Management of malignant airway obstruction

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06-11-2020

Terminology

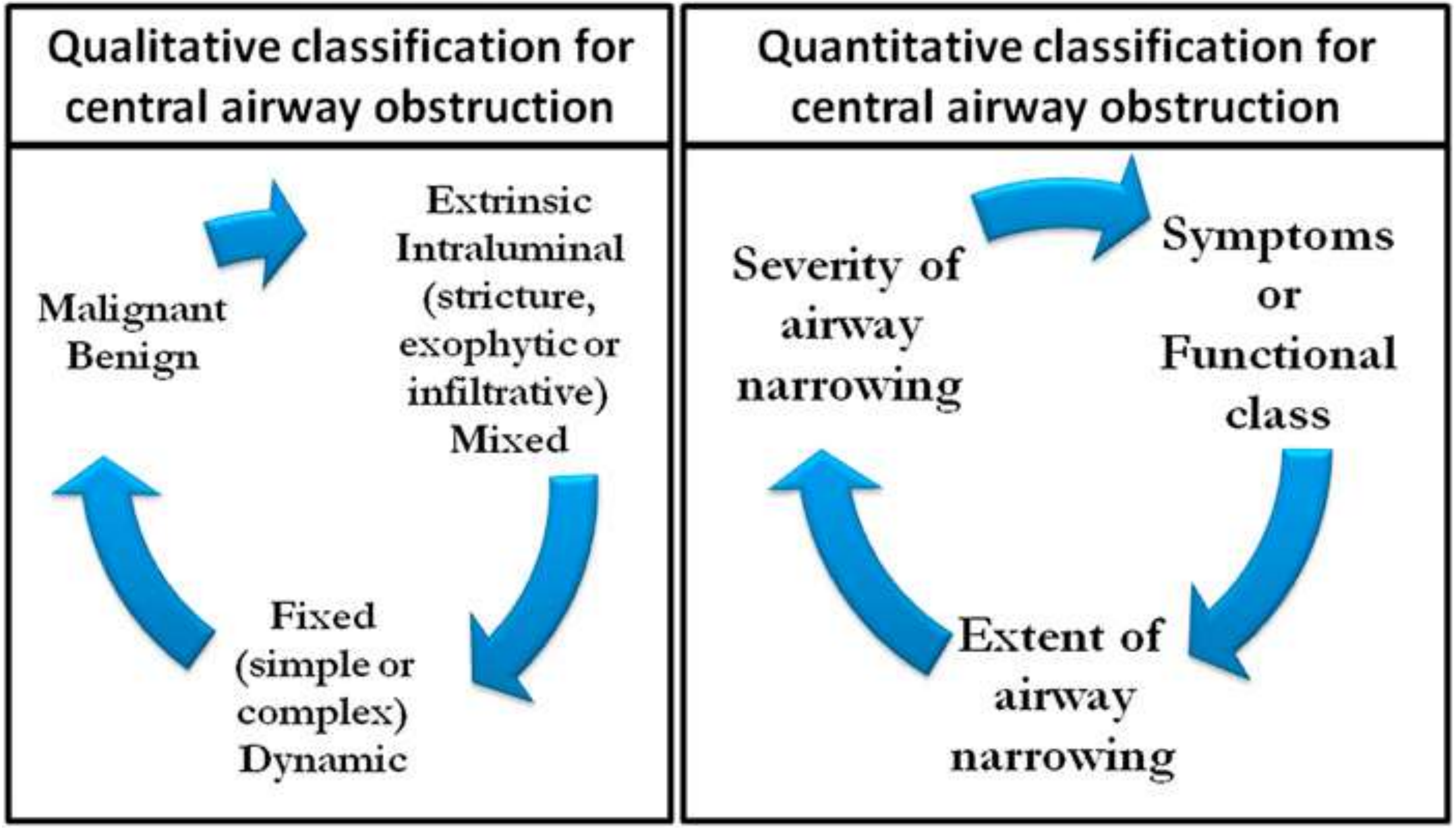
- CAO – Central airway obstruction - Defined as obstruction of airflow in trachea and mainstem bronchi
- Syndrome of CAO- if occlusion is 50%

Murgu SD et al, Central Airway Obstruction, CHEST, Volume 150, Issue 2, 426 – 441

Terminology

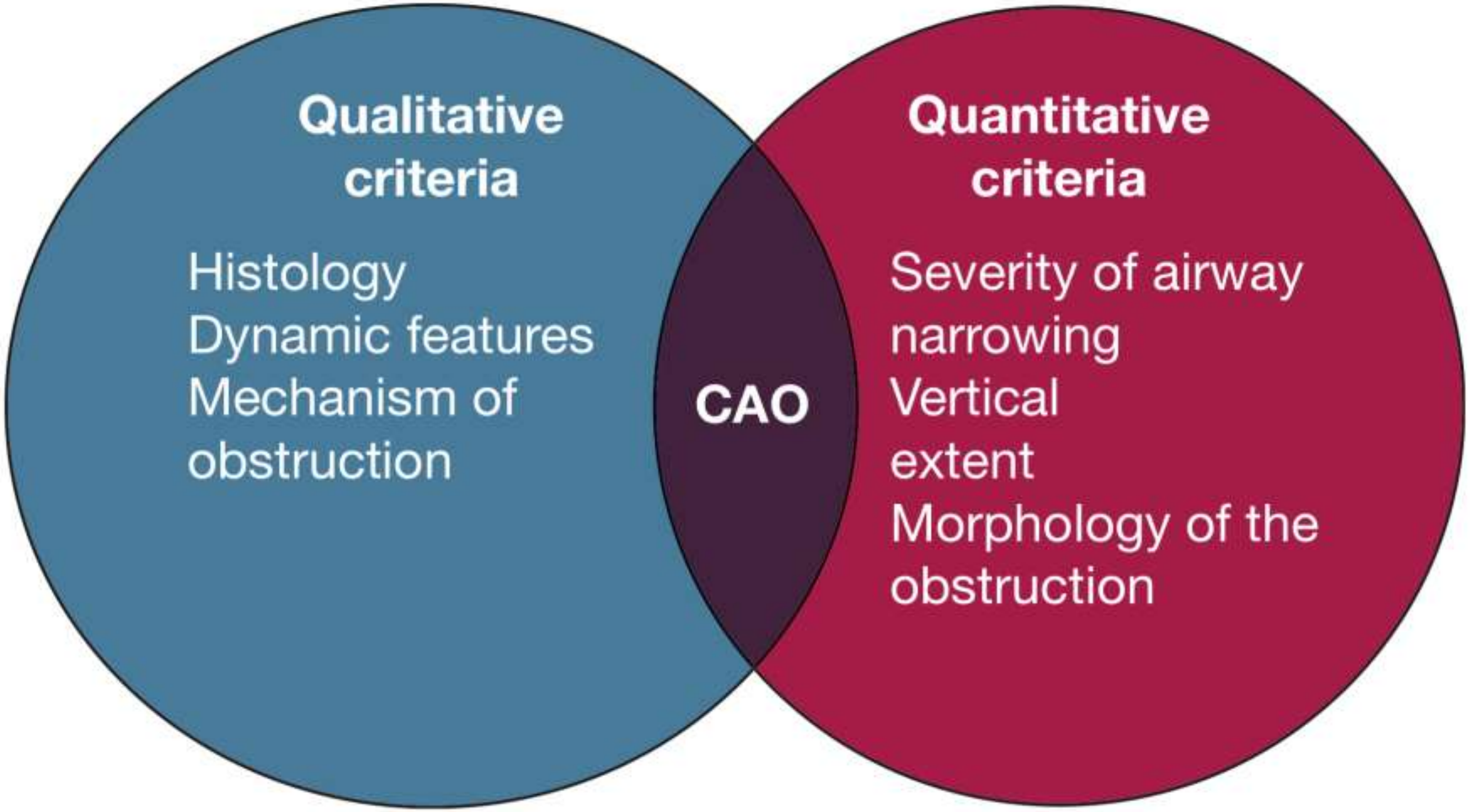
- CAO has a wide range of aetiologies, among which airway malignancy (usually non-small cell lung cancer [NSCLC]) is the most common
- Exact incidence and epidemiology is unknown

CAO-Classification



CAO-Classification

- Typically classified as malignant and non-malignant



Malignant Central Airway Obstruction

- "Malignant Central Airway Obstruction" (MCAO) refers to any malignant, mechanical, obstructive process that impedes the airflow within the central airways (trachea, main-stem bronchi, and right bronchus intermedius)

Oberg C, Folch E, Santacruz JF. Management of malignant airway obstruction. AME Med J 2018;3:115.

Malignant Central Airway Obstruction

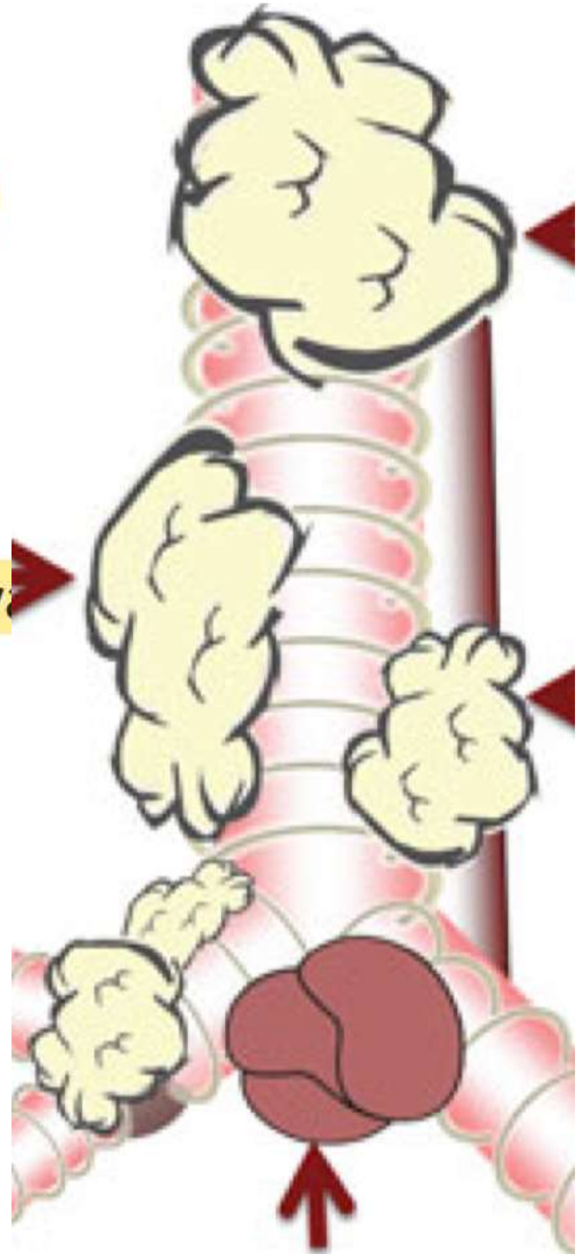
- Usually presents late in the course of the disease, and most individuals have a limited life expectancy
- 20-30% of lung cancer patients have complications due to airway obstruction[1]
- In USA, malignant neoplasms cause CAO in 80,000 cancer patients a year[2]

1-Ernst A et al, Am J Respir Crit Care Med. 2004;169(12):1278
2-Chen et al, J EmergMed. 1998;16(1):83-92

Etiology

Primary endolumenal carcinoma
- Bronchogenic
- Adenoid cystic
- Mucoepidermoid
- Carcinoid

Metastatic carcinoma to the airw
- Bronchogenic
- Renal cell
- Breast
- Thyroid
- Colon
- Sarcoma
- Melanoma



Laryngeal carcinoma

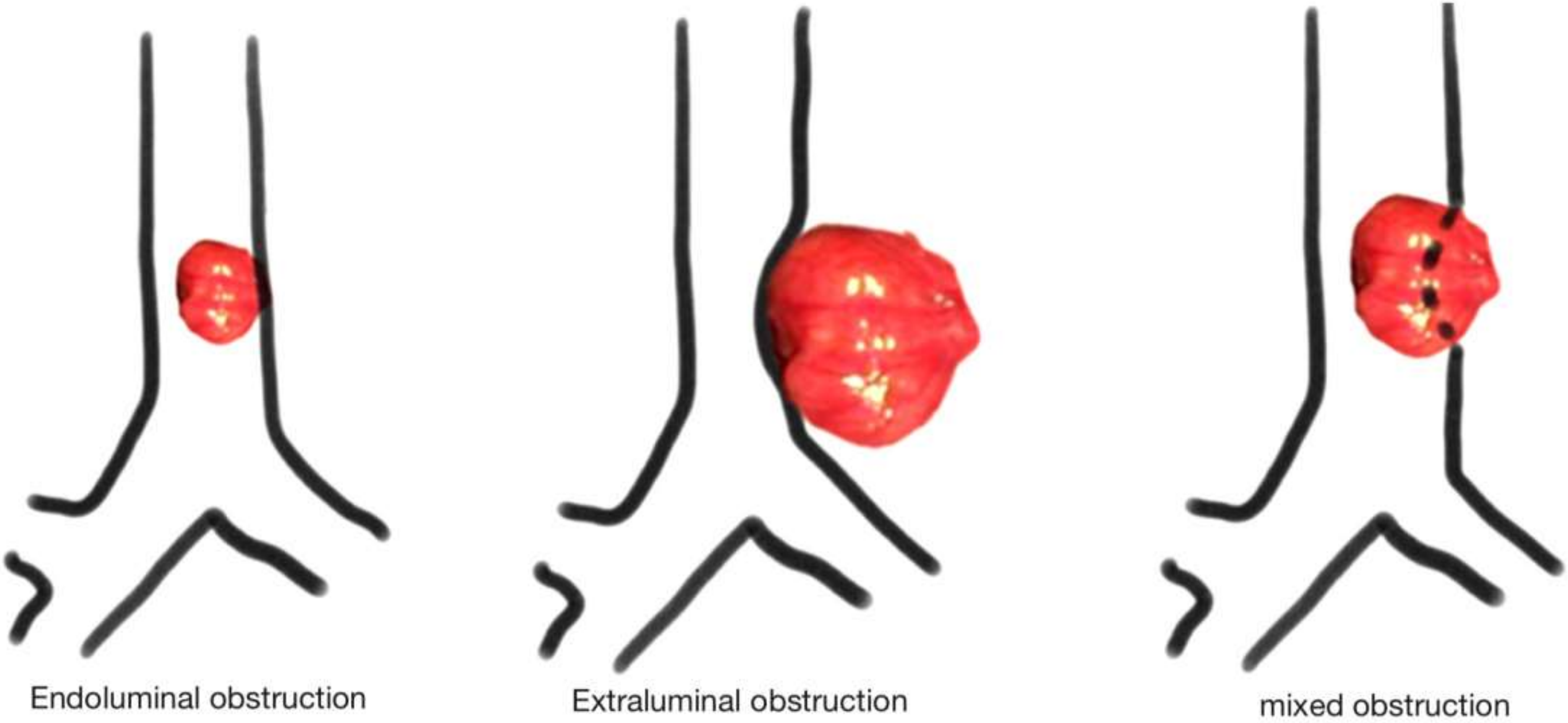
Esophageal carcinoma

Mediastinal tumors
- Thymus
- Thyroid
- Germ cell

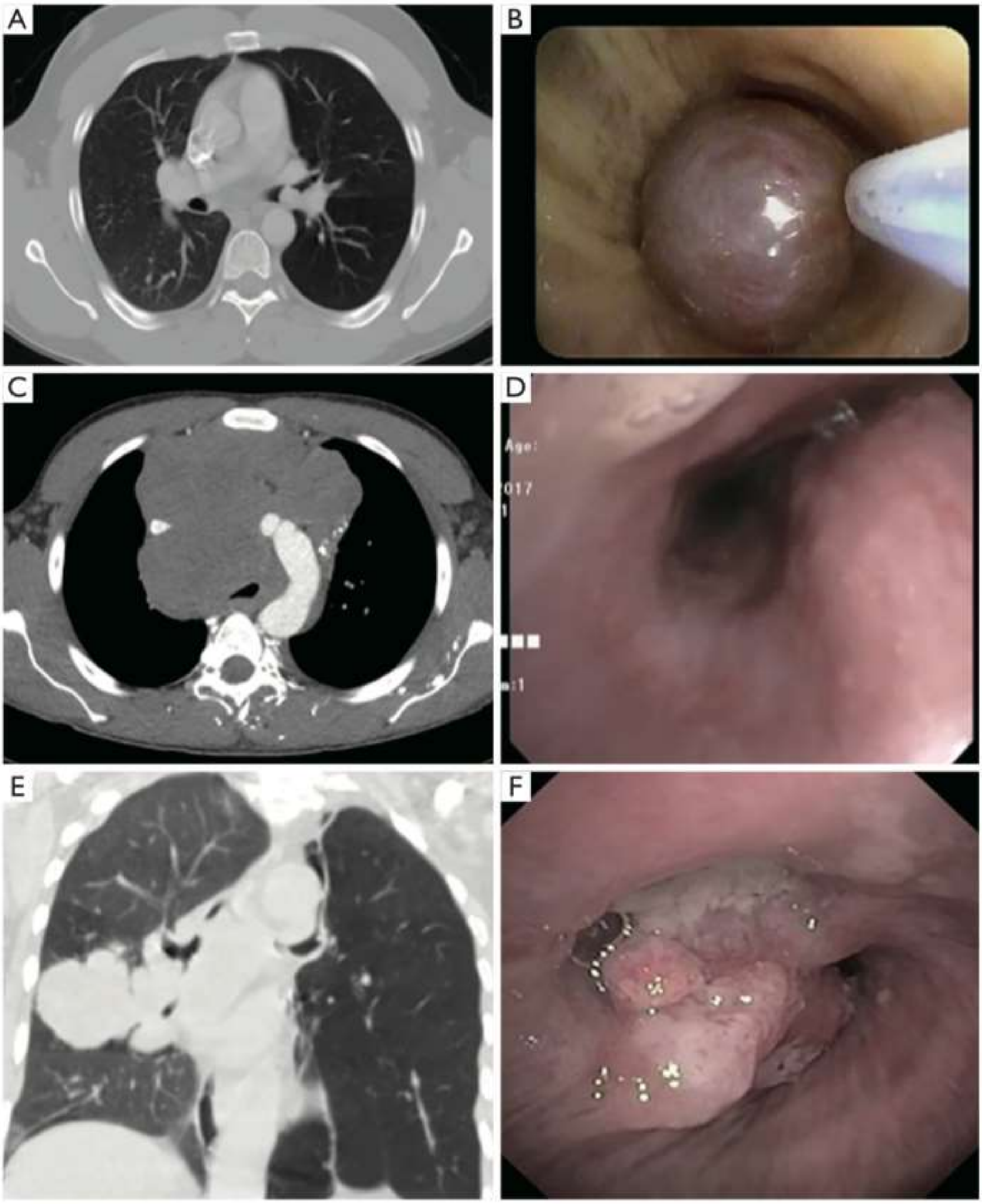
Lymphadenopathy
- Associated with any of the above malignancies
- Lymphoma

