis based on severity, location, length and number of stenoses. For severity, they borrowed from Cotton's classification, but divided into three grades: mild (less than 70%), moderate, (71 to 90%), and severe (greater than 90%). Locations were defined as glottic, cervical or thoracic. Lengths were divided into less than 1 centimeter, 1 to 3 centimeters and greater than 3 centimeters. Multiple areas of stenosis were found in some patients. More recently, Myer (6) and colleagues determined degree of tracheal stenosis by using standard endotracheal tubes as guides and seeing how they pass through the narrowest point. By comparing to age appropriate endotracheal tube sizes one can classify 4 grades of stenosis: Grade I (up to 50%), Grade II (51-77%), Grade III (>70%), and Grade IV (complete obstruction).

The major focus of these studies (1-6) has been retrospective attempts to discern outcome of various surgical procedures for the treatment of LTS. All attempts at classifications have concentrated on the upper airway and none have extended beyond the trachea. While these

descriptive classifications are useful, they do not allow for easily reproducible and analyzable comparisons of results between centers. Newer types of interventional bronchoscopy including laser, dilatation and stent placement have been discussed in various journals. Their efficacy and their place value as an alternative to surgical approaches can only be defined if outcome descriptors are comparable. The lack of a universal classification system limits true comparison of approaches with respect to outcomes.

Proposed classification of tracheobronchial stenosis

We developed and tested a simple bronchoscopic scheme for the classification of tracheobronchial stenosis that will allow different centers to prospectively compare results and analyze outcome over a wide range of interventions. We present our classification system hoping that the proposal will be accepted by other centers or at least stimulate further discussion in this journal.

We propose a classification method that can be used simply and reproducibly between different centers for the characterization of tracheobronchial stenosis. Such a system will lend itself to placing stenoses into specific and a finite number of categories that can be more easily collated. This classification system should then allow for a quantitative analysis of outcome. We include drawn and photographed examples with a suggested charting device to ease implementation. Specialists of six major institutions from Europe and from the US have agreed on this system.

Types

There are two major groups of stenoses, structural and dynamic (functional).

I. Structural Stenosis

The structural group has four major types. Type 1 stenosis includes all types of exophytic intraluminal malignant or benign tumors and granulation tissue. Type 2 stenosis is due to extrinsic compression such as from enlarged lymph nodes, goiter, large vessels or other mediastinal structures including non-pulmonary tumors. Type 3 stenosis is due to distortion, kinking, bending or buckling. These may be complications seen after surgical interventions such as sleeve resections, transplantation and the like as well as mediastinal or pleural diseases causing traction of the bronchi. Though the bronchial wall thickness may be normal, off-axis distortion results in ovally shaped stenotic segments. Type 4 stenoses are those in which shrinking and scarring predominate. Post-intubation stenoses, burn injuries and secondary healing after surgery are typical examples.

II. Dynamic (Functional) Stenosis

Dynamic stenoses are malacic conditions that vary with the respiratory cycle. They include two different types. Type 1 is the triangular (tent) shaped benign stenosis in which the cartilages are damaged. This saber sheath (scabbard) trachea should be distinguished from the more common type 2 that is often seen in emphysema patients where there is an inward bulging of the floppy posterior membrane.

Stenosis Groupings

	Type	Character
I. Structural	1	exophytic/intraluminal
	2	extrinsic
	3	distortion
	4	scar/stricture
II. Dynamic (functional)	1	damaged cartilage/malacia
	2	floppy membrane

Degree of stenosis

The degree of stenosis is assigned a numerical code that can be applied to any site. 0 is assigned to no appreciable stenosis and 1, 2, 3 and 4 are assigned to approximately 25%, 50%, 75 % and 90% decrease in cross-sectional area, respectively. 5 is assigned to complete obstruction. For dynamic stenoses, the condition during forced exhalation is considered. Operator judgment is used to pick the closest appropriate degree.

Numerical Assignment of Degree

#	Degree (%)
0	none
1	- 25
2	26 - 50
3	51 - 75
4	76 - 90

5	90 - complete
---	---------------

Location

The method we propose defines 5 locations within the central airways: I. Upper third of trachea; II. Middle third of trachea; III. Lower third of trachea; IV. Right main bronchus; V. Left main bronchus. The resulting scoring system, which lends itself readily to a computerized system, the location will be at the appropriate position of the numerical scoring. That is each stenosis will have 5 digits assigned to it. The degree of stenosis number is reported in the first through fifth numerical position representing the first through fifth location number. Thus for instance 50% stenosis in the lower trachea will be represented by the computerized scoring system in the following way: 00300. In the 3rd position (location III) the number 3 represents 50% reduction in the lumen while the rest of the evaluable tracheobronchial tree is within normal limits.

