REVIEW ARTICLE

ENDOBRONCHIAL ABLATIVE THERAPIES

Joseph C. Seaman MD*, Jawad K. Ansari MBBS**. Ali I. Musani MD*
**National Jewish Health and University of Colorado, Denver, USA*
***Army Medical College/ National University of Science & Technology, Rawalpindi, Pakistan*

ABSTRACT

Endobronchial ablative therapies are minimally invasive therapies that are rendered through rigid or flexible bronchoscopes to address endoluminal lesions that are associated with respiratory. These therapies can be rendered to patients with malignant and benign lesions. The choiceto utilize one therapy over another is dependent on technical and patient specific factors. Having knowledge of each of the therapies, potential complications related to each therapy, and knowing when and how to blend the benefits of each therapy is of utmost importance. Pubmed was used as the search engine to identify articles related to the following search terms: endobronchial ablative therapies; Nd:YAG laser; electrocautery; cryotherapy; photodynamic therapy; brachytherapy; and bronchoscopy. This review will concisely review each endobronchial ablative therapy, indications and contraindications for each therapy, complications of endobronchial ablative therapies, and end with a brief discussion of practical consideration with endobronchial ablative therapies.

INTRODUCTION

Endobronchial ablative therapies are employed to desiccate endobronchial lesions obstructing the airways and leading to symptoms of dyspnea, cough, post obstructive atelectasis and post obstructive pleural effusion [1, 2]. Malignant and benign lesions can be approached with a variety of endobronchial ablativetherapies [1, 3]. Many lesions may require the use of more thanone modality during the same procedure and some cases may require repeat procedures [4-6]. Malignant endobronchial and endotracheal disorders are generally approached in a palliative fashion whereas benign disorders are typically approached with curative intent [1, 7]. In some situations the bronchoscopists utilizes these therapies in an effort to bridge patients to a definitive surgical procedure such as tracheal resection, lobectomy, pneumonectomy etc. Endobronchial ablative therapies are generally rendered to lesions that compromise more that 50% of the lumen of the trachea or mainstem bronchi[1]. A variety of endobronchial ablative therapies existand choosing which endobronchial ablative therapy to use is dependent on a number of technical and patient specific factors [1, 8].

Endobronchial Ablative Therapies (Table to compare the differences)
Hot and Cold Therapies: Laser, elctrocautery and argon plasma coagulation are among some of the common hot therapies used for ablative purposes. Cryotherapy on the other hand is an example of a cold therapy. Hot therapies are flammable in oxygen rich medium. The safe use of hot therapies requires a low oxygen environment (below 40% FiO_2) to prevent endobronchial and endotracheal fires. All of the abovementioned modalities can be used with flexible and rigid bronchoscopy, under conscious sedation or general anesthesia with or without intubation. (Table I)

LASER

Laser (**L**ight **A**mplification by **S**imulated **E**mission of **R**adiation) refers to the use light energy that is transferred through optical fibers to treat a variety of endotracheal and endobronchial disorders. Several different types of lasers exist (potassium titanyl phosphate (KTP), yttrium aluminiumpevroskite (YAP), carbon dioxide (CO_2), and neodymium-yttrium aluminium garnet (Nd:YAG)) although the most commonly used laser is the Nd:YAG [1]. Laser therapy is the most commonly used endobronchial ablative therapy due to it's predictable effects on tissue, it's focal area of treatment effect, it's rapid and immediate results, the ability to repeat treatments, and the ability to combine the treatments with other modalities [8, 9]. Laser therapy destroys tissue through thermal activity by applying light energy directly to tissues. This transfer of light energy results in coagulation, carbonization, and vaporization of tissue [1, 8]. The degree to which coagulation versus vaporization occurs is dependent on the energy settings, with higher settings resulting in vaporization of tissue and lower settings resulting in coagulation[1, 10-12]. The variation in power settings also affects the depth of penetration of the laser with low settings resulting in shallow laser effects and high settings resulting in deep penetration [1, 10]. Laser therapy allows for immediate removal of tissue, hemostatic control, and immediate symptomatic results through improved patency of the airway lumen [1, 8, 10-11]. As with other endobronchial ablative therapies, laser therapy has an immediate effect and a delayed effect. The immediate effect is due to the direct carbonization and vaporization of tissue. The delayed effect is a result of tissueremodeling due to the cytocidaleffect of laser therapy. The cytocidal effect is due to thermal death of cells whichresults in changes to the airway several days after the treatment. Figure I depicts a typical airway intervention using laser therapy. Figure II depcits three common laser fibers deployed in airway interventions.