Am J Respir Crit Care Med Vol 169. pp 1278–1297, 2004

Classification



Mudambi L, Miller R, Eapen GA. Malignant central airway obstruction. J Thorac Dis 2017;9(Suppl 10):S1087-S1110


A
B
C
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Age:
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E
F

Pathogenesis

- Intraluminal compromise due to intrinsic or extrinsic compression from benign or malignant tumours
- Endobronchial granulation tissue from secondary infection
- Airway wall thinning or collapse from cartilage destruction
- Airway wall oedema from tumour infiltration, infection, and bleeding

Pathogenesis

- These pathogenetic processes can result in fixed or variable obstruction
- Dyspnoea at rest

Tracheal lumen narrowed to 5 mm or 25 % of diameter

- Dyspnoea on exertion

Tracheal lumen is narrowed to 8 mm or 50 % of diameter

Clinical features

Presenting symptoms are nonspecific and can be subacute or acute.

- Dyspnoea
- Cough
- Wheeze
- Haemoptysis
- Stridor
- Hoarseness

- Chest pain
- Dysphagia
- Constitutional symptoms

Clinical features

- Often misdiagnosed as
- Exacerbation of COPD/BA
- Bronchitis
- Pneumonia

Clues to differentiate are

- Dyspnoea that is constant and unresponsive to bronchodilators, or unilateral monophonic wheeze (if the lesion is distal to the carina)
- Symptoms and/or radiographic infiltrates that do not resolve within four to six weeks following a course of antibiotics

Imaging

Subacute

- CXR
- CT Chest (SN-93%,SP-100%)
- Dynamic CT
- Virtual bronchoscopy
- MRI (vascular ring)
- PFT

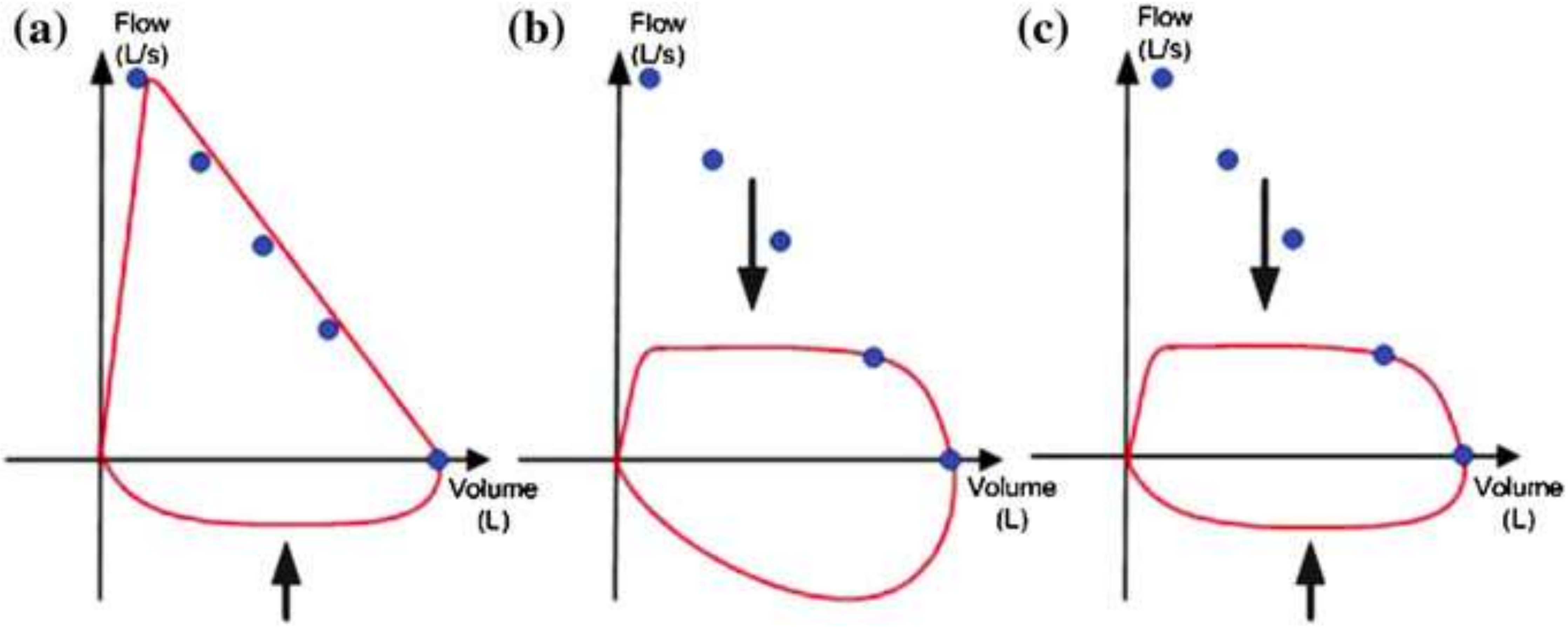
Acute

- Secure airway
- FOB/ Rigid

Spirometry

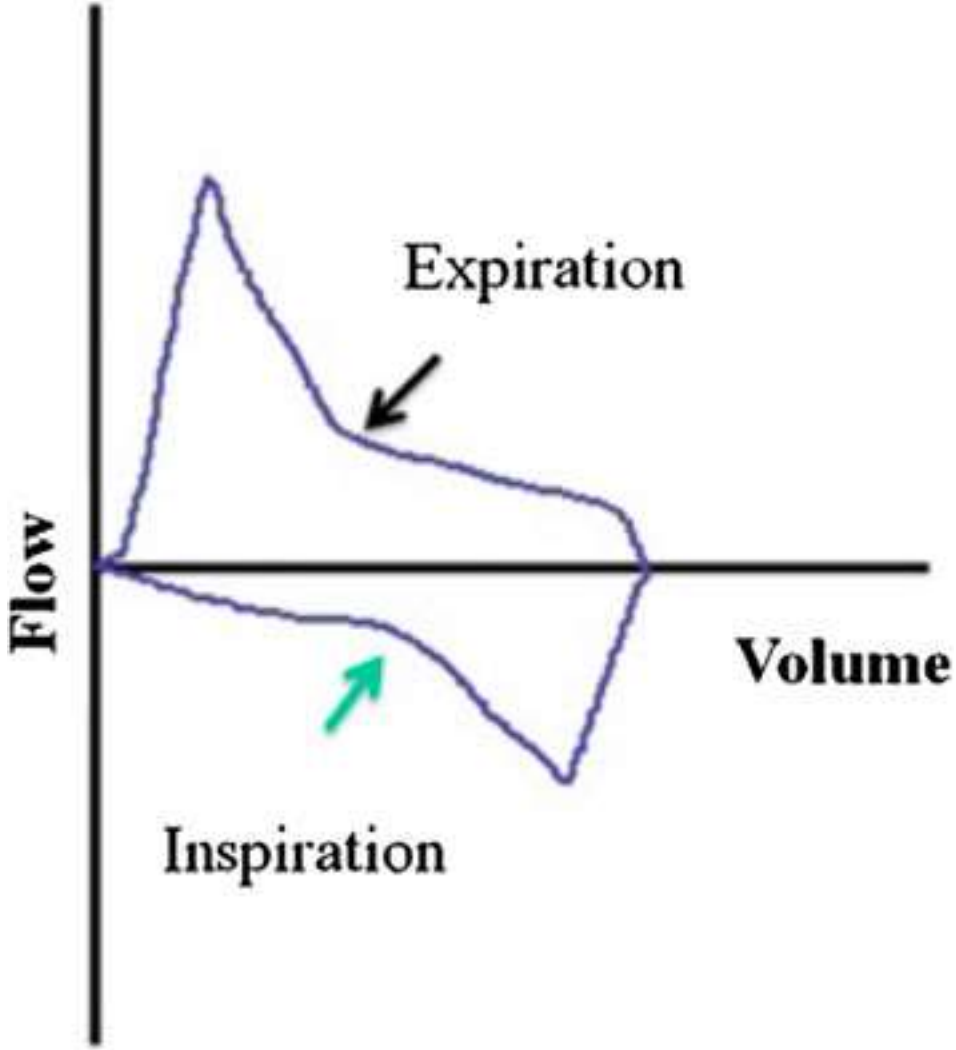
- May be done in subacute presentation
- Flow volume loops will show characteristic signs of CAO before reduction in spirometry values

Spirometry



Stoller JK Cleve Clin J Med. 1992;59:75–8

Spirometry



Unilateral main-stem obstruction

sometime shows a

biphasic expiratory and inspiratory flow

volume loop

Anzueto A, Levine SM, Tillis WP, Calhoon JH, Bryan CL. Use of flow volume loop in the diagnosis of bronchial stenosis after single lung transplantation. Chest. 1994;105:934–6

Life-threatening central airway obstruction

- Patient should be oxygenated and secure airway
- Support typically includes initial bag valve mask ventilation followed by endotracheal intubation
- Upper airway obstruction:

Tracheostomy/cricothyrotomy

- Distal airway obstruction : ETT, rigid bronchoscopy

Life-threatening central airway obstruction

- Should be performed with anaesthesia of the mucous membranes in an awake or mildly sedated patient who is actively breathing
- Avoid paralytics
- Fibre optic assisted intubation with ETT placement under direct visualisation should be considered for proximal tracheal obstructions
- ET > 8 mm is preferred

Life-threatening central airway obstruction

- LMA is an alternative to ET intubation

If any doubt regarding airway stability, rigidbronchoscopy is the procedure of choice

- Provides secure airway
- Enables oxygenation
- Enables ventilation

Heliox

- Has a lower Reynolds number
- Reduces turbulence
- Provides laminar flow
- Decreases driving pressure to achieve given flow

- Reduces work of
- breathing
- Cannot deliver FiO_2 of >40%
- No randomized trials demonstrating improved outcomes

Role of bronchoscopy

- Once the airway is secured and adequate gas exchange is documented
- Immediately or in 12-24 hours
- Assessed visually, distal secretions are suctioned, and diagnostic tissue is obtained if feasible
- Plan further interventions

Non life-threatening central airway obstruction

- Imaging
- PFT
- Bronchoscopic evaluation

Bronchoscopic evaluation

- Gold standard for confirming the presence of airway obstruction
- FOB with or without endobronchial ultrasound (EBUS) helps in
- Extent and nature of the obstruction (eg intrinsic versus extrinsic obstruction, involvement of the carina, oropharynx, or distal bronchi)
- The identification of unexpected distal airway involvement
- Tissue biopsy
- Planning for additional interventions

EBUS

- Extremely sensitive for determining degree of tracheal invasion
- Aids in planning therapeutic interventions

Endobronchial ultrasound in therapeutic bronchoscopy

F. Herth*, H.D. Becker*, J. LoCicero III Jr[#], A. Ernst[¶]

Endobronchial ultrasound in therapeutic bronchoscopy. F. Herth, H.D. Becker, J. LoCicero III Jr, A. Ernst. ©ERS Journals Ltd 2002.

ABSTRACT: Endobronchial ultrasound (EBUS) has been introduced as an adjunct to diagnostic bronchoscopy as it allows evaluation of the submucosal and parabronchial structures. Its use in therapeutic bronchoscopy has not been assessed. A large observational study of the value of EBUS in therapeutic bronchoscopy is presented here.

From January 1998–January 2001 all patients undergoing therapeutic bronchoscopy and EBUS were evaluated prospectively. Patient demographics, indication for bronchoscopy, interventional treatments used and changes in therapy as influenced by the use of EBUS were documented. A total 2,446 therapeutic bronchoscopies were performed. In 1,174 cases EBUS was used (29% mechanical tumour debridement, 20% airway stenting, 13% Neodymium:yttrium aluminium garnet (Nd:YAG) laser use, 23% argon plasma coagulation, 11% brachytherapy, 2% foreign body removal and 2% endoscopic abscess drainage).

EBUS guided or changed therapy significantly in 43% of cases. Changes included adjustment of stent dimensions, termination of tumour debridement when nearing vessels, and referral for surgical interventions rather than endoscopic treatment. Complications associated with EBUS use were minimal. No patient undergoing EBUS guided tumour destruction experienced severe bleeding or fistula formation.

In summary, endobronchial ultrasound was easily performed and changed or guided therapeutic decisions during therapeutic bronchoscopic procedures in a substantial number of cases. As this may result in better outcomes, it has become a standard adjunct in the authors practice.
Eur Respir J 2002; 20: 118–121.

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endobronchial ultrasound
interventional bronchoscopy
laser
stenting

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Outcome/prognosis

- Majority of cases, malignant airway obstruction is not curable, and the approach is aimed at the palliation of symptoms
- Survival of patients with untreated malignant CAO is generally poor and ranges from 1 to 2 months*
- Quality of life is extremely poor, and they may die with asphyxia or on mechanical ventilation

Razi SS, Lebovics RS, Schwartz G, et al. Timely airway stenting improves survival in patients with malignant central airway obstruction. Ann Thorac Surg 2010;90:1088-93.

Prognostic factors for survival after bronchoscopic intervention in patients with airway obstruction due to primary pulmonary malignancy

Bo-Guen Kim[1†], Beomsu Shin[2†], Boksoon Chang[3], Hojoong Kim[1] and Byeong-Ho Jeong[1*]

Methods: This retrospective study was conducted at a university hospital and included 224 patients who received interventional bronchoscopy from 2004 to 2017, excluding patients with salivary gland-type tumor. A multivariable Cox proportional hazard regression analysis was used to identify independent prognostic factors associated with survival after the first bronchoscopic intervention.

and 28.3%, respectively. Poor survival was associated with underlying chronic pulmonary disease, poor performance status, extended lesion, extrinsic or mixed lesion, and MCAO due to disease progression and not receiving adjuvant treatment after bronchoscopic intervention.