#	Location
I	upper 1/3 trachea
II	middle 1/3 trachea
III	lower 1/3 trachea
IV	right main bronchus
V	left main bronchus

Transition Zone

For decisions regarding therapeutic approaches, not only the overall length of the stenosis but also the transition or abruptness of stenosis is relevant. The description should include the information

whether there is an abrupt change like a web stenosis or a slow bottleneck-type transition such as in a cicatricial post-intubation stenosis.

Charting

For ease of use, diagrammatic representations of the degrees of stenosis are and can be incorporated in a standard report form. These visual guides can be used to help assign numbers. For practical reasons a graphic file form (Figure 3) has been created that can be easily adapted by individual institutions. This file can be downloaded from our website. The description was originally based on endoscopic findings but can be correlated with radiologic findings including bronchography, computed tomography, virtual bronchoscopy or magnetic resonance imaging. Other techniques of measurement such as acoustic reflection (7) or use of designated bronchoscopic equipment (2,8) might be used. Correlations between this descriptive code and functional data (9,10) are now being collected and will be presented in a following paper.

Validation

To assess feasibility of this proposed classification system, 18 participants of an Interventional Pulmonology course (Lille, France) were asked to independently assess 10 cases using this system. After a short instruction session, participants were able to review a video of the bronchoscopy as well as a description of the findings in a conventional endoscopy report. The group of participants consisted of 4 fellows and 14 pulmonary specialists. The range of years in practice was from 1 to 20 years.

The coefficient of variation was used to measure variability and precision while Pearson's Rho correlation coefficient was used to measure agreement. Distributions with $CV < 100\%$ are

considered high-precision and low-variance, while those with $CV > 100\%$ are considered low-precision and high-variance. Correlations of 100% indicate perfect agreement between raters, while correlations of 0% indicate complete non-agreement.

The precision and agreement data are presented in table 1. There was strong precision and agreement between raters, with the strongest precision and agreement for abnormalities in the lower trachea, as well as right and left mainstem. In the following discussion it turned out that most of the discrepancies could be explained with the fact that some colleagues marked the degree of stenosis during inspiration while others used the minimal cross-sectional area at the end of expiration. For the future we propose to rate the highest degree of stenosis during normal breathing which is in most cases at the end of expiration.

Conclusion

In essence, we have proposed a simple system to distinguish between the different types of airway stenosis. It can be used prospectively to numerically classify stenosis of the tracheobronchial tree. It allows for the assignment to multiple points within the large airways numerical representations of the degree and sites of stenosis. The system therefore accommodates the full range of patients from those with a single area of simple stenosis to those with multiple complex stenoses. The numerical assignment of grades that are easily gleaned from a diagnostic template allows for both rapid classification and subsequent numerical analysis. Our pilot validation trial confirms that the system is easy to use and precise.

Several shortcomings need to be addressed. Precision in some areas is not as high as in others and this requires some improvement. Additionally, the current system does not allow for independent abnormalities in one patient to be scored on one sheet. These issues are areas of active research for improvement and we would recommend a larger trial to assess the validity of our results.

Additionally, possible extensions or improvements of the system could include the larynx and the lobar bronchi. Biomechanical measurements could be included to distinguish between soft and rigid stenosis. However, though more precise, these extensions would complicate the use of the system and we think that for most purposes the proposed classification system is feasible.

We hope that our system will allow for a more uniform and quantitative prospective approach to the analysis of the outcome of the myriad approaches taken in the treatment of tracheobronchial stenosis.

Bibliography

- 1) Cotton, RT. Pediatric laryngotracheal stenosis. J Pediatr Surg 1984;19:699-704
- 2) Grundfast KM, Morris MS, Bernsley C. Subglottic stenosis: Retrospective analysis and proposal for standard reporting system. Ann Otol Rhinol Laryngol 1987;96:101-5
- 3) McCaffrey TV. Classification of laryngotracheal stenosis. Laryngoscope 1992;102:1335-40