ELECTROCAUTERY

Electrocautry utilizes the flow of electricity to generate heat. The electrical current flows from a probe into target tissues. Heat is generated in target tissues due to the difference in resistance of different mediums and different tissues [1].The effects of electrocautery are dependent on a number of different variables which include the nature of the lesion, current wave form properties, the power setting, machine mode, and the probe used[1, 11, 13]. In general, high power settings can vaporize and carbonize tissue whereas low power settings can be used for coagulation [1, 13]. Similarly, high power settings penetrate deep into tissue whereas low power settings have a shallow effect [1, 13]. The area of effect is generally focused. A variety of different probes can be used that allow some customization of treatment [13]. As with laser, there is an immediate and a delayed effect of electrocautery. The immediate effectis due to direct tissue destruction and the delayed effect is due to the cytocidal effect of heat generation in cells. Although the effects and outcomes are similar to laser therapy electrocautery can be more time consuming. The costs related to electrocautery are minimal as most institutions have electrocautery generators and only have tobuy specialized probes [13 – 15].

Electrocautery allows use of multiple instruments such as cautery snare, forceps, knife, and probe (Figure III) [13]. These ancillary instruments make elctrocautery very versatile in handling different types of endobronchial lesions.With it’s small size, cheaper cost and more forgiving nature in case of misfires compared with laser, it offers an ideal first ablative tool for centers starting to do interventional pulmonary programs [14]. Figure IV depicts the use of the electrocautery knife and electrocautery probe in the treatment of benign subglottic stenosis. Figure IV depicts the use of the electrocautery snare in the treatment of a polypoid mass lesion.

ARGON PLASMA COAGULATION

Argon Plasma Coagulation (APC) works similar to electrocautery [1]. Instead of direct contact or the use of air as the medium through which electrocautery exerts its affects, APC uses argon gas as the medium through which the electrical current flows to the tissue being treated [1]. APC provides excellent coagulation effects given the shallow topical effects on target tissue [1, 8, 13]. APC can allow for treatment of lesions that have unusual locations or locations that are not easily approached by the probes used with laser or electrocautery [1, 8, 13]. Argon gas fills the area adjacent to the tip of the bronchoscope and facilitates the transfer of energy to the tissue. Given the diffuse area of treatment effect and the shallow nature of the treatment, carbonization and vaporization of tissue is far less likely [8]. As with laser and electrocautery there is an immediate and a delayed effect of APC. As with the other “hot” therapies, the immediate effect is to due to direct tissue destruction from thermal injury and the delayed effect is due to the cytocidal effects of heat. APC is a time consuming process, is not an optimal option for debulking large lesions, and lacks precision that is offered by other therapies.

CRYOTHERAPY

Cryotherapy refers to the use of extreme cold in the treatment of airway lesions[1]. Cryotherapy utilizes a special probe through which a rapidly expanding cryogenic gas (commonly nitrous oxide or liquid nitrogen) flows to cool the tip of the catheter to a temperature of -40ºC. The specialized probe is applied directly to the target tissue to effectively freeze the tissue. The probe is actively cooled for a period of 30 to 60 seconds to affect tissue freezing followed by a 60 to 90 second period of passive thawing [1, 16]. The freeze and thaw procedure is repeated two to three times to effectively treat the target tissue. Cryotherapy lacks precision, is difficult to focus on one particular area, and has a shallow treatment effect [16]. Malignant tissue is particularly sensitive to cryotherapy given the high water content of malignant cells. Cartilage and fibrous tissues are relatively resistant to cryotherapy[1, 16]. Cryotherapy is not an optimal option for benign fibrous lesions or scar tissue. There are no immediate effects with cryotherapy and maximal tissue destruction occurs days to weeks after the treatment [1, 16]. Cryotherapy can be performed with any concentration of inspired oxygen[1, 16]. Cryotherapy is time consuming and can require multiple repeat treatments.