Chronic pulmonary disease	1.764 (1.135–2.740)	0.012	1.640 (1.082–2.488)	0.020
Poor performance status[a]	1.946 (1.276–2.968)	0.002	1.750 (1.206–2.540)	0.003
Extrinsic compression	2.525 (1.245–5.125)	0.010	2.119 (1.120–4.011)	0.021
Mixed lesion	2.555 (1.685–3.874)	< 0.001	2.388 (1.657–3.442)	< 0.001
Extended lesion	1.399 (0.903–2.167)	0.133	1.545 (1.035–2.305)	0.033
MCAO as disease progression without adjuvant treatment	5.296 (3.142–8.926)	< 0.001	5.099 (3.075–8.453)	< 0.001

Management principles

- Etiology-specific interventions for airway obstruction
- Goals of treatment are
  - Curative
  - Palliative -airway patency and symptom palliation

Management principles

- Multidisciplinary approach
- Surgical cure is appropriate- consider as the primary mode of therapy
- If not-palliative

Targeting airway patency, decreasing symptom burden, improving quality of life and/or reducing time to extubation

- Bridging therapy

Management-options available

Bronchoscopic ablative therapies

Thermal ablation

- Laser therapy
- Electrocautery
- Argon plasma coagulation
- Endobronchial brachytherapy (EBBT)

Non thermal intervention

- Photodynamic therapy(PDT)
- Cryotherapy
- Dilation
- Debridement
- Airway stent

Management-options available

- Mechanical debulking by rigid bronchoscopy
- Surgical resection
- Investigational
- External beam radiotherapy
- Medication-focused palliation of symptoms

Choosing among options depends on

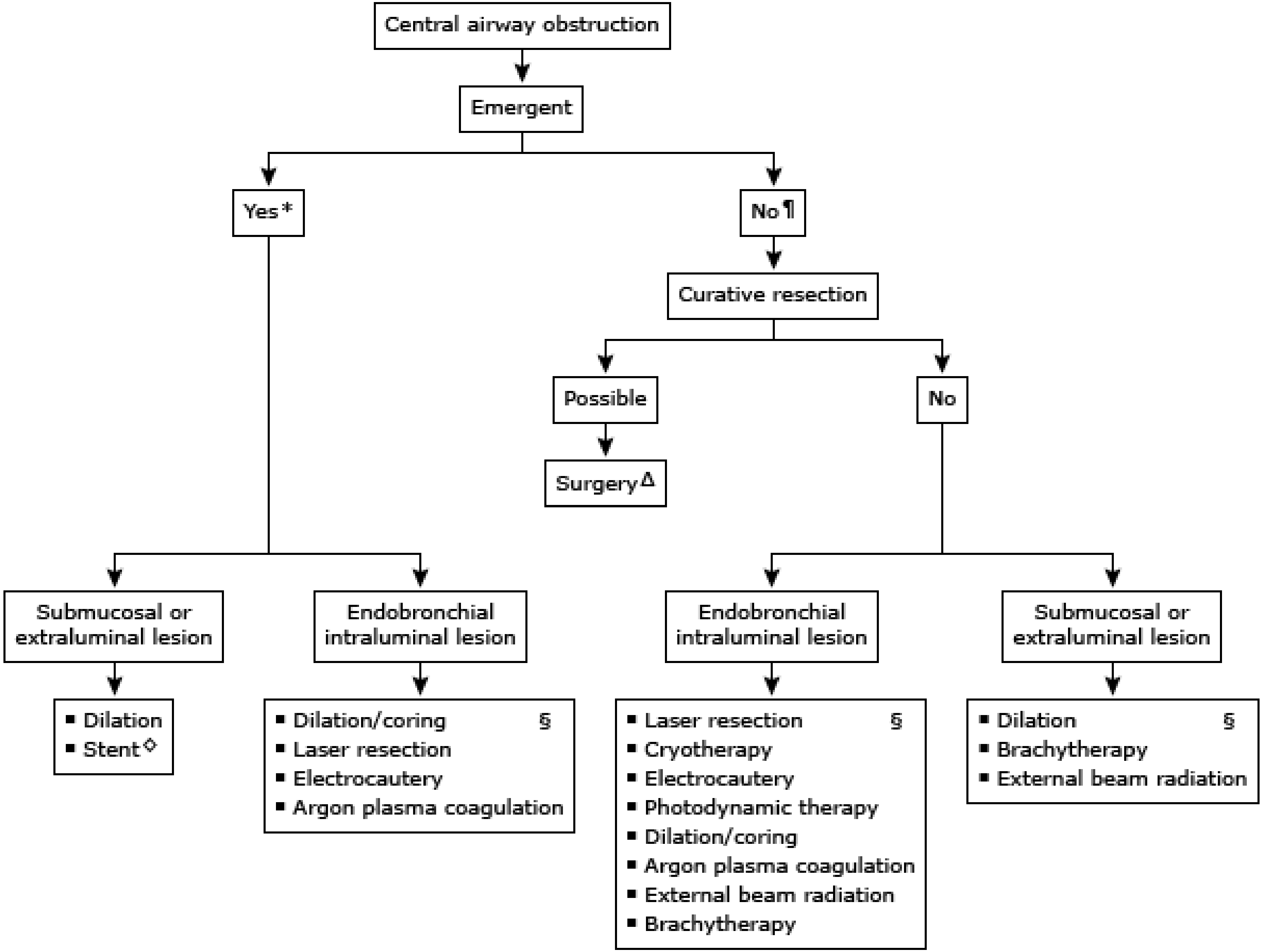
- Cause of the lesion
- Predicted response to therapy
- Operator experience
- Available expertise
- Patient prognosis
- Ability of the patient to tolerate a selected procedure

Choosing among modalities

For immediate therapeutic effect

- Coring or mechanical debridement using a rigid bronchoscope
- With or without dilation and stenting
- Bronchoscopic ablative techniques-APC, electrocautery, and laser are suitable alternatives
- Cryosurgery, PDT and EBBT should not be used as their effects are delayed

BolligerCT, et al,Eur Respir J. 2002;19:356-373



Central airway obstruction
Emergent
Yes *
No ¶
Curative resection
Possible
No
Surgery Δ
Submucosal or extraluminal lesion
Endobronchial intraluminal lesion
Endobronchial intraluminal lesion
Submucosal or extraluminal lesion
Dilation
Stent ◊
Dilation/coring
Laser resection
Electrocautery
Argon plasma coagulation
§
Laser resection
Cryotherapy
Electrocautery
Photodynamic therapy
Dilation/coring
Argon plasma coagulation
External beam radiation
Brachytherapy
§
Dilation
Brachytherapy
External beam radiation
§

Multimodality approaches

- Combination of several bronchoscopic interventions

Oviatt PL et al	Prospective study 37 patients	• 6 MWT – increased by 99.7m • FEV1 – increased by 448 ml • Dyspnoea scores improved in 90%
Amjadi K et al	Prospective study 24 patients	• Improvement in airway diameter in all patients • 80% patency in 80% patients • Dyspnea scores improved in 85%

Complications Following Therapeutic Bronchoscopy for Malignant Central Airway Obstruction

Results of the AQuIRE Registry

January 2009 to February 2013

METHODS: We used the American College of Chest Physicians (CHEST) Quality Improvement Registry, Evaluation, and Education (AQuIRE) program registry to conduct a multicenter study of patients undergoing therapeutic bronchoscopy for malignant central airway obstruction. The primary outcome was the incidence of complications. Secondary outcomes were incidence of bleeding, hypoxemia, respiratory failure, adverse events, escalation in level of care, and 30-day mortality.

RESULTS: Fifteen centers performed 1,115 procedures on 947 patients. There were significant differences among centers in the type of anesthesia (moderate vs deep or general anesthesia, $P < .001$), use of rigid bronchoscopy ($P < .001$), type of ventilation (jet vs volume cycled, $P < .001$), and frequency of stent use ($P < .001$). The overall complication rate was 3.9%, but significant variation was found among centers (range, 0.9%-11.7%; $P = .002$). Risk factors for complications were urgent and emergent procedures, American Society of Anesthesiologists (ASA) score > 3, redo therapeutic bronchoscopy, and moderate sedation. The 30-day mortality was 14.8%; mortality varied among centers (range, 7.7%-20.2%, $P = .02$). Risk factors for 30-day mortality included Zubrod score > 1, ASA score > 3, intrinsic or mixed obstruction, and stent placement.

Majority of deaths related to progression of the underlying malignancy

Urgency of the procedure	
Elective	767 (68.8)
Emergent	104 (9.3)
Urgent	244 (21.9)
ASA score	
≤3	701 (62.9)
>3	414 (37.1)
First therapeutic bronchoscopy	
Yes	800 (71.7)
No (redo bronchoscopy, second or later)	315 (28.3)
Cancer related	
Primary lung cancer	800 (71.7)
Time from cancer diagnosis >75 d	556 (49.9)
Location of disease[a]	
Trachea	255 (22.9)
Left main	416 (37.3)
Right main	459 (41.2)
Bronchus intermedius	268 (24)
Lobar	323 (29)
Any tracheoesophageal fistula	9 (0.8)

Type(s) of obstruction present[a]	
Any endobronchial	549 (49.2)
Any extrinsic	161 (14.4)
Any mixed	485 (43.5)
Type of bronchoscopy	
Flexible	382 (34.3)
Rigid	733 (65.7)
Ablative technique used	
Any laser used	262 (23.5)
Any electrocautery used	238 (21.3)
Any APC used	393 (35.2)
Any cryotherapy used	89 (8)
Any dilation done	448 (40.2)
Stent placed[a]	
Any stent placed	406 (36.4)
Stent shape[a]	
Any tube stent[d]	331 (29.7)
Any Y stent[e]	85 (7.6)
Stent material	
Any metal stent	298 (26.7)
Any silicone stent	118 (10.6)
Any silicone tube stent	36 (3.2)
Any metal tube stent	295 (26.5)

Patient and Clinical Characteristics for Any Complications

Urgency of the procedure			
Elective	747 (97.4)	20 (2.6)	...
Emergent	96 (92.3)	8 (7.7)	...
Urgent	228 (93.4)	16 (6.6)	.002
Zubrod score			
≤1	458 (97.7)	11 (2.3)	...
>1	613 (94.9)	33 (5.1)	.02
ASA score			
≤3	685 (97.7)	16 (2.3)	...
>3	386 (93.2)	28 (6.8)	.0002
First therapeutic bronchoscopy			
No	294 (93.3)	21 (6.7)	...
Yes	777 (97.1)	23 (2.9)	.003

Anesthesia			
Deep or general anesthesia			
Moderate sedation	142 (92.2)	12 (7.8)	...
Deep or general anesthesia	929 (96.7)	32 (3.3)	.008
Paralysis			
No	264 (93.3)	19 (6.7)	...
Yes	807 (97)	25 (3)	.006
Type of ventilation			
Volume cycled[d]	689 (96.5)	25 (3.5)	...
Jet	224 (97.4)	6 (2.6)	...
Spontaneous	158 (92.4)	13 (7.6)	.02

Patient and Clinical Characteristics by Complication Resulting in Death

6 patients(0.5%) died due to procedural complication

Urgency of the procedure			
Elective	766 (99.9)	1 (0.1)	...
Emergent	103 (99)	1 (1)	...
Urgent	240 (98.4)	4 (1.6)	.01
Primary lung cancer			
No	311 (98.7)	4 (1.3)	...
Yes	798 (99.8)	2 (0.3)	.056

Type of bronchoscopy		
Flexible	380 (99.5)	2 (0.5)
Rigid	729 (99.5)	4 (0.5)
Any laser used		
No	848 (99.4)	5 (0.6)
Yes	261 (99.6)	1 (0.4)
Any electrocautery used		
No	874 (99.7)	3 (0.3)
Yes	235 (98.7)	3 (1.3)
Any APC used		
No	717 (99.3)	5 (0.7)
Yes	392 (99.7)	1 (0.3)
Any cryotherapy used		
No	1,020 (99.4)	6 (0.6)
Yes	89 (100)	0 (0)
Any dilation done		
No	662 (99.3)	5 (0.7)
Yes	447 (99.8)	1 (0.2)
Stent		
Stent placed		
No	705 (99.4)	4 (0.6)
Yes	404 (99.5)	2 (0.5)
Metal stent		
No	813 (99.5)	4 (0.5)
Yes	296 (99.3)	2 (0.7)

Type of obstruction			
Any intrinsic			
No	564 (99.6)	2 (0.4)	...
Yes	545 (99.3)	4 (0.7)	.45
Any extrinsic			
No	949 (99.5)	5 (0.5)	...
Yes	160 (99.4)	1 (0.6)	1.0
Any mixed			
No	626 (99.4)	4 (0.6)	...
Yes	483 (99.6)	2 (0.4)	.73
Silicone tube stent			
No	1,073 (99.4)	6 (0.6)	...
Yes	36 (100)	0 (0)	1.0
Tube stent			
No	780 (99.5)	4 (0.5)	...
Yes	329 (99.4)	2 (0.6)	1.0
Y stent			
No	1,024 (99.4)	6 (0.6)	...
Yes	85 (100)	0 (0)	1.0

Patient and Clinical Characteristics by Any Complication That Also Had an AE

Urgency of the procedure			
Elective	759 (99)	8 (1)	...
Emergent	98(94.2)	6 (5.8)	...
Urgent	234(95.9)	10 (4.1)	.0005
Zubrod score			
≤1	468 (99.8)	1 (0.2)	...
>1	623 (96.4)	23 (3.6)	.0001
ASA score			
≤3	695 (99.1)	6 (0.9)	...
>3	396 (95.7)	18 (4.3)	.0001

Patient and Clinical Characteristics by Any Complication That Also Had an AE

Type of bronchoscopy			
Flexible	374 (97.9)	8 (2.1)	...
Rigid	717 (97.8)	16 (2.2)	.92[c]
Any laser used			
No	835 (97.9)	18 (2.1)	...
Yes	256 (97.7)	6 (2.3)	.86
Any electrocautery used			
No	860 (98.1)	17 (1.9)	...
Yes	231 (97.1)	7 (2.9)	.34
Any APC used			
No	704 (97.5)	18 (2.5)	...
Yes	387 (98.5)	6 (1.5)	.29
Any cryotherapy used			
No	1,003 (97.8)	23 (2.2)	...
Yes	88 (98.9)	1 (1.1)	.71[c]
Any dilation done			
No	657 (98.5)	10 (1.5)	...
Yes	434 (96.9)	14 (3.1)	.07
Stent			
Stent placed			
No	695 (98)	14 (2)	...
Yes	396 (97.5)	10 (2.5)	.59
Metal stent			
No	801 (98)	16 (2)	...
Yes	290 (97.3)	8 (2.7)	.46
Silicone tube stent			
No	1,056 (97.9)	23 (2.1)	...
Yes	35 (97.2)	1 (2.8)	.40
Tube stent			
No	769 (98.1)	15 (1.9)	...
Yes	322 (97.3)	9 (2.7)	.09
Y stent			
No	1,008 (97.9)	22 (2.1)	...
Yes	83 (97.6)	2 (2.4)	.70[c]

J Bronchology Interv Pulmonol. 2020 Apr;27(2):95-105. doi: 10.1097/LBR.0000000000000624.

A Prospective Outcome Assessment After Bronchoscopic Interventions for Malignant Central Airway Obstruction

Anant Mohan [1], Prajowl Shrestha [1], Karan Madan [1], Vijay Hadda [1], Ravindra M Pandey [2], Ashish Upadhyay [2], Gopi C Khilnani [1], Randeep Guleria [1]

- Single-center, prospective observational, cohort study-AIIMS New Delhi
- All patients with symptomatic malignant central airway obstruction (CAO) scheduled for therapeutic bronchoscopy procedures were included over a 2-year period from June 2015 to May 2017
- Primary objective-assess symptomatic and functional improvement after endobronchial procedures

AIIMS data

- Secondary objectives -determine the complications rates associated with the various procedures and short-term survival 3 months after the procedures
- Assessments were performed at baseline and at 48 hours, 4 weeks, and 12 weeks after the procedure
- 96 patients with CAO underwent various therapeutic bronchoscopic interventions

- Lung cancer was the MC aetiology of malignant CAO (n=24, 36.9)
- Oesophageal carcinoma (n=16, 24.6%),
- Primary tracheal carcinoma (n=12, 18.4%),
- Thyroid carcinoma (n=8, 12.3%),
- Lymphoma (n=4, 6.1%).

Morphologic Type	n (%)
Non–small cell carcinoma	18 (75)
Squamous cell carcinoma	10 (41.6)
Adenocarcinoma	4 (16.6)
Mucoepidermoid carcinoma	2 (8.4)
Non–small cell carcinoma-(NOS)	2 (8.4)
Small cell lung carcinoma	6 (25)
Total	24 (100)

AIIMS-Data

TABLE 2. Interventions Performed to Manage Malignant Central Airway Obstruction

Procedure	n (%)
Airway stenting	47 (56.6)
Tracheobronchial Y-SEMS	23 (48.9)
Tracheal SEMS	19 (40.4)
Bronchial SEMS	2 (4.2)
Silicone stent	3 (6.3)
Mechanical debulking	22 (26.5)
Cryodebulking	5 (6.0)
Electrosurgical debulking	4 (4.8)
CRE balloon dilatation	3 (3.6)
Laser debulking	2 (2.4)
Total	83

CRE indicates controlled radial expansion; SEMS, self-expandable metallic stent.