- 4) Grillo HC, Mark EJ, Mathisen DJ, Wain JC. Idiopathic laryngotracheal stenosis and its management. *Ann Thorac Surg* 1993;56:80-7
- 5) Anand VK, Alemar G, Warren ET. Surgical considerations in tracheal stenosis. *Laryngoscope* 1992;102:237-43
- 6) Myer CM 3rd, O'Connor DM, Cotton RT. Proposed grading system for subglottic stenosis based on endotracheal tube sizes. *Ann Otol Rhinol Laryngol* 1994;103(4 Pt 1):319-23
- 7) Hoffstein V, Zamel N. Tracheal stenosis measured by acoustic reflection technique. *Am Rev Resp Dis* 1984;130:355-7
- 8) Kleinsasser N, Kronsdorf D, Merckenschlager A, Dellian M, Goetz AE, Holtmann S, Mantel K. Endoskopische, dreidimensionale Vermessung von Neubildungen und Stenosen des Larynx und der Trachea. *Laryngo-Rhino-Otol* 1994;73:428-31
- 9) Miller RD, Hyatt RE. Evaluation of obstructing lesions of the trachea and larynx by flow-volume loops. *Am Rev Respir Dis* 1973;108:475-81
- 10) Gamsu G, Borson BB, Webb WR, Cunningham JH. Structure and function in tracheal stenosis. *Am Rev Resp Dis* 1980;121:519-53

Figures:

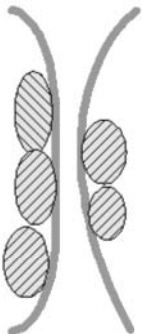
Figure 1: Examples of the basic types of structural and functional stenosis and the transition or abruptness of change between the normal lumen and the most narrowed part.



intraluminal tumor
or granulation



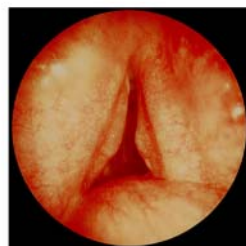
distorsion or buckling



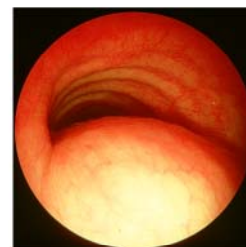
extrinsic compression



scar stricture



scabbard trachea



floppy membrane



abrupt transition:
web stenosis



tapered transition:
hour glass stenosis

Figure 2: Worksheet to mark the location, degree and type of the stenosis.

☐ Bronchoscopy

☐ Bronchography

☐ CT

☐ Virtual bronchoscopy

☐ MRI

patient

Dominant type of structural stenosis or malacia.

Type of transition

intraluminal
extrinsic
distortion
stricture

scabbard
floppy

abrupt
tapered

Localization and degree

0 1 2 3 4 5

upper trachea

0 1 2 3 4 5

middle trachea

0 1 2 3 4 5

lower trachea

Stenosis code

upper
middle
lower
right
left

Figure 3: Example of a classification

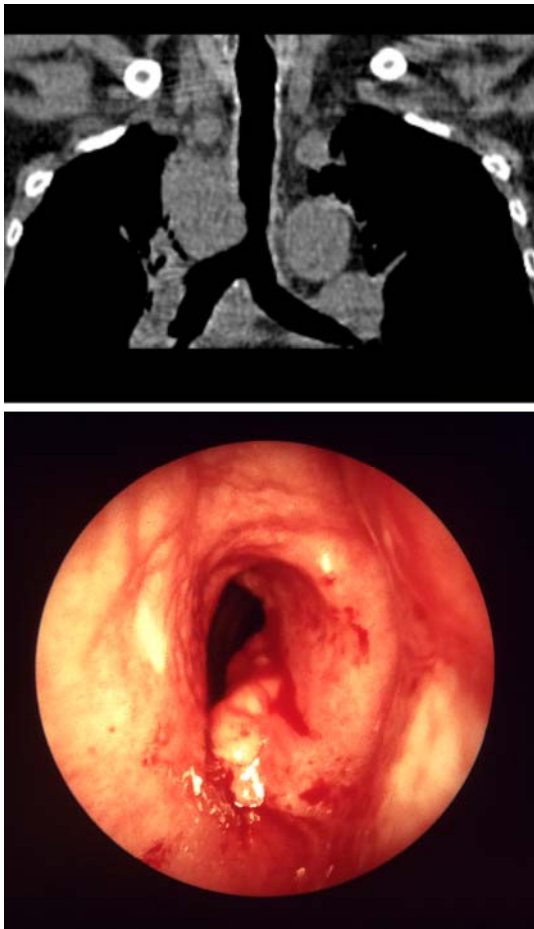


Table 1

Precision (coefficient of variation):

Distributions with $CV < 100\%$ are considered high-precision and low-variance, while those with $CV > 100\%$ are considered low-precision and high-variance.

Variable	N	Summary Coefficient of Variation
Upper trach	10	18%
Middle trach	10	27%
Lower trach	10	~0%
Right stem	10	~0%
Left stem	10	~0%

Agreement (between-rater correlation):

Correlations of 100% indicate perfect agreement between raters, while correlations of 0% indicate complete non-agreement.

Variable	N	Summary Correlation (Rho)
Upper trach	10	86%
Middle trach	10	67%
Lower trach	10	97%
Right stem	10	99%
Left stem	10	99%