BRACHYTHERAPY

Brachytherapy refers to the use of radiation to treat malignant lesions. Brachytherapy is generally not utilized in benign lesions and is not used in malignant lesions that are causing acute severe symptoms of dyspnea[16,18].Brachytherapy can be delivered through the insertion of seeds that are implanted through specialized catheters or through the use of specialized catheters that allow radiation therapy to be delivered from radioactivecatheters[16,17]. The seeds or catheters are inserted through the working channel of a standard flexible bronchoscope and placed under direct visualization or with the assistance of fluoroscopy or ultrasound[16, 17]. Brachytherapy is generally used for lesions that are growing into airways or lesions that are compressing airways[16,17]. Endobronchial radiotherapy can deliver high doses of radiation to selected areas allowing for excellent treatment response[16, 17].

It can be offered to patients who have already received maximal external beam radiation and are not candidates for more conventional radiation for growing endobronchial or peribronchial tumors causing airway obstruction[19]. There is no immediate effect with brachytherapy making it a poor technology for patients who are acutely symptomatic. The response to brachytherapy can take several weeks. Brachytherapy can be delivered to patients with any degree of inspired oxygen. Brachytherapy is expensive and requires specialized facilities to render the treatments.

PHOTODYNAMIC THERAPY

Photodynamic therapy (PDT) refers to the application of light energy to tissues that have been pre-treated with a photosensitizer [1, 8]. Patient's receive a systemic infusion of a photosensitive porfimer (such as Photofin™) 48 to 72 hours prior to bronchoscopy [1, 20]. The photosensitizing agent accumulates preferentiallyin malignant cells [20]. The light energy activates the photosensitizer and results in cell death. PDT does not result in immediate relief of obstruction although effects are generally seen within 2-4 days of therapy [20]. Repeat bronchoscopy in 2-3 days is necessary in patients treated with PDT to facilitate removal of sloughed off tissue [20].Repeat treatments may berequired to treat deeper layers of malignant tissue [20]. PDT is generally well tolerated [20]. Patients who receive PDT must stay out of direct sunlight for days to weeks depending upon the photosensitizer used for their therapy [8].

INDICATIONS AND CONTRAINDICATIONS FOR ENDOBRONCHIAL ABLATIVE THERAPIES

Endobronchial ablative therapies are indicated for lesions that occupy more than 50% of the lumen of the airway with associated shortness of breath or dyspnea on exertion [1, 8]. Patients who have hemoptysis related to an endobronchial lesion may receive significant improvement if not cessation of their hemoptysis with endobronchialablative techniques[8, 21]. Lesions that prevent effective mucociliary clearance or lesions that are responsible for recurrent pneumonia may be effectively addressed by endobronchial ablative techniques [1-3]. If a subtotal lesion is the suspected source of a chronic unrelenting cough an ablative technique to remove the target lesion may be attempted to improve the cough. (Table II)

Contraindications: An absolute contraindication for endobronchial ablative therapies is the presence of extrinsic compression of the airway [1, 8, 11]. Relative contraindications include inability to lower the inhaled oxygen to less than 40%, the presence of a distal airway obstruction, an airway obstruction present for more than 4 weeks, or the presence of a lesion that involves a very long segment of an airway (more than 4 cm) [8].An extrinsic lesion that is compressing the airway is best addressed with airway stenting or external beam radiation [2, 11]. Elevated oxygen concentrations predispose patients to airway fires [11]. Distal airway obstructions are associated with poor success rates due to the fact that distal airways may have poor structural integrity and distal airways that are beyond the reach of the ablative therapies may remain occluded [8]. Lesions that have been present for more than 4 weeks maybe associated with irreparable lung damage and thus have little functional return of the lung after opening the airway [8]. And finally, lesions that are longer than 4 cm in length are difficult to address given the amount of tissue that must be removed and the underlying damaged airway wall (due to the infiltrative process) [8]. Although, asmentioned above some of these contraindications are relative and do allow for alternative methods or techniques to address this difficult lesions. Photodynamic therapy, brachytherapy, and cryotherapy can be used in patients with increased inspired oxygen concentrations [16]. Brachytherapy can be used in lesions that are associated with extrinsic compression or for lesions that approach 4cm in length [16-17]. Choosing among the different therapies and weighing the risk and benefits of utilizing different therapies is difficult and should be performed by individuals who have extensive experience in the use of endobronchial ablative therapies. (Table II)