TABLE 4. Survival among Patients With Malignant Central Airway Obstruction After Procedure

	0	4 wk	8 wk	12 wk
Survival	65	54 (83.0%)	46 (70.7%)	43 (66.1%)
Mortality	0	11	19	22

TABLE 5. Cause of Deaths Among Study Group During Follow-up Period

Cause of Death	n (%)
Progression of disease	11 (50.0)
Death at home/cause could not be determined	5 (22.7)
Bacterial pneumonia/severe sepsis	4 (18.2)
Fungal pneumonia	1 (4.5)
Massive hemoptysis	1 (4.5)
Total	22 (100)

Summary of Major Studies of Bronchoscopic Interventions for Malignant CAO

References	No. Patients/ No. Procedures	Scope Used (Study Design)	Intervention(s) Performed	Outcomes Assessed	Complications
Lemaire et al[5]	140/172	Rigid scope (retrospective)	Stenting: 140 Core-out: 20 Mechanical dilatation: 61 Nd:YAG Laser: 50	Median survival poststenting: 3.4 mo 1-year survival: 15%	N = 23 (not specified) (< 30 d, n = 5; > 30 d, n = 18)
Wood et al[19]	Total: 143/309 (malignant: 96/NR)	Rigid: 307 Flexible: 02 (retrospective)	Stenting: 143 Dilatation: 35 (11%) Coring: 57 (18%)	95% subjects reported improved symptoms	N = 131/309 (42%) One major event requiring thoracotomy
Saji et al[20]	65/79	Both rigid and flexible scope (number not specified) (retrospective)	Stenting Silicon: 42 (60%) Metallic: 19 (29%) Both: 8 (11%)	Acute relief of central airway and significant improvement seen in 98% 1-year survival: 25.2% Median survival time: 6.2 mo	Severe complications: 13 (22%) Severe mucus: 6 Pneumothorax: 3 Idiopathic pyothorax: 2 Esophageal stenosis: 1 Acute pulmonary distress: 1 Stent-related morbidity and mortality: 22% and 8%, respectively

Summary of Major Studies of Bronchoscopic Interventions for Malignant CAO

References	No. Patients/ No. Procedures	Scope Used (Study Design)	Intervention(s) Performed	Outcomes Assessed	Complications
Cosano Povedano et al[2]	136/320	Rigid scope (retrospective)	Laser: 145 Stent: 116 Balloon or mechanical Dilatations: 33 Electrocauterization: 26	Improvement in dyspnea was observed in 96%	Mortality: 1.4% Stent migration (9/116; 8%) Granulation: (11/116; 9%)
Cavaliere et al[16]	2008	Rigid scope (retrospective)	Laser resections: 2610 in 1838 patients High-dose rate brachytherapy: 66 Stents: 393 silicone stents in 306 patients	Immediate luminal patency achieved: 93%	Overall mortality: 12 (0.4%)
Oviatt et al[11]	37 patients	Rigid scope (prospective)	Balloon bronchoplasty: 12 Stenting: 25 Electrocautery forceps/snaring: 37	Significant improvement in 6MWD, FEV_1, FVC, dyspnea score and QoL at 30 d	Median survival: 166 d (23.7 wk) 6 mo survival: 46% Oropharyngeal minor trauma: 8.1% Upper airway swelling: 5.4% Stent migration: 2.7%

Summary of Major Studies of Bronchoscopic Interventions for Malignant CAO

References	No. Patients/ No. Procedures	Scope Used (Study Design)	Intervention(s) Performed	Outcomes Assessed	Complications
Hespanhol et al[21]	804	Rigid scope (retrospective)	Laser: 598 Airway stenting: 129 Both: 65 Instrumental debulking: 12	Successful luminal clearance > 50% of original airway: 84.7%	Mortality: 02
Vishwanathan et al[18]	23	Rigid scope (retrospective)	Coring Mechanical dilatation	Successful luminal clearance: 87.1% Significant improvement in dyspnea	Complication rate: 10 (32.3%) Significant bleeding: 8 (25.8%) Hypotension: 1 (3.3%) Arrhythmia: 1 (3.3%)
Madan et al[17]	38	Rigid (32); flexible (6) scope (retrospective)	Airway stenting with Y-SEMS	Rapid improvement in symptoms and resolution of respiratory failure	Stent fracture: 1 (2.6%) Secretions requiring bronchoscopy: 12 (31.6%) Granulation tissue: 8 (21.1%) Mortality at 3 mo: 18 (47.4%)

Summary of Major Studies of Bronchoscopic Interventions for Malignant CAO

References	No. Patients/ No. Procedures	Scope Used (Study Design)	Intervention(s) Performed	Outcomes Assessed	Complications
Dasgupta et al[4]	37/52	Flexible scope under GA using fluoroscopic guidance (prospective)	SEMS (Wallstent; Schneider Corp; Minneapolis)	Airway patency restored in all Symptoms improved in all except 1 subject	0.06 complication per patient-month Granulation: 5 Staphyloccocal associated bronchitis: 1
Marasso et al[22]	234; 183 malignant tumors, 44 benign tumors, and 7 tumors of uncertain prognosis	Rigid scope (retrospective)	Cryotherapy	Satisfactory airway patency achieved in all	NR
Maiwand et al[23]	622 Malignant CAO (n = 600) and post-transplant anastomotic stricture: 22	Rigid scope (retrospective)	Cryotherapy	78% overall subjective improvement	NR
Verma et al[24]	16	Flexible and rigid scope (retrospective)	Nd:YAG Laser Coring SEMS (Boston Scientific Ultraflex)	Significant improvement in dyspnea (87.5%) Survival similar	Granulation tissue Mucus plug Tumor ingrowth

References	No. Patients/ No. Procedures	Scope Used (Study Design)	Intervention(s) Performed	Outcomes Assessed	Complications
Shin et al[25]	98 patients/189 procedures (extrapulmonary malignant CAO)	Rigid scope (retrospective) (2004-2011)	Mechanical debulking (84.7%) Stent (70.4%) Laser (37.8%)	Procedural success (89.9%) Better survival in carcinoma thyroid and lymphoma	Acute complications (20.4%): respiratory distress/ excessive leading/ pneumothorax Procedural-related death (3.1%) Chronic complication: Mucus plug Granulation tissue Stent migration
Chen et al[26]	481 patients/554 procedure	Therapeutic bronchoscope (retrospective) (2008-2015)	Stent (26.4%): Ultraflex SEMS Electrocautery (58.4%) Stent and electrocautery (15.2%)	No statistically significant difference in survival	Halitosis (n = 41, 6.7%) Iatrogenic pneumonia (n = 24, 3.9%)
Stratakos et al[27]	36 patients	Flexible and rigid scope (prospective study with 12 control)	Electrocautery Stent placement	Significant improvement in mean survival abd QoL in intervention group as compared with control group ($P = 0.04$ and <0.05, respectively) Patients of the control group had worse QoL and dyspnea in all time points	NR

Surgery

- Surgery for MAO is desirable when a cure for cancer is feasible
- Can be done for primary tracheal tumors
- Lung cancers -not feasible
- most lesions are assessed as T4 (stage-IIIA)
- only select patients undergo surgery when surgical cure is deemed feasible (small lesions [2 to 3 cm] without nodal mets[T4N0M0])
- Surgery is technically difficult and requires expertise

Bronchoscopic ablative therapies

Thermal Ablation

- LASER
- Electrocautery
- APC
- Cryotherapy

Non Thermal Intervention

- PDT
- Airway dilation
- Airway stent
- Debriderment

BRONCHOSCOPY RIGID OR FLEXIBLE

- Majority of interventional techniques can be employed via a flexible bronchoscope
- But for MAO most of the require rigid support
- Mortality from flexible bronchoscopy is rare, with a reported death rate of up to 0.04%
- Complication rates from rigid bronchoscopy are low at 0.1%
- Procedure-related mortality is rare

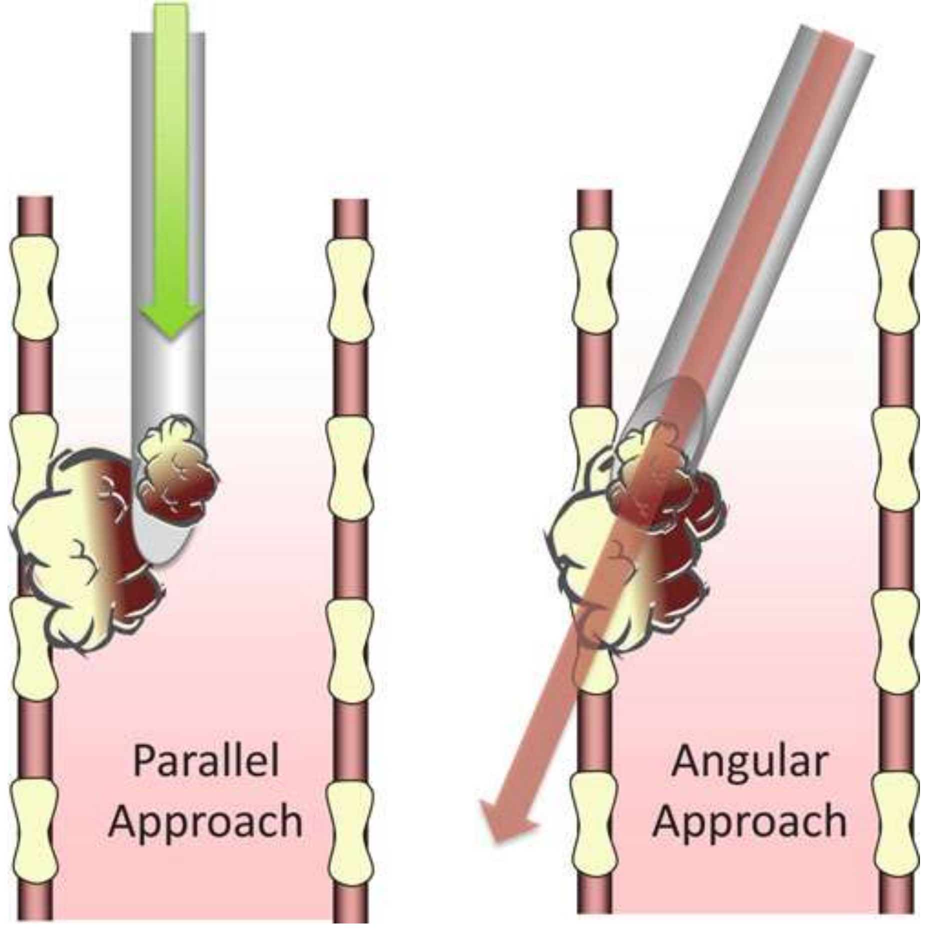
	Rigid bronchoscopy	Flexible bronchoscopy
Indications		
Massive hemoptysis	++	+
Tumor resection	++	++
Deep bronchial-wall biopsy	++	+ (cryoprobe)
Stent placement	All stents	Self-expandable stents
Electrocautery, laser, cryotherapy, brachytherapy, PDT	++	++
Microdebrider		++
Advantages		
Availability/training	Uncommon	Common
Anesthesia	General anesthetic	Conscious sedation
Reach	Proximal airway (common practice is to pass a flexible bronchoscope through rigid bronchoscope to reach distal airways)	Proximal and distal airway

	Rigid bronchoscopy	Flexible bronchoscopy
Expense	++	+
Suction	+++	+
Tools	Rigid, large	Flexible, small
Specific complications		
	Over sedation and hypoxia	Those pertaining to general anesthetic
	Vocal cord trauma	Dental, laryngeal edema/ vocal cord trauma
		Tracheal or esophageal perforation

Also used for mechanical dilation-by single or serial

Mechanical debulking by rigid bronchoscopy

- Retrospective studies has shown that rigid bronchoscopy and mechanical debulking as a sole therapy is safe and successful in up to 83% of cases of central airway tumors
- Complications with mechanical debulking range from 1–20%, and include pneumothorax, hemoptysis, and pneumonia



Rigid Bronchoscopy and Mechanical Debulking in the Management of Central Airway Tumors

An Indian Experience

Gella Vishwanath, MD, DM, Karan Madan, MD, DM,* Amanjit Bal, MD, DipNB,† Ashutosh N. Aggarwal, MD, DM,* Dheeraj Gupta, MD, DM,* and Ritesh Agarwal, MD, DM**

- Retrospective review of charts-over a period of 2 years
- Successful” outcome was defined as procedure leading to reduction of luminal obstruction to <50% an improvement of respiratory distress
- Out of 30 patients of CAO- 23 patients underwent 31 rigid bronchoscopy
- Respiratory failure was present in 15 (65.2%) patients

PGIMER data

- Adenoid cystic carcinoma was the most common primary tracheal tumor
- Squamous cell ca was the most common secondary tracheobronchial tumor
- Procedure was successful in 19 (82.6%) patients.
- Complications in 10 of the 31 (32.3%) rigid bronchoscopies
- There was no procedural mortality

	Number (%)
Symptoms	
Cough	20 (86.9)
Dyspnea	20 (86.9)
Hemoptysis	13 (56.5)
Wheeze	9 (39.1)
Stridor	6 (26)
Dysphagia	5 (21.7)
Chest pain	5 (21.7)
Chest radiograph	
Abnormal	15 (65.2)
Mass	8 (34.7)
Collapse	6 (26)
Pleural effusion	1 (4.3)
Other findings	2 (8.6)
Site of tracheobronchial involvement	
Upper trachea	2 (8.6)
Mid trachea	3 (13)
Lower trachea	10 (43.4)
Carina	4 (17.3)
Right main bronchus	12 (52)
Left main bronchus	3 (13)
Bronchoscopic findings	
Mass	23 (100)
Infiltration	4 (17.3)
Extrinsic compression	1 (14.3)
Severity of luminal obstruction	
Grade 1 (< 50%)	0
Grade 2 (50%-74%)	7 (30.4)
Grade 3 (75%-89%)	5 (21.7)
Grade 4 (90%-100%)	11 (47.8)

TABLE 2. Details of Rigid Bronchoscopy Procedures, Outcomes, and Complications

Outcomes	
Successful	19 (87.1)
Unsuccessful	4 (12.9)
Complications*	
Significant bleed	8 (25.8)
Hypotension	1 (3.3)
Arrhythmia	1 (3.3)
Duration of rigid bronchoscopy procedure*, median (range)	45 (30-140) min
Assisted ventilation postprocedure*	
Number	17 (73.9)
Time to extubation (median)	6 (4-72) h
Procedures done on follow-up with flexible bronchoscopy	
Electrocautery	2 (6.4)
Argon plasma coagulation	3 (9.6)

*31 procedures.

No.	Procedure	Luminal Obstruction (Pre) (%)	Luminal Obstruction (Post) (%)	Outcome	Histopathology	Current Status
1	Coring	70	60	2	Esophageal squamous cell carcinoma	2
2	Coring	100	0	1	Endobronchial lipoma	1
3	Coring	70	20	1	Malignancy NOS	2
4	Coring, stenting	80	20	1	Large cell neuroendocrine carcinoma	2
5	Coring	90	20	1	Adenocarcinoma	2
6	Coring	50	10	1	Esophageal squamous cell carcinoma	2
7	Coring, stenting	90	40	1	Adenoid cystic carcinoma	1
8	Coring	80	20	1	Squamous cell carcinoma	2
9	Coring	50	30	1	Basal cell adenocarcinoma of salivary gland origin	2
10	Coring	100	10	1	Metastatic clear cell carcinoma	2
11	Coring	100	0	1	Adenoid cystic carcinoma	1
12	Coring	90	10	1	Typical carcinoid	1
13	Coring	90	40	1	Squamous cell carcinoma	2
14	Coring	100	75	2	Squamous cell carcinoma	2
15	Coring	100	20	1	Infiltrating follicular thyroid carcinoma	2
16	Coring	100	90	2	Atypical carcinoid	2
17	Coring	80	10	1	Adenoid cystic carcinoma	1
18	Coring	80	10	1	Squamous cell carcinoma	2
19	Coring, stenting	90	25	1	Mucoepidermoid carcinoma	1
20	Coring	70	10	1	Squamous cell carcinoma	2
21	Coring	100	100	2	Typical carcinoid	1
22	Coring	70	20	1	Esophageal squamous cell carcinoma	2
23	Coring, stenting	80	20	1	Squamous cell carcinoma	2

NOS indicates not otherwise specified; Outcome 1 = successful, 2 = unsuccessful; current status 1 = alive, 2 = dead.

LASER ABLATIVE THERAPY

- Multiple biomedical lasers – neodymium doped yttrium-aluminum-garnet (Nd:YAG), neodymium doped yttrium-aluminum-perovskite (Nd:YAP), CO_2 laser, potassium titanyl phosphate (KTP) laser
- Nd:YAP – cheaper, more portable and better coagulating properties than Nd:YAG laser

Nd:YAG LASER

- Non contact modality
- Creates light energy by directing excited electrons at focused medium
- Neodymium – Pink colored rare earth element, doped into crystal structure of yttrium, aluminium and garnet
- Creates infrared light with wavelength of 1,064 nm → absorbed by local tissue → Photokinetic energy
- Generation of heat that denaturates protein, causes vascular photocoagulation, and vaporizes tissue
- Compared to CO2 laser, Nd:YAG laser poorly absorbed by both water and hemoglobin leading to tissue penetration of 10 mm

Nd:YAG LASER

- Should be avoided in hemoptysis

- High depth of tissue penetration and increased risk of airway perforation
- Limited efficacy with dark tissues (i.e. charred tissue) as such tissue absorbs more light and limits depth penetration and reduced effectiveness in photocoagulation of vessels
- Bleeding is most common complication
- POPCORN EFFECT – explosion of steam when power density exceeds target tissue power density resulting in hemorrhage, airway damage or perforation

Cavaliere S CHEST 1988;94(1):15-21

MEHTA’S RULE OF FOUR

- For application of Nd:YAG laser with flexible bronchoscope

- Length of lesion <4 cm
- Duration of atelectasis <4 weeks
- Initial settings

- Power (noncontact) 40W
- Pulse duration 0.4 sec

LASER BEAM SHOULD BE FIRED PARALLEL TO WALL OF AIRWAY AND NOT DIRECTLY AT IT

Book of interventional bronchoscopy by Atul Mehta, Year 2013

MEHTA'S RULE OF FOUR

- For application of Nd:YAG laser with flexible bronchoscope

- Distances

- Endotracheal tube to lesion >4 cm

- Fiber tip to lesion 4 mm

- Distal end of scope to fiber tip 4 mm

- Fraction of inspired oxygen ≤0.4

Book of interventional bronchoscopy by Atul Mehta, Year 2013

MEHTA’S RULE OF FOUR

- For application of Nd:YAG laser with flexible bronchoscope
- Number of pulse between cleaning <40
- Procedure time <4h
- Total number of laser treatment <4
- Life expectancy >4 weeks
- Laser team ≥4

Table 2 Properties of commonly used airway lasers (53)

Laser	Properties	Tissue Effects	Comments
Neodymium:yttrium-aluminum-garnet (Nd:YAG)	Wavelength: 1,064 nm; depth of penetration: 5–15 mm; absorption: proteins	Cutting: poor; coagulation: excellent; vaporization: excellent	Most commonly used laser in bronchoscopy; poor absorption by blood and water result in deep tissue penetration which in advantageous for management of airway tumors but increases risk of airway perforation; multiple modes of emission can be used which alter tissue effects
Neodymium:yttrium-aluminum-perovskite (Nd:YAP)	Wavelength: 1,340 nm; depth of penetration: 5–10 mm; absorption: water	Cutting: poor; coagulation: excellent; vaporization: fair	Similar properties to Nd:YAG with less depth of penetration; more cost effective and portable than Nd:YAG
Holmium:yttrium-aluminum-garnet (Ho:YAG)	Wavelength: 2,100 nm; depth of penetration: 0.5 mm; absorption: water	Cutting: good; coagulation: excellent; vaporization: good	Can be used in contact or non-contact modes; combined ability to cut and coagulate; low depth of penetration minimizes risk of non-visible tissue damage
Diode	Wavelength: multiple available; depth of penetration: 1–5 mm; absorption: water	Cutting: excellent; coagulation: good; vaporization: poor	Available as portable and compact tabletop system; similar effects as the Ho:YAG
Carbon dioxide (CO_2)	Wavelength: 10,600 nm; depth of penetration: 0.1 mm; absorption: water	Cutting: excellent; coagulation: poor; vaporization: excellent	Commonly used in otolaryngology due to precise cutting effect; extremely poor coagulative effect; traditionally transmitted by mirrors instead of optical fibers limiting role in bronchoscopy; recently developed flexible fiber system now allows use through flexible bronchoscope

TABLE 1] Comparison of Multiple Electrosurgical Tools and Laser Therapies

Electrosurgical Technique/Tool	Advantages and Disadvantages	Mechanism of Action	Effect on Tissue	Depth of Penetration (mm)	Potential Complications
Electrocautery	Advantages: • Tissue destruction • Hemostasis Disadvantage: • Variable penetration depths depending on tool used	Contact, alternating high-frequency electric current passing through a probe to generate heat	Protein denaturation, coagulation, and direct cell death	Variable depending on electrocautery probe used	• Airway perforation • Bronchial wall damage • Bleeding • Airway fire
Argon plasma coagulation (APC)	Advantage: • Hemostasis Disadvantage: • Difficult to achieve debulking effect due to noncontact nature	Noncontact, APC catheter delivers an inert gas that acts as an effective conductor of high-frequency monopolar current via a flexible probe	Denatures protein and evaporates water, causing tissue destruction and coagulation	2-3	• Intracardiac gas embolism • Cerebral gas embolism • Airway perforation • Airway fire
Radiofrequency ablation (RFA)	Advantages: • Tissue destruction • Hemostasis • Smoke evacuation Disadvantage: • Limited flexibility in bronchoscope	Contact, heat energy is induced by delivering high-frequency pulses of radiofrequency energy at the tip of the RFA catheter to generate electrical plasma to heat up adjacent tissue	Protein denaturation, tissue desiccation, and vessel coagulation	1.9	Same as for electrocautery
Nd:YAG laser	Advantages: • Tissue vaporization • Vascular constriction Disadvantage: • Deep penetration depth	Noncontact, light energy absorbed and converted to heat energy	Protein denaturation, coagulation, and direct cell death	Up to 10	Same as for electrocautery

FACTORS AFFECTING OUTCOME OF LASER PHOTORESECTION

Factors	Favorable	Unfavorable
Location	Trachea and right or left main-stem bronchi	Lobar and segmental bronchi
Type of lesion	Predominantly endobronchial	Predominantly extrinsic
Endoscopic appearance	Exophytic	Submucosal
Length of lesion	<4 cm	>4 cm
Distal lumen	Visible and free of tumor	Not visible or diffusely infiltrated with the tumor
Duration of atelectasis	<4–6 weeks	>4–6 weeks
Mediastinal anatomy	Normal	Distorted
Pulmonary vascular supply	Intact	Compromised due to infiltration or compression by the tumor
Hemodynamic status	Stable	Unstable
Performance status	Good	Poor
Cardiopulmonary reserve	Adequate to withstand anesthesia	Inadequate
Oxygen requirement	≤40 %	>40 %
Coagulation profile	Normal	Abnormal

Laser Ablative Therapy

- Immediate acting
- It can be used adjunctively before salvage chemotherapy, radiation (eg, external beam radiation or brachytherapy) or surgical resection
- Cautious in patients with stents-chance of burns

Efficacy

- Most are derived from retrospective case series
- Outcomes studied are usually airway patency and symptom palliation as well as weaning from mechanical ventilation, and survival

Cavaliere *et al*	1,838 patients over a 13-year period	• Restore airway patency in 93% • Mortality of less than 0.4%
Moghissi *et al*	1,159 patients with >50% obstruction of the bronchial lumen who underwent 2,235 procedures with Nd:YAG laser over a 21-year period	48% increase in the caliber of the bronchial lumen, 15% increase in the forced expiratory volume in one second and a low mortality rate (0.17%)

Comparison with other bronchoscopic techniques

- No high quality studies comparing the use of laser with other locally ablative therapies, although when used appropriately, they all appear to result in similar rates of airway patency and symptom palliation
- Laser resection has excellent debulking capacity and may be as efficient at achieving haemostasis as APC but has a higher risk of airway perforation

Combined use of laser therapy with other modes of therapy

- In one study, the survival of patients who underwent emergent palliative laser photoresection and external beam radiation therapy was significantly better than historical cohorts who underwent emergent external beam radiation therapy alone

Desai SJ, Mehta AC, VanderBrug Medendorp S, et al. Survival experience following Nd:YAG laser photoresection for primary bronchogenic carcinoma. Chest 1988;94:939-44

Clinical Trial > Lung Cancer. 2000 Mar;27(3):169-75. doi: 10.1016/s0169-5002(99)00102-6.

Combined Nd-YAG laser/HDR brachytherapy versus Nd-YAG laser only in malignant central airway involvement: a prospective randomized study

A Chella [1], M C Ambrogi, A Ribechini, A Mussi, M G Fabrini, G Silvano, L Cionini, C A Angeletti

Affiliations

PMID: 10699690 DOI: 10.1016/s0169-5002(99)00102-6

Patients and methods: From 1995 to 1998, 29 consecutive patients, with non-small cell lung cancer (NSCLC) and central airway involvement, were randomized in two groups: group 1 (15 patients) received Nd-YAG laser only; group 2 (14 patients) underwent a combined Nd-YAG laser/HDR brachytherapy treatment.

Results: There was no mortality or morbidity related to the treatment. The period free from symptoms was 2.8 months for group 1 and increased to 8.5 months in group 2 (P<0.05). The disease's progression free period grew from 2.2 months of group 1 to 7.5 months of group 2 (P<0.05) and the number of further endoscopic treatment reduced from 15 to 3 (P<0.05).

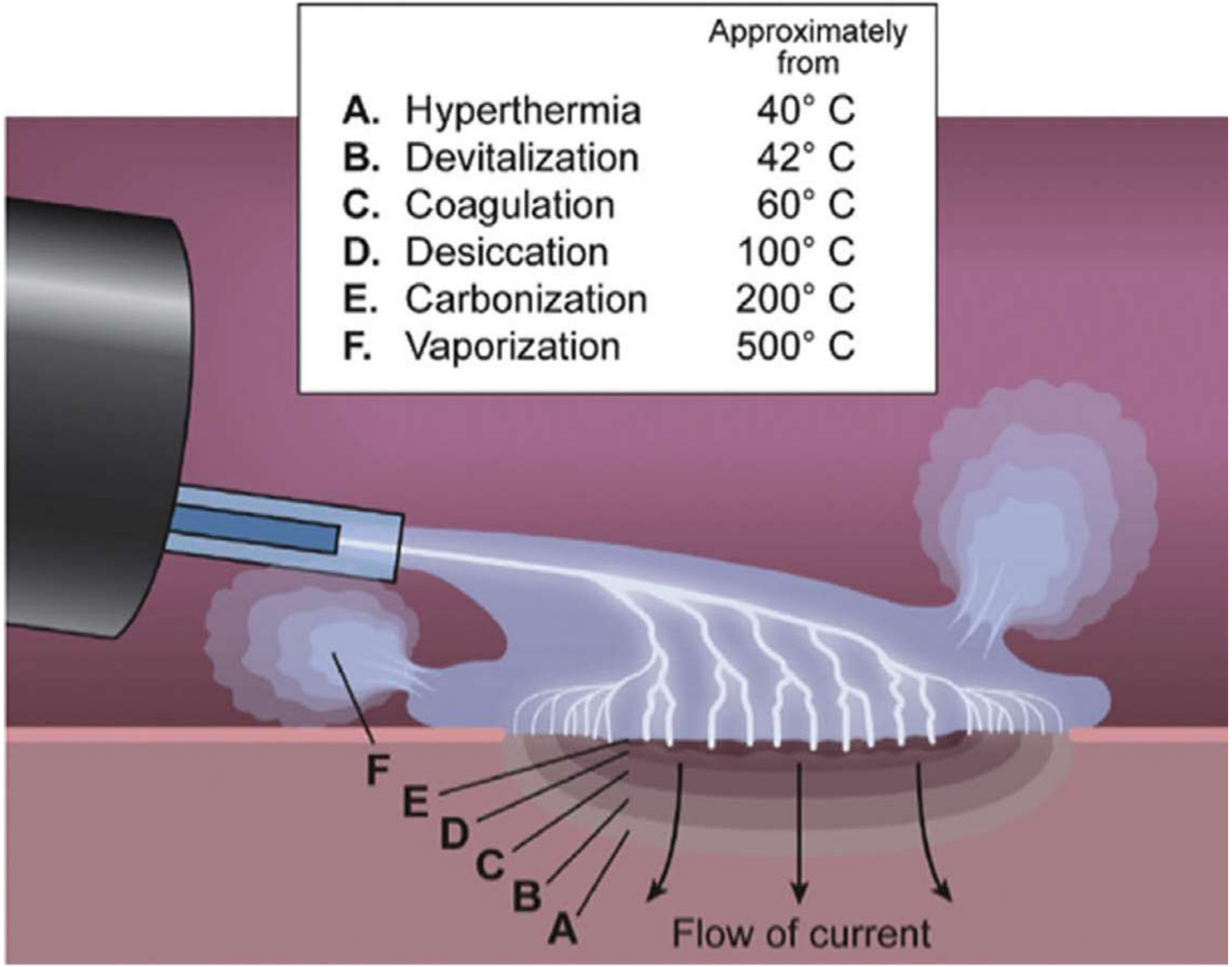
First Author (Ref.)	Year	n	Indication	Therapy	Results/Comments
Dumon (80)	1982	111	Benign and malignant CAO	Nd:YAG	Best results with malignant disease, laser Rx with gentle dilation for tracheal stenosis
McDougall (76)	1983	22	Malignant CAO	Nd:YAG	20/22 with symptomatic improvement and improvement in airway diameter, 2 deaths due to massive hemorrhage
Hetzel (196)	1984	100	Malignant CAO	Argon (n = 14), Nd:YAG (n = 86)	Symptomatic improvement seen in 68% of patients treated for hemoptysis, 76% of patients treated for partial airway obstruction, and 38% treated for complete airway obstruction
Kvale (83)	1985	55	Benign (n = 10) and malignant (n = 45) CAO	Nd:YAG	Benign disease required more repeat Rx, 34 of 45 patients (75%) with malignant disease had improvements in airway diameter and dyspnea
Shapshay (38)	1987	5	Subglottic and tracheal stenosis	Nd:YAG/CO_2 laser + rigid dilation	100% success at up to 17 mo follow-up
Brutinel (82)	1987	116	Benign (n = 9) and malignant (n = 107) CAO	Nd:YAG	83% with improvement in airway diameter, patency achieved in 58% of patients with complete CAO, improvement in 63% treated for hemoptysis, and 66% treated for dyspnea

First Author (Ref.)	Year	n	Indication	Therapy	Results/Comments
van Boxem (99)	1998	19	CAO due to typical bronchial carcinoid (laser and electrocautery)	Nd:YAG or electrocautery	14 with complete response, distal disease unable to be visualized in the remaining 5, no difference between laser and electrocautery
Cavaliere (78)	1988	1,000	649 with malignant CAO, 139 with tracheal stenosis	Nd:YAG	Best success with tracheal, right mainstem, and bronchus intermedius tumors, 94% immediate improvement in patients with tracheal stenosis
Stanopoulos (84)	1993	17	CAO and respiratory failure	Nd:YAG	9 of 17 liberated from mechanical ventilation
Mehta (39)	1993	18	Concentric tracheal and subglottic stenosis	Nd:YAG and rigid dilation	75% success
Shea (85)	1993	46	Malignant CAO	Nd:YAG vs. Nd:YAG + brachytherapy	Mean survival 16.4 wk in laser group vs. 40.8 wk in combination group ($p = 0.001$)
Cavaliere (81)	1994	1,585	Malignant CAO	Nd:YAG	93% with radiographic and endoscopic improvement
Moghissi (197)	1997	17	Malignant CAO	Nd:YAG + PDT	100% with symptomatic relief, 65% alive at 1 yr, 47% alive at 2 yr
Laccourreye (198)	1999	50	Endolaryngeal malignancy	CO_2	93% success rate in treatment group, 88% in palliation group
Venuta (178)	2002	273	Malignant CAO	Nd:YAG ± stent	Goal of palliation in 237 patients: median survival, 12 mo; goal of bridge to surgery in 36 (± induction chemotherapy): 52–59% alive at 3 yr; significant improvement in oxygenation, FEV_1, and quality of life

ELECTROCAUTERY

- Ohm's law : I = V/R (I is current, V is voltage and R is resistance)
- Power in circuit proportional to square of current x resistance
- High frequency current passes through tissue opposed by resistance
- Resistance intrinsic property of tissue based on specific chemical composition. Tissue resistance decreases with good conductors of energy such as water and metal ions and opposite in tissues such as adipose, cartilage or bone

Homassom. Endobronchial electrocautery. Semin Respir Crit Care Med.1997


Approximately from
A. Hyperthermia 40° C
B. Devitalization 42° C
C. Coagulation 60° C
D. Desiccation 100° C
E. Carbonization 200° C
F. Vaporization 500° C
F
E
D
C
B
A
Flow of current

MODES

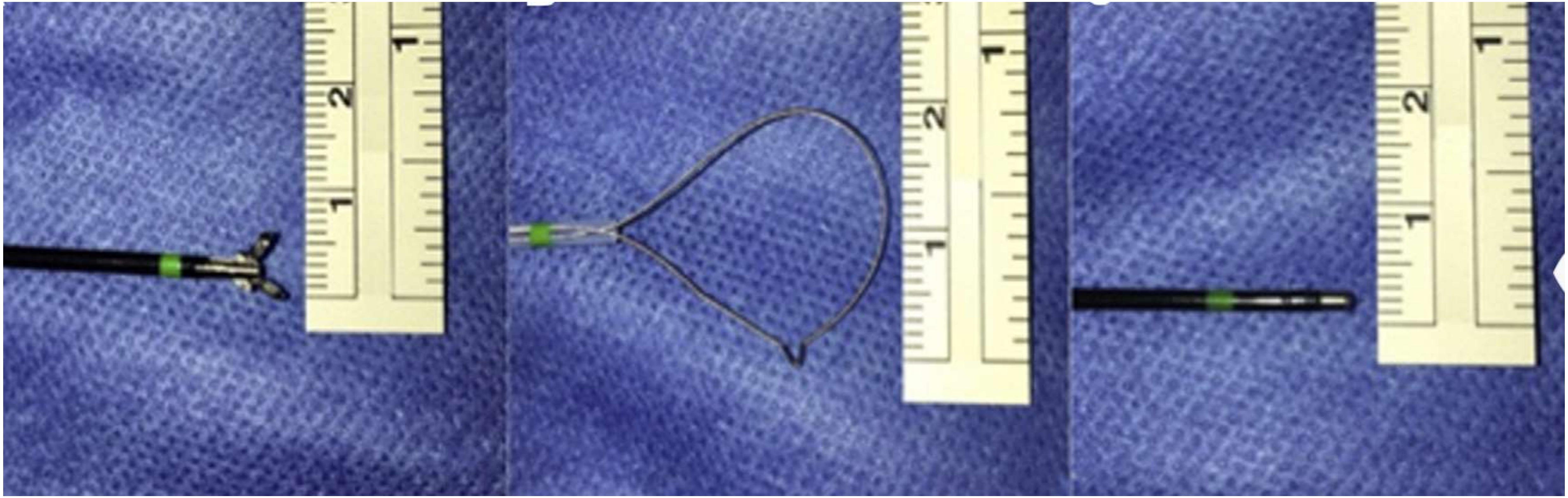
- CUTTING: At high voltages (>200 V) to create electrical arc between electrode and tissue, leading to immediate vaporization
- COAGULATION: Achieved by heating tissues (approx. 70° C)

- Soft coagulation – Voltage currents less than 200 V and unmodulated

Electrode is in direct contact with tissue avoiding direct arc formation and carbonization

- Forced coagulation (Dessiccation) : Procedure uses higher-voltage modulated currents (>500 V) but creates electrical arcs and may cause carbonization

- SPRAY COAGULATION (Fulguration) – High voltage (>2000 V), strongly modulated currents used in non contact mode
- Coagulation – Happens when proteins and glucose containing coagulam heated above 70°C
- Vaporisation – Disruption of cell structure and cellular necrosis



HOT FORCEPS – to perform endobronchial biopsies and mechanical debridement of highly vascularized tumors

WIRE SNARE – Endobronchial lesions
Achieves hemostasis

ELECTROCAUTERY PROBE –
- Both coagulation and cutting effects
- Can be used in rigid or flexible
- Most effective in treatment of lobar or segmental bronchi


OLYMPUS

Electrocautery

- Rigid bronchoscope- reusable rigid electrocautery probe combines suctioning capabilities with electrocautery and can be used for both hemostasis and tissue destruction
- The flexible blunt probe can provide similar coagulative and desiccative effects through a flexible bronchoscope with out suction
- Data available is case reports and case series

Electrocautery

- In a largest descriptive study on the application of electrocautery in 94 patients with benign (30%) and malignant (70%) airway obstruction, electrocautery, when combined with other modalities such as balloon dilatation and airway stents produced substantial endoscopic improvement in 94% of cases and symptom improvement in 71% cases

Wahidi MM, Unroe MA, Adlakha N, et al. The use of electrocautery as the primary ablation modality for malignant and benign airway obstruction. J Thorac Oncol 2011;6:1516-20.