COMPLICATIONS OF ENDOBRONCHIAL ABLATIVE THERAPIES

Common complications related to endobronchial ablative therapies are similar to those experienced with routine flexible bronchoscopy in addition to some unique complications related to the specific therapy (Table III). These complications include respiratory failure, myocardial infarction, cardiac arrhythmia, and death[9,22]. Although these complications are ubiquitous among the different endobronchial ablative therapies the reason that the incidence is increased is due to prolonged sedation given during the procedure and the need for decreased fractional inspired oxygen levels (in laser, electrocautery, and APC) which may allow transient or prolonged hypoxia during the procedure.

Airway perforation is a potential complication related to therapies that immediately ablate tissues – laser, electrocautery, and to a lesser extent APC [9, 11]. These therapies destroy and dissect through tissue. When tissue plans are being dissected or the angle of instrument penetration is perpendicular to the airway wall, it is possible that the airway wall can be perforated leading to pneumomediastinum, pneumothorax, and hemorrhage. To decrease the incidenceof these severe complications the bronchoscopists should deploy the therapy parallel to the airway wall and constantly re-evaluate the tissue plans being dissected to prevent dissecting to deep into the airway wall. Additionally, the power settings of the different therapies can be reduced to minimize the depth of penetration. Cryotherapy, PDT, and brachytherapy are unlikely to cause airway rupture as they do not immediately ablate tissue and do not actively dissect through the airway wall [16].

Although many therapies are actively employed to address lesions that are bleeding, many of the endobronchial ablative therapies can cause hemorrhage [1, 11]. Laser and electrocautery are excellent therapies to address lesionsthat are bleeding, however both of these therapies can dissect through airway walls and into bronchial vesselsand cause massive hemoptysis. APC is unlikely to cause bleeding due to the shallow penetration of this therapy[11,13,21]. Cryotherapy, PDT, and brachytherapy are less likely to cause hemorrhage due to the fact that they do not directlydissect or ablate tissues [16]. Cryotherapy, PDT, and brachytherapy can be associated with delayed hemoptysis due to mucosal ulceration or tissue breakdown as the airway remodels from the treatment[8, 16-17]. Airway fires are a potentially catastrophic complication of therapies that use heat generation in destroying tissue. With high inspired oxygen levels airway fires can ignite the bronchoscope, the endotracheal tube, or the tissue itself. The tip of the fiber or probe being used should be more than a centimeter aware from the bronchoscope and several centimeters away from the endotracheal tube. Laser therapy, electrocautery, and APC must be rendered with great care and the amount of supplemental oxygen should be as low as reasonably allowed and should be maintained less than 40%[11]. Endotracheal tubes should not be regularly used with laser, electrocautery, or APC. Laryngeal mask airways provide adequate ventilation and are well removed from the area of treatment. In high risk airways metallic rigid bronchoscopy provides for an excellent alternative to the flexible bronchoscope and reduces the risk of instrument fire.

Air embolism is a rare complication of laser therapy[23-24]. It is believed that the etiology is due to the disruption of bronchial blood vessels in the setting of positive pressure ventilation and the use of gas cooled laser contact fibers[24].This catastrophic complication can be reduced through the use of non-contract laser fibers and using non-gas cooled fibers[24].