Rigid bronchoscopy

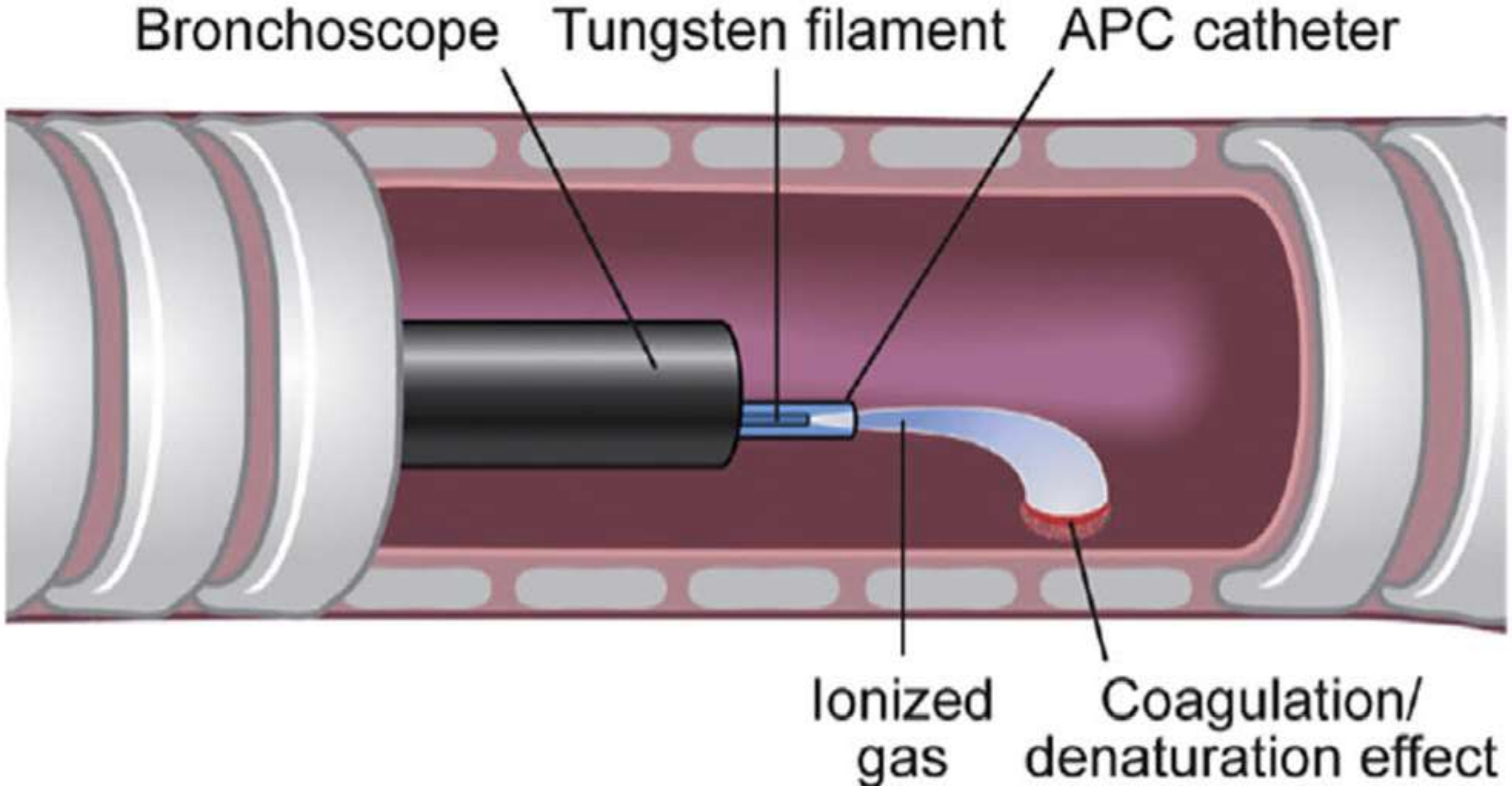
Ref.	n	Technique	Response	Complications
Ledingham and Goldstraw [31]	15	general anesthesia, rigid loop + radioactive grains	successful palliation, 11/15 alive >1 month; median 2.5 months	no
Pedersen et al. [32]	10	general anesthesia, jet ventilation and rigid loop	palliative 3–14 months, adenocystic 2–29 years	no
Petrou et al. [33]	29	general anesthesia and rigid loop (+ stents, + radioactive grains)	19/20 improved symptoms	no

Flexible bronchoscopy

Frizelly [34]	17	GA/LA, FFB	average palliation 4–5 months (9 months)	1 hemorrhage
Hooper and Jackson [35]	4	GA, FFB + snare	all successful	1 fire/explosion + respir. failure
Hooper and Jackson [36]	18	GA/LA, FFB + snare + bipolar probe	5 benign successful 13 palliation follow-up 3 years	1 bleeding and 1 fire
Gerasin and Shafirovsky [37]	14	GA, FFB + snare	10/14 complete and 2/14 >75% clearance	1 bleeding (100 ml) 2 emergencies for bleeding/suffocation
Sutedja et al. [38]	17	LA and FFB + probe	15/17 successful 2 extraluminal	1 minor bleeding 1 pneumonia
Homasson et al. [39]	32	LA, rigid and flexible	27/32 >50% tumor reduction, 11/12 hemostasis	2 bleeding
Sutedja et al. [40]	56	GA/LA, mostly FFB + probe	39/56 (70%) remaining extraluminal tumor	1 bleeding

Electrocautery

- Relatively modest cost
- Complications with electrocautery are rare but include haemorrhage, airway perforation, airway fire and scarring/stenosis, electrical burns, Ventricular fibrillation and Aspiration pneumonia
- Risks of perforation and inflammation are minimized with the soft coagulation mode of electrocautery



- High voltage current delivered by tungsten wire ionizing the gas which is delivered at tip of catheter
- Plasma refers to electrical conducting medium produced when atoms in gas become ionized
- APC devitalizes tissue (> 100°C), surface becomes less electrically conductive
- Positively charged gas proceed to closest negatively charged areas, allowing target to be in front, tangential, radial or around anatomic corners
- Gas is directed to adjacent tissue with less electrical resistance, resulting in more uniform, superficial penetration (2 to 3 mm depth) decreasing risk of airway perforation

Reichle et.al. Pneumologie 2000;54(11):508-516

Argon Plasma Coagulation

- Immediate-acting therapy
- Ideally suited to treating short(<4 cm), flat, intraluminal obstructing and/or bleeding lesions, those at or around bifurcations in the airway
- Outcome is best if the airway lumen can be visualized beyond the obstruction and the distal lung is still functional
- Obstructions in lobar or segmental bronchi or large, extensive lesions where an airway is not easily identified may be more amenable to APC than laser or electrocautery
- Not suitable for lesions causing CAO from extrinsic compression

ARGON PLASMA COAGULATION

- Dreaded side effect:

- Local infiltration of gas and systemic air embolism through bronchial veins or systemic veins

- Related to flow rate of argon gas, proximity to tissue and vessel exposure

- To prevent air embolism, argon gas flow rate to be set at lowest possible rate

- Argon itself is not combustible gas nor promote combustion of combustible materials. Ignition is only possible in presence of combustible gas like oxygen

Reddy et.al. CHEST.2008;134(5):1066-1069
Shaw et.al. RESPIRATION.2012;83(3):267-270

Argon plasma coagulation (APC)- Efficacy

Reichle G et al prospective cohort study 364 patients, 90 %malignant and 50 % obstruction	Bronchoscopic APC (mostly rigid bronchoscopy; 482 interventions)	Airway patency in two-thirds of the treated population
Morice RC et al Retrospective cohort study 60 patients, 90 % bronchogenic carcinoma	Bronchoscopic APC (mostly flexible bronchoscopy; 70 procedures)	Overall decrease in the degree of airway obstruction from 76 to 18% & symptom improvement
Crosta C et al Retrospective cohort study 47 patients	Repeated APC (an average of more than three sessions per patient)	Successful outcome (obstruction and/or symptoms) in 92 percent of patients, which was maintained over a mean follow-up of 6.7 months

Pneumologie. 2000;54(11):508.
Chest. 2001;119(3):781.
Lung Cancer. 2001;33(1):75.

Comparison with other techniques

- No high-quality studies for comparing the APC with other bronchoscopic ablative therapies

Study	Intervention	Looking for	Results
Kızılgöz D et al Retrospective analysis N-89 patients	Argon plasma coagulation with mechanical tumor resection (APC + MTR) Vs cryorecanalization	efficiency, complications, restenosis rate, and time to restenosis	Airway patency rate with APC + MTR-97.3% (n = 36) vs CR -80.8% (n = 42) Higher in tumors with distal bronchial involvement No significant difference in complications, restenosis rate, and time to restenosis.

Argon plasma coagulation (APC)

- One retrospective review of bronchoscopic treatment of benign endobronchial tumors reported that there was no difference in efficacy between diode laser and APC, at times in combination with cryotherapy
- Initial   tumor debulking with any mechanical methods--→APC
- APC may be more efficient than electrocautery or laser resection at achieving hemostasis but is less efficient at debulking tissue

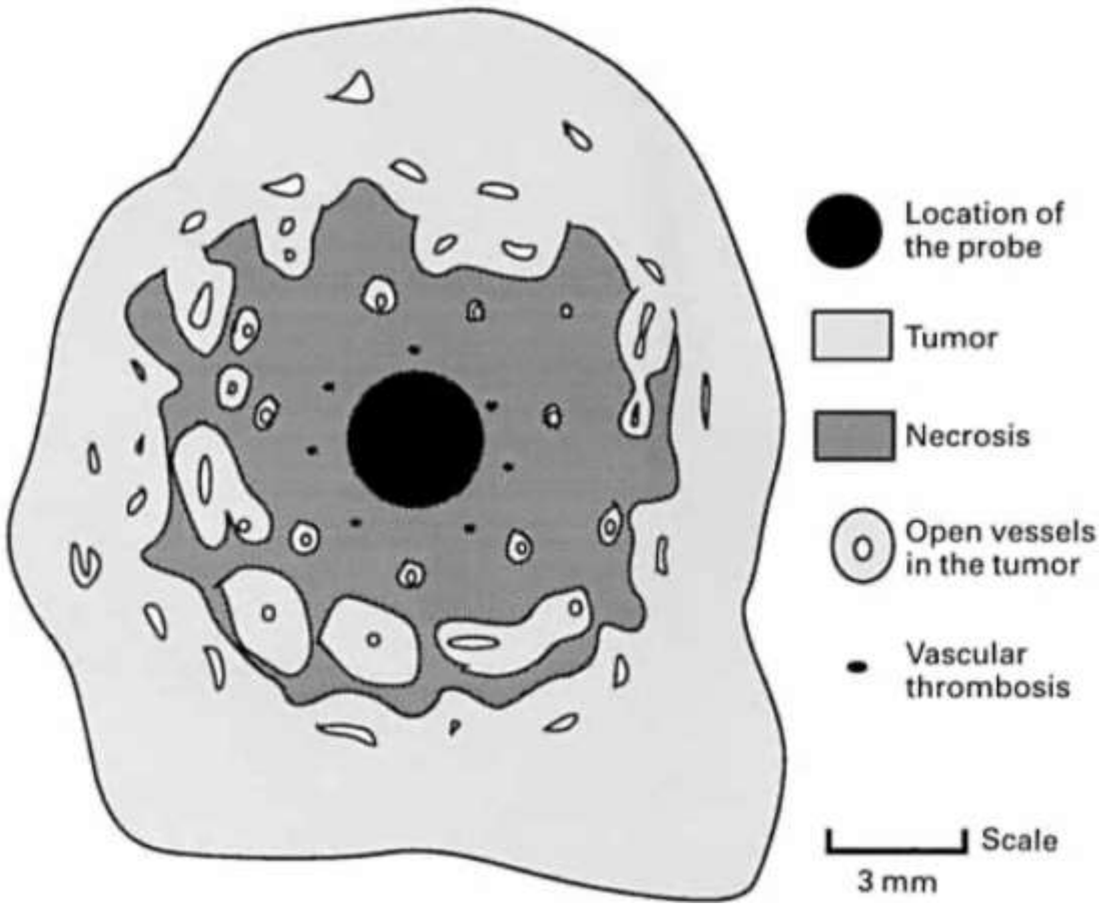
Dalar L et al Can Respir J. 2019;2019:5269728. Epub 2019 Feb 27.

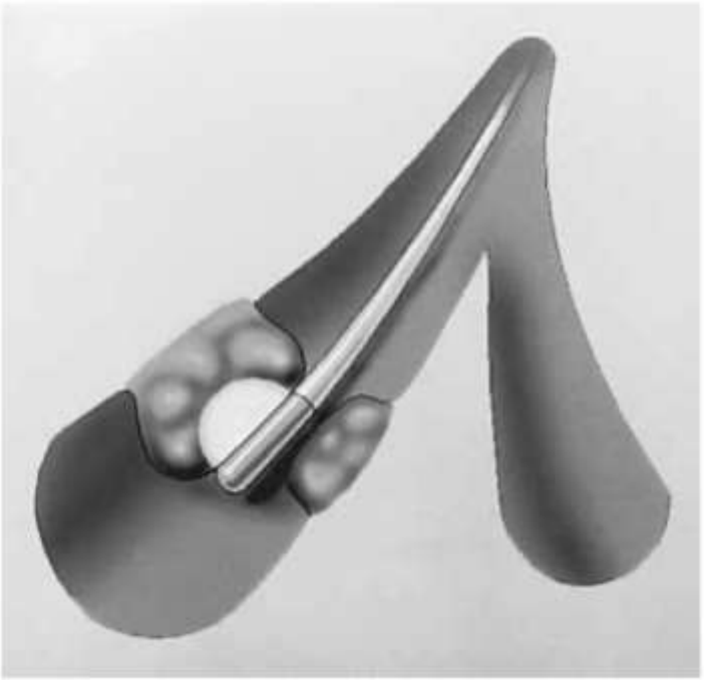
Cryotherapy-Cryoablation & Cryocanalization

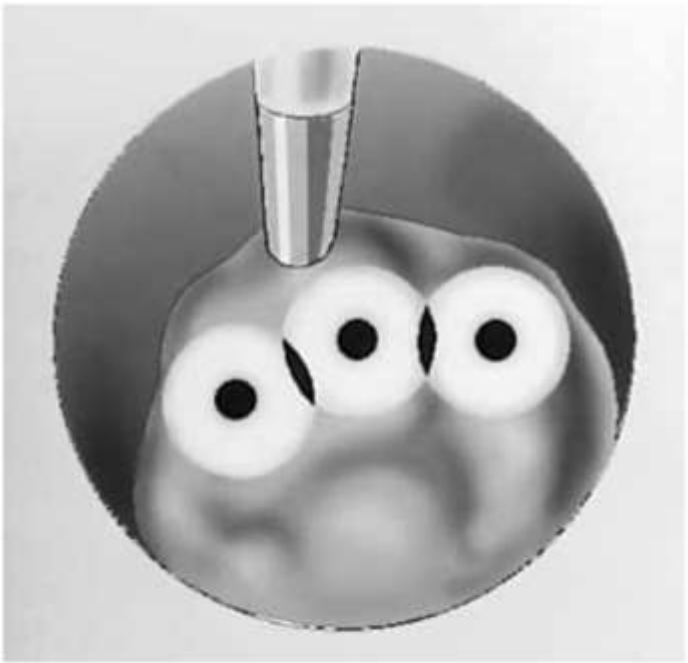
- CONTACT MODE
- Placed on target tissues in succession of adjacent areas i.e. freeze zone overlap; repeated (usually 3) freeze thaw cycles, each lasting for 30 secs
- Uses nitrous oxide gas and rigid or flexible probes
- Cooling governed by Joule Thompson principle – Decrease in temperature with expansion of gas as it moves from area of high pressure to area of low pressure
- Rapid decrease in pressure as gas released from tip of probes causing rapid cooling to temperature below - 70°C that causes tissue surrounding probe to freeze within few seconds

MECHANISM

- Repeated cycles of freezing and thawing causes cellular injury and death
- Intracellular ice damages vital cell organelles such as mitochondria
- Extracellular ice crystals cause osmotic injury and cellular dehydration
- Delayed ischemic injury due to vasoconstriction, platelet aggregation and vascular thrombosis developing after 6-12 hrs after procedure
- Maximum damage observed when tissue is frozen at rapid speed and thawed at slow speed
- Number of freeze-thaw cycles and water content of tissue – determinants of ultimate effect







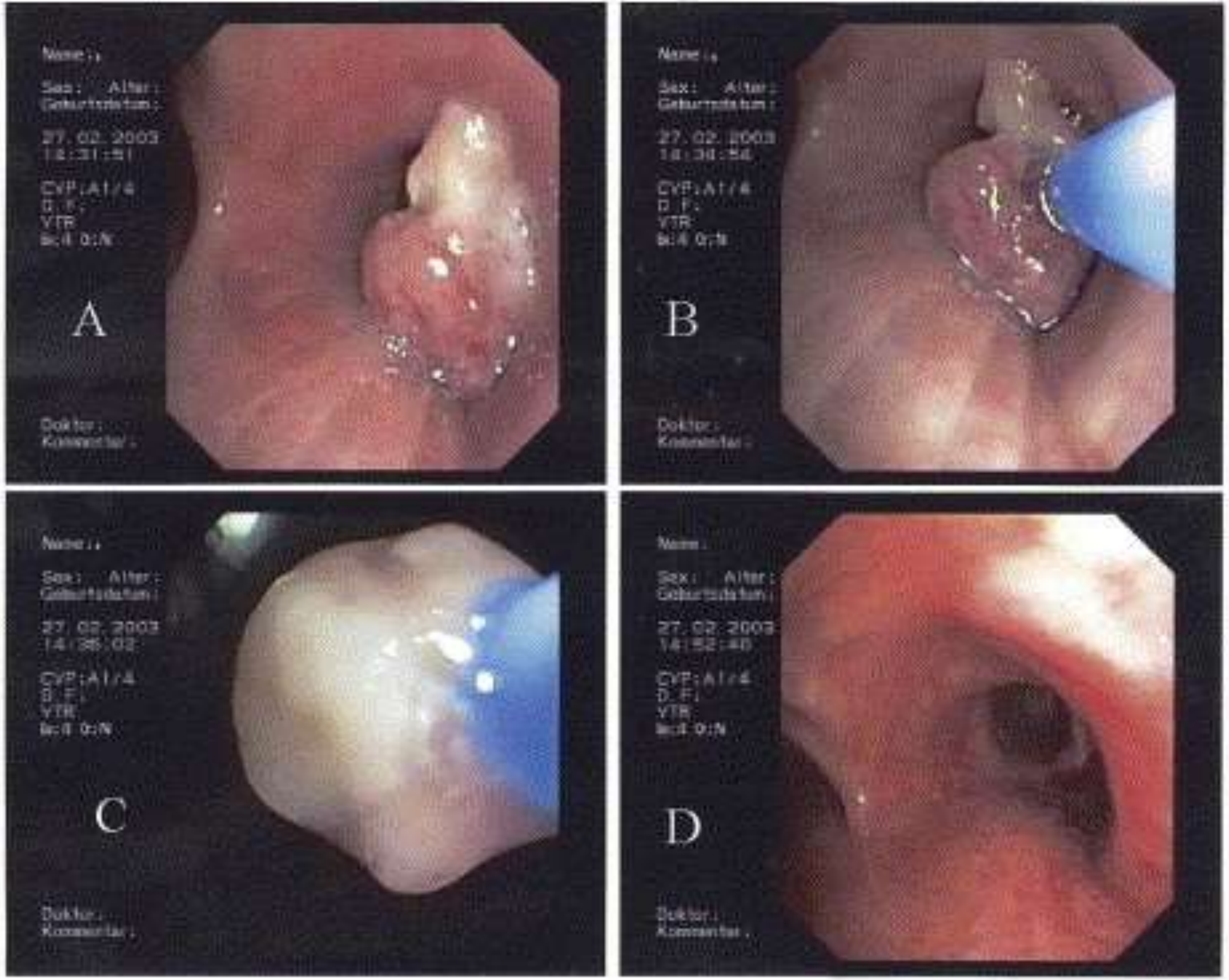
Cryosensitive	Cryoresistant
Skin	Fat
Mucous membrane	Cartilage
Nerve	Nerve sheath
Endothelium	Connective tissue
Granulation tissue	Fibrosis

Cryotherapy-Cryoablation

- Destructive effects of cryoablation are not immediate, but rather delayed such that it takes a number of days to weeks for the full effect of tissue necrosis to occur with continued tissue sloughing that often necessitates bronchoscopic removal of necrosed tissue during follow-up

CRYOREcANALISATION

- Greater freezing power and more stable joint between gas channel and tip which can withstand 50 N
- Probe – 2.3 mm and can be used with any standard therapeutic bronchoscope
- No clean up bronchoscopy needed
- Complication- significant hemorrhage (up to 10 percent requiring argon plasma coagulation)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BENEFITS

- Because of low water content, fibrous tissue, and cartilage are inherently resistant to cryodestruction - low incidence of airway perforation
- Suitable for highly vascular tumors (carcinoids and adenoid cystic carcinoma)
- Can be performed regardless of need of high-flow oxygen therapy as no risk of airway fire
- lesions down to the second or third order of bronchi can be successfully treated with cryoablation

DISADVANTAGES

- Delay in treatment response – novel extension – cryorecanalisation
- Delayed necrosis of tumor needed over 5-10 days
- Clean up bronchoscopy needed
- Mild reactive airway edema can occur that is usually not severe

Complications

- Bleeding
- Pneumothorax
- Bronchospasm
- Fever
- Bradycardia

Study	Year	No	Major complications	Bleeding (APC ± Electrocautery)
Hetzel et al	2004	60	Nil	10%
Schumann et al	2010	225	Nil	12%
Inaty et al	2016	88	Nil	4%

First Author (Ref.)	Year	n	Indication	Results/Comments
Homasson (114)	1986	27	Benign (n = 5) and malignant (n = 22) CAO	62% success for malignant disease; 100% success for benign disease
Walsh (113)	1990	33	Malignant CAO	70% overall subjective improvement, 77% with improvement in airway diameter, 67% with improvement in hemoptysis, 56% with improvement in dyspnea
Vergnon (110)	1992	38	Malignant CAO	Used combination of cryotherapy and XRT; 26 of 38 (68%) had a > 50% improvement in airway diameter; 17 of these 26 (65%) had no residual tumor after XRT, and had significantly increased survival (397 vs. 144 d, $p < 0.001$); 12 of 12 with < 50% improvement in airway diameter had residual tumor after XRT
Marasso (108)	1993	234	Benign (n = 44) and malignant (n = 183) CAO (4 patients with carcinoid, 3 with bronchial cylindroma)	Improvement in 93% treated for hemoptysis, 81% with improvement in dyspnea, 76% resolution of lobar atelectasis, 57% resolution in lung atelectasis
Maiwand (104)	1995	622	Malignant CAO (n = 600) and posttransplant anastomotic stricture (n = 22)	78% overall subjective improvement, 79% with improvement in endobronchial obstruction, 70% with improvement in stridor, 66% with improvement in dyspnea, 65% with improvement in hemoptysis, 69% success in patients with anastomotic stricture
Mathur (112)	1996	22	Malignant CAO (n = 20) and posttransplant anastomotic stricture (n = 2)	Complete removal of endobronchial tumor in 18 of 22 (82%) (remaining 3 with extrinsic compression); 5 of 5 with improvement in hemoptysis; 12 of 17 (71%) with improvement in dyspnea; 100% success in patients with anastomotic stricture
Maiwand (201)	1997	21	Posttransplant anastomotic stricture	15 of 21 (71%) with complete removal of obstruction; 6 of 21 (29%) with partial removal of obstruction; 8 patients later required stent placement
Noppen (202)	2001	12	Malignant (n = 10), poststent granulation tissue (n = 1), capillary hemangioma (n = 1)	One session achieved permanent airway patency in 4 of 5 (80%) with metastatic CAO and in 2 of 4 (50%) with carcinoma *in situ*, as well as the patient with capillary hemangioma; 2 or more sessions required in remaining patients

Trial	Study design	Intervention	Patient Selection	Outcomes measured	Complications
Cryosurgery in bronchoscopic treatment of tracheobronchial stenosis. Indications, limits, personal experience (98) (N=234)	Retrospective review	Rigid bronchoscopy with rigid 3.2 mm cryotherapy probe	Patients undergoing bronchoscopic cryosurgery for either malignant or benign tracheobronchial lesions	Resolution of lung atelectasis 57%; resolution of lobar atelectasis 76%; improvement in hemoptysis 93%; improvement in dyspnea 81%; improvement in PaO_2 71%; improvement in sepsis 40%	Text describes bleeding as most common complication but does not report complication rates
The role of cryosurgery in palliation of tracheobronchial carcinoma (95) (N=153)	Prospective observational review	Rigid bronchoscopy with 9.2 mm rigid cryotherapy probe	Patients undergoing bronchoscopic cryosurgery for malignant tracheobronchial lesions	Improved dyspnea 85/133 (63.9%); improved cough 82/120 (68.3%); control of hemoptysis 51/55 (92.7%); improved Karnofsky score 76/153 (54.6%)	Bleeding 2.0%; pneumothorax 0.6%; respiratory complications 1.3%; anesthetic complications 7.2%
The application of cryosurgery in the treatment of lung cancer (99) (N=476)	Retrospective review	Rigid bronchoscopy with either large rigid (9.2 mm) or flexible bronchoscope (2.4 mm) cryotherapy probe	Patients undergoing bronchoscopic cryosurgery for malignant tracheobronchial lesions	Improvement in hemoptysis 76.4%; improvement in cough 69.0%; improvement in dyspnea 59.2%; improvement in chest pain 42.6%; average increase in FEV1 90 mL; average increase in FVC 130 mL; average Karnofsky scale improvement 15.6 points	Bleeding 0.7%; pneumothorax 0.1%; respiratory distress 0.9%; anesthetic complications 0.2%; cardiac 1.6%; overall 3.5%
Endobronchial tumor debulking with a flexible cryoprobe for immediate treatment of malignant stenosis (91) (N=225)	Retrospective review	Flexible bronchoscopy (N=193 or rigid bronchoscopy (N=31) with flexible cryotherapy probe	Patients undergoing bronchoscopic cryosurgery for malignant tracheobronchial lesions	Successful cryorecanalization (91.1%)	Mild bleeding (4.0%); moderate bleeding (8.0%); severe bleeding (0%); pneumothorax (0%); pneumomediastinum (0.4%)

Combination with chemotherapy and radiation

- Limited data to suggest that it may increase the chemo- or radiosensitivity
- CR+CT-In small observational series- Increased accumulation of chemotherapeutic agent within the tumor following cryotherapy
- But the effect on growth was reported in animal studies only
- CR+RT- In a review of 38 patients treated with cryotherapy followed by radiation, a higher proportion of patients achieved local control of the obstructing tumor, when compared with historical controls (65 versus 35 percent)

Ikekawa S -Cryobiology. 1985;22(5):477.
Vergnon JM -Chest. 1992;102(5):1436.

Airway Dilation

- Rigid bronchoscopic airway dilation in emergent situations

Main disadvantage is granulation tissue formation

- Balloon dilatation or bronchoplasty

Balloon dilatation or bronchoplasty

- Rigid or flexible bronchoscopy
- Use increasingly larger diameter balloons filled with saline and maintain in position for 15-60 (30)seconds to gently dilate the airway
- Less mucosal trauma and subsequent granulation tissue formation than does rigid dilation

Balloon dilatation or bronchoplasty

- Immediate improvement in 79% patients
- But effects are not long lasting
- Has to be followed by other therapies such as laser resection, radiotherapy, or stenting
- Complications - stenosis recurrence, pain, mediastinitis, bleeding, pneumothorax or pneumomediastinum

Airway stents

- Silicone and metallic/hybrid-frequently used
- Best suited for extrinsic malignant compression
- Sometimes used to maintain airway patency after intrinsic or mixed endobronchial tumor ablation, or in cases of persistent airway narrowing
- Immediate and durable palliation, with symptomatic-in up to 84% of patients
- Improve QOL and survival in patients with advanced malignant obstruction

Choosing a stent

- Choosing a stent (type and size) depends upon the type, size, and location of lesion being treated, the future length of time that it will likely be needed, the patient's preference, cost, and the expertise available
- Consider advantages and risks
- Covered metallic stents are a reasonable option if only short-term use is planned (eg, 6 to 12 weeks)
- Lon term-silicone is preferred

Trial/Study design/Intervention	Retrospective review	Airway stenting for benign or malignant tracheobronchial obstruction	Stent type	Outcomes	Complications
Seven-Year Experience with the Dumon Prosthesis (101) (N=1,058, 677 malignant), total number of stents placed 1,574	–	–	Silicone	Not clearly defined	All complications 335/309 (21.2%); stent migration 9.5%; occlusion from secretions 3.6%; granuloma formation 7.9%
Airway Stenting for Malignant and Benign Tracheobronchial Stenosis (102) (N=143, 96 malignant), total number of procedures 309	Retrospective review of cases collected in prospective patient database	Airway stenting or stent revision for benign or malignant tracheobronchial obstruction	Silicone 182 (87%), metallic 27 (13%)	95% with symptom improvement overall	All complications 131/309 (42%); stent migration 5.2%; occlusion from secretions 27.2%; occlusion from granulation tissue 8.7%; airway perforation 1.3%
Outcomes of Tracheobronchial Stents in Patients with Malignant Airway Disease (103) (N=172, all malignant)	Retrospective review	Airway stenting for malignant tracheobronchial obstruction	166 SEMS, 6 rigid metal	Not reported	All complications: 23/172 (13.3%); stent migration 2.9%; tumor ingrowth 5.2%; excessive granulation 4.1%; restenosis 1.2%
Respiratory Infections Increase the Risk of Granulation Tissue Formation Following Airway Stenting in Patients With Malignant Airway Obstruction (104) (N=172, all malignant)	Retrospective cohort study	Airway stenting for malignant tracheobronchial obstruction	Silicone=46, SEMS=149	Not reported	Not reported

Airway stent-related complications

Complication	Frequency (%)
Common	
Migration	5 to 20
Granulation/tumor infiltration	15 to 20
Retained airway secretions	4 to 20
Uncommon	
Stent fracture	10
Airway obstruction	<10
Recurrent infection/halitosis	<10
Airway perforation	<10
Rare	
Metal fatigue with distortion	
Airway perforation	
Massive bleeding	
Fistula (airway, esophageal, vascular)	
Mediastinal perforation	

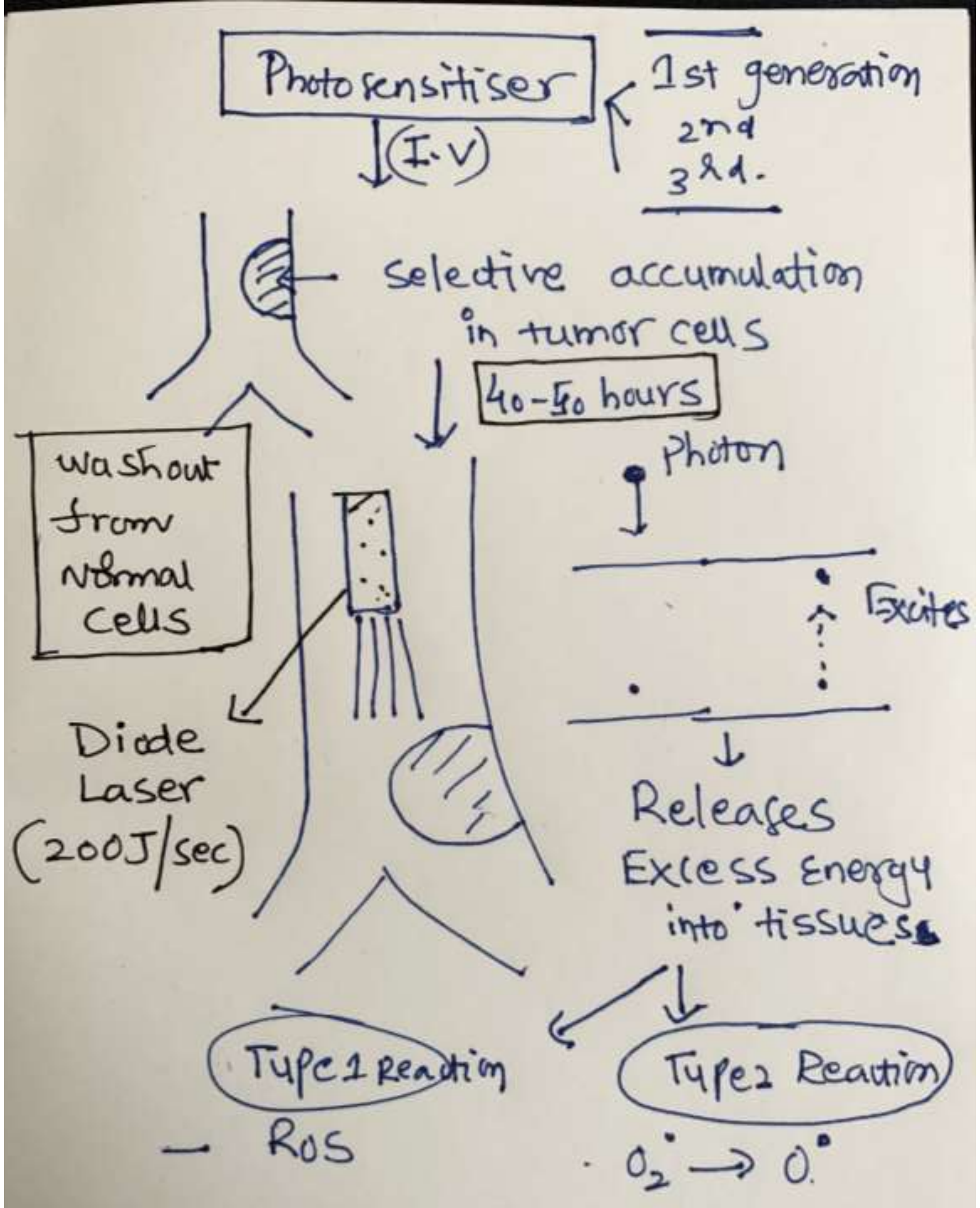
Advantages and disadvantages of different airway stents

Advantages and disadvantages of different airway stents

	Silicone	Metal (uncovered)	Hybrid
Bronchoscopy	Rigid	Flexible	Variable
Migration	+++*	+¶	++
Tumor/granulation tissue growth	+ (proximal and distal ends)	+++	+ (proximal and distal ends)
Airway perforation	–	+	±
Resists extrinsic compression	–	+++	++
Suitability for indefinite use	+++	–	±
Suitability for temporary use	+++	–	±
Mucus plugging	++	+	+
Stent fracture	±	+	+
Expense	+	++	+++

Photodynamic therapy (PDT)

- PDT is the term applied for the use of a specific wavelength of light to activate a systemically or topically administered photosensitizing agent that selectively accumulates in tumor cells



Photodynamic therapy (PDT)

- Above process is repeated for a total of 3 sessions 6 weeks apart
- Bronchoscopy needs to be performed 3 days after the first treatment session to examine the mucosa and clear the airways of sloughed mucosa
- Response rates range between 41% to 100%
- Can be used in distal endobronchial obstruction (eg, down to the second or third order of bronchi)

Complications

- Photosensitivity – The main adverse effect of PDT is photosensitivity (ie, sunburn) of the skin, which in general occurs in <5-20 % of patients
- Airway edema and secretions – Within 24 to 48 hours after treatment, edema and secretions due to tissue sloughing may lead to airway compromise or respiratory insufficiency that sometimes requires intubation and mechanical ventilation (typically <2 percent)
- Hemoptysis
- Chest pain

Endoluminal brachytherapy

- In this method, a blind-tipped catheter is placed close to the tumor under bronchoscopic guidance through the nose or artificial airway and secured
- The after loading technique allows the radiation oncologist to deploy beads of iridium-192 through the catheter after it is placed and minimizes radiation exposure to technical staff

Endoluminal brachytherapy

- **High dose rate (HDR)** – HDR EBBT involves greater than 10 to 12 Gray (Gy)/hour, with the total dose ranging from 5 to 40 Gy, and the dose per session (fraction) varying from approximately 3 to 10 Gy
- **Low dose rate (LDR)** – LDR EBBT delivers less than 2 Gy/hour and a total dose of 1500 to 5000 Gy, given over a few days (usually up to three days)
- HDR EBBT is more commonly employed than low dose rate (LDR) EBBT because treatment times are shorter, allowing it to be an outpatient procedure

Endoluminal brachytherapy

- In 2012 meta-analysis of 14 randomized trials involving 953 patients which reported that compared to external beam radiation (EBRT) and Nd:YAG laser therapy, there was no survival benefit associated with EBBT or EBBT in combination with chemotherapy
- Some trials report that EBBT combined with EBRT may offer improved efficacy

Endoluminal brachytherapy

- Used in this population when patients cannot tolerate or fail other local ablative therapies
- In case of acute after other bronchoscopic therapies
- No high-quality studies directly comparing EBBT with EBRT
- Consider brachytherapy for endobronchial lesions arising in the segmental bronchi and extending peri bronchially which are inaccessible to other ablative technology

Endoluminal brachytherapy

- Development of severe radiation bronchitis fistulas, abscesses, hemorrhage (even fatal) and infection have been observed

Author, year (reference)	N	Treatment[a]	Prior/concurrent EBRT	Prior laser	Massive hemoptysis	Radiation bronchitis (any grade)	Radiation bronchitis grade III/IV	Fistula	Airway stenosis
Manali et al. [25]	34		68%	26%	3%	21%			
Hauswald et al. [26]	41	5 Gy × 1–5	100%		15%	5%		5%	
Weinberg et al. [72]	9	5 Gy @ 5 mm q1w × 3 + PDT	36%	11%	0%	78%		0%	22%
Ozkok et al. [27]	158	5–7.5 Gy q1w × 2–3	100%		11%	5%			
Carvalho et al. [85]	84	5–7.5 Gy × 1–5	55%	24%	10%				
Hennequin et al. [28]	106	5–7 Gy q1w × 6	47%			8%	4%		
Escobar-Sacristán et al. [29]	81	5 Gy q1w × 4	63%	2%	0%		1%	1%	1%
Mantz et al. [24]	39	4–9 Gy q1w × 2–4	100%	0%	0%				2.6%
Langendijk et al. [17]	47	7.5 Gy q1w × 2	100%	0%	15%				4%
Hara et al. [84]	36	4–45 Gy total dose	81%	22%	19%				
Anacak et al. [31]	30	5 Gy q2w × 3	100%		11%	70%	7%		13%
Petera et al. [32]	67	5–7.5 Gy q1–2w × 1–5	84%		3%	7%	1.5%	1.5%	4%

Author, year (reference)	N	Treatment[a]	Prior/concurrent EBRT	Prior laser	Massive hemoptysis	Radiation bronchitis (any grade)	Radiation bronchitis grade III/IV	Fistula	Airway stenosis
Muto et al. [21]	84	10 Gy × 1	100%	5%	2.5%	80%	37%	1%	
	47	7 Gy × 2			6.5%	48%	13%	2%	
	50	5 Gy × 3			5.5%	22%	17%	3%	
	139	5 Gy @ 5 mm × 3			2.5%	16%	8%	0%	
Stout et al. [20]	49	15 Gy × 1	0%	0%	8%				
Marsiglia et al. [35]	34	5 Gy q1w × 6	0%			3%			
Kelly et al. [34]	175	15 Gy q2w × 1–3	NS	11%	5%			0.5%	0.5%
Taulelle et al. [36]	189	8–10 Gy q 1w × 3–4	62%	14%	7%	22%	6%	1.6%	6%
Hennequin et al. [83]	149	4–7 Gy × 2–6	75%	6%	7%	9%			1%
Langendijk et al. [86]	98	7.5 Gy × 2 or 10–15 Gy × 1	87%	NS	29%				
Ornadel et al. [38]	117	15 Gy × 1	79%	44%	9%				
Huber et al. [16]	56	4.8 Gy × 2	100%	16%	19%				
Pérol et al. [40]	19	7 Gy q1w × 3–5		0	11%	56%	11%		
Nomoto et al. [39]	39	6 Gy q1w × 3 + EBRT or 10 Gy × 1	NS		8%				

Debridement

- Forceps debridement by using a rigid bronchoscope along with coring
- Microdebriders have also been used during rigid bronchoscopy to achieve the same effect; a hollow metal tube with a rapidly rotating blade (1000 to 3000 rpm) that is coupled to suction allows obstructing tissue to be dissected while simultaneously evacuating debris and blood

Investigational

- Intratumoral injection of cisplatin has been reported but is considered investigational
- Tracheobronchial reconstruction

In comparison all procedures

Modality	Indications	Effect	Rigid or flexible bronchoscope	Cautions and contraindication	Complications
Electrocautery (probe, forceps, snare) [5–8, 24–28]	Hemoptysis Debulking of endobronchial tumor	Immediate	Both	Caution: Pacemaker or defibrillators Skin surface Overlying a metallic joint prosthesis be avoided for return electrodes Contraindications: FiO_2 of >0.4 (burns)	Hemorrhage 1.8% Airway fire Airway perforation Pneumothorax
Argon plasma coagulation [6–8, 30–37]	Hemoptysis Debulking of endobronchial tumor	Immediate	Both	Per electrocautery	Bronchial or tracheal perforations 1.4% Gas embolism (rare) Per electrocautery
Thermal laser [6–8, 39–44, 47–49]	Debulking of endobronchial tumor	Immediate	Both	Caution: FiO_2 <0.4 Contraindication: Tracheoesophageal fistula Total airway obstruction and no functional distal airway open No exophytic lesion visible	Massive hemorrhage (1%) Pneumothorax (0.4%) Pneumomediastinum (0.2%) Airway fire and scarring (complication rate reduced if maximum of 40 W used)
Microdebrider [55]	Debulking of endobronchial tumor	Immediate	Rigid	Caution: None Contraindication: Distal lesions	Pneumothorax Infection Hemorrhage

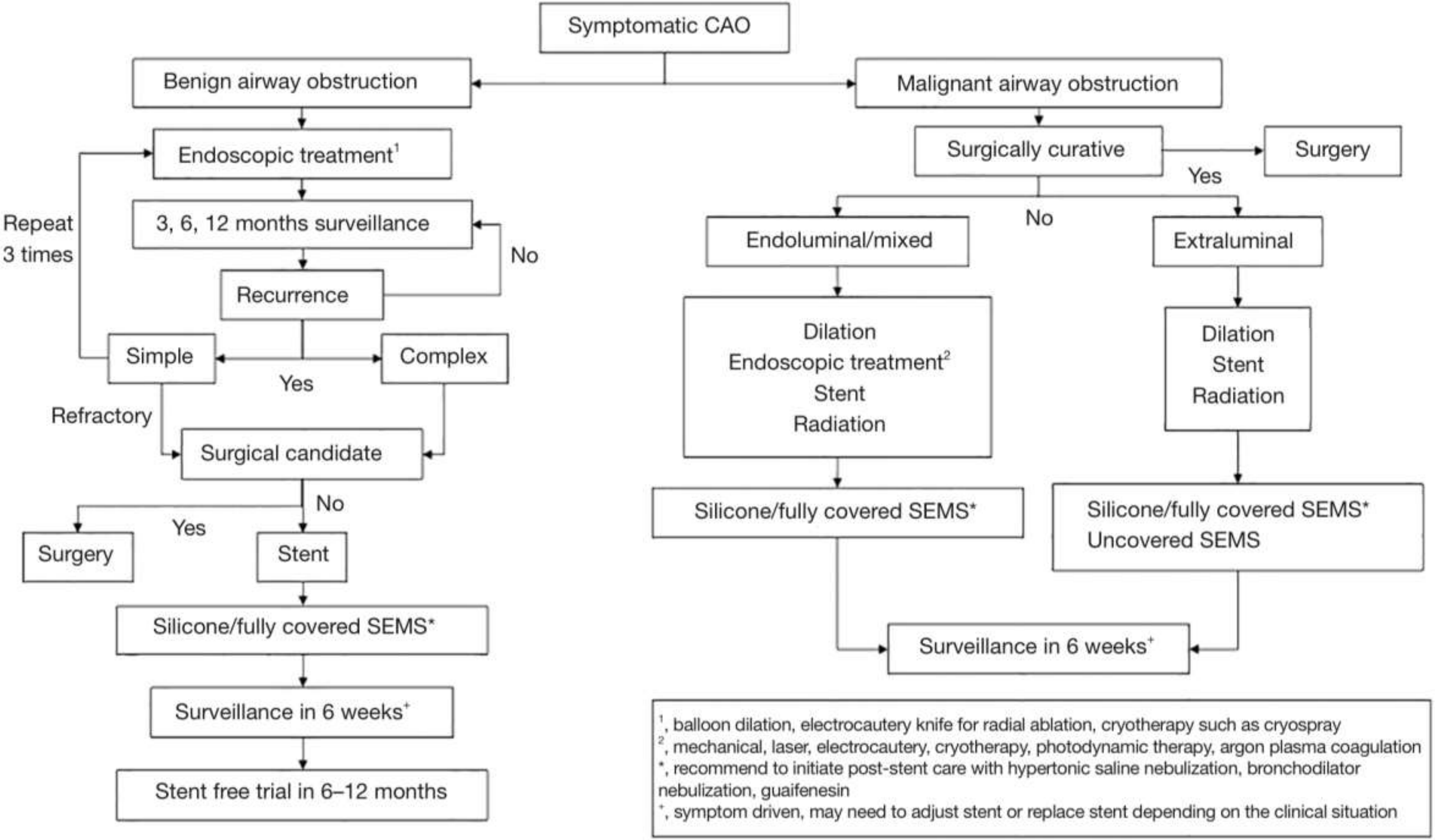
Modality	Indications	Effect	Rigid or flexible bronchoscope	Cautions and contraindication	Complications
Cryotherapy [6–8, 59–61, 67–71]	Debulking of endobronchial tumor	Delayed	Both	Caution: None Contraindication: Acute airway obstruction requiring immediate relief	Pneumothorax Infection Hemorrhage
Brachytherapy [6–8, 76–87]	Treatment of endobronchial or peribronchial tumor	Delayed	Both	Caution: Expensive Healthcare worker shielding Contraindication: Treatment for malignant tracheoesophageal fistula Repeat brachytherapy in the same area	Radiation bronchitis Airway stenosis Massive hemoptysis Bronchial necrosis Airway fistulas Fibrotic stenosis
Photodynamic therapy [6–8, 60, 99–110]	Treatment of endobronchial or peribronchial tumor	Delayed	Both	Caution: Skin photosensitivity for several weeks Contraindication: Life threatening central airway obstruction Malignancy involving esophagus or major vessels Patients with porphyria Allergy to photosensitizer	Massive hemoptysis Bronchopleural fistula Complications from delayed necrosis of treated tissue Subepithelial fibrosis

Table 1 Comparison of available endobronchial modalities in types of malignant airway obstruction and clinical urgency of procedure

Type of airway obstruction	Endoluminal	Extrinsic compression	Mixed lesion	Malignant airway fistula	Immediate effect/ urgent clinical need
Mechanical debulking	+	–	+	–	+
Laser (YAG, YAP)	+	–	+	–	+
Electrocautery	+	–	+	–	+
APC	+	–	+	–	+
Cryotherapy probe debulking	+	–	+	–	+
Cryotherapy spray	+	–	+	–	-
Balloon dilation	+	+	+	–	+
Stent placement	+	+	+	+	+
Brachytherapy	+	–	+	–	–
Photodynamic therapy	+	–	+	–	–

+, possibly indicated with potential clinical benefit; –, not indicated. APC, argon plasma coagulation.

Approach to MAO-in summary


Symptomatic CAO
Benign airway obstruction
Malignant airway obstruction
Endoscopic treatment[1]
Repeat 3 times
3, 6, 12 months surveillance
No
Recurrence
Simple
Yes
Complex
Refractory
Surgical candidate
No
Yes
Surgery
Stent
Silicone/fully covered SEMS*
Surveillance in 6 weeks[+]
Stent free trial in 6–12 months
Surgically curative
Yes
Surgery
No
Endoluminal/mixed
Extraluminal
Dilation
Endoscopic treatment[2]
Stent
Radiation
Dilation
Stent
Radiation
Silicone/fully covered SEMS*
Silicone/fully covered SEMS*
Uncovered SEMS
Surveillance in 6 weeks[+]
[1], balloon dilation, electrocautery knife for radial ablation, cryotherapy such as cryospray
[2], mechanical, laser, electrocautery, cryotherapy, photodynamic therapy, argon plasma coagulation
*, recommend to initiate post-stent care with hypertonic saline nebulization, bronchodilator nebulization, guaifenesin
[+], symptom driven, may need to adjust stent or replace stent depending on the clinical situation