PRACTICAL CONSIDERATIONS OF ENDOBRONCHIAL ABLATIVE THERAPIES

Patients can present with a variety of different malignant and benign lesions. Choosing the appropriate therapy will be dependent on a number of different factors – location and type of lesion, malignant or benign, ability to lower the fractional inspired oxygen concentration, availability of the different therapies at the institution, technical trainingand experience of the practitioner rendering the therapy, and the need for a rapid intervention. (Table IV) Laser and electrocautery are two therapies that have immediate effects and are most commonly employed inpatients with critical airway stenosis that require immediate opening[14-15]. These therapies are commonly combined with other therapies that may enhance the duration or effect of maintaining airway patency[4, 6]. Although they are fundamentally different technologies, these two therapies are similar in the results that they achieve and electrocautery is generally much more economical as facilities generally have the necessary generator and are only required to purchase new specialized probes [14-15]. The experience needed to optimally employ these therapies as well as the potential life threatening complications which can result from these therapies require that the bronchoscopist have adequate training. The knowledge to choose the appropriate therapy and to maximize benefit while reducing complications to patients is of utmost importance and can only be achieved by well-trained bronchoscopists.

CONCLUSION

Several endobronchial ablative therapies exist. The therapies differ significantly and each has a set of unique characteristics that can make it more or less advantageous for a given patient. Patients may benefit significantly from these therapies and in many benign cases have a lifelong cure. The choice of employing a specific therapyis dependent on a number of patient and technical factors. A bronchoscopist should be experienced and well trained with the specific therapy which they are rendering to maximize patient benefit and reduce costly and life threatening complications.

Disclaimers:

Joseph C. Seaman MD – None
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Table II. Indications and Contraindications for Endobronchial Ablative Therapies

Indications:

1. Endotracheal or endobronchial lesion occupying more than 50% of the airway with symptoms of dyspnea on exertion or shortness of breath
2. Hemoptysis
3. Recurrent pneumonia due to ineffective mucus clearance
4. Intractable cough

Absolute Contraindication:

1. Extrinsic compression of airway*

Relative Contraindication:

1. Inability to lower FiO2 to less than 40%†
2. Distal airway obstructions
3. Airway obstruction present for more than 4 weeks
4. Length of obstruction more than 4cm‡

*Catheter directed brachytherapy can be used to deliver radiotherapy to lesions externally compression the airway.

†This applies to laser, electrocautery, and APC

‡ Catheter directed brachytherapy can be used to deliver radiotherapy to lesions that are more than 4cm

Table I – Comparison of different Endobronchial Ablative Therapies

Variable Laser Electrocautery Argon Plasma Cryotherapy Brachytherapy Photodynamic
Coagulation
Rapidity of +++ +++ +/- - - -
improvement
Hemoptysis +++ +++ +++ - - -
Control
Tumor - - - - + +
Specifics
Depth of Variable, Variable, 3mm 3mm Variable, 3mm
penetration dependent on dependent on dependent on
power settings power settings radiation dose
Expense ++ + ++ ++ +++ +++

The above table compares and contrasts different Endobronchial Ablative Therapies.

Type of Endobronchial Therapy	Airway Perforation	Hemorrhage	Air Embolism	Respiratory failure	Myocardial Infarction	Arrythmias	Death
Laser	Possible	Possible	Very rare	Possible	Unlikely	Unlikely	Unlikely
Electrocautery	Possible	Possible	No	Possible	Unlikely	Unlikely	Unlikely
Argon Plasma Coagulation	Unlikely	Unlikely	No	Possible	Unlikely	Unlikely	Unlikely
Cryotherapy	No	No	No	Possible	Unlikely	Unlikely	Unlikely
Photodynamic therapy	No	No	No	Possible	Unlikely	Unlikely	Unlikely
Brachytherapy	No	Unlikely	No	Possible	Unlikely	Unlikely	Unlikely

*Rates of complication vary significantly among pulmonologists, airway centers, and patients. The above table is provided to guide describing complications to patients.

Table III Complications of Endobronchial Ablative Therapies

Table IV Practical consideration of Endobronchial Ablative Therapies

"Hot" Therapies (Laser, Electrocautery, APC)

- Keep FiO2 less than 40% to prevent or reduce the risk of airway fires.

- Consider the use of a rigid bronchoscope when available and appropriate to limit the risk for airway fires.
- These are ideal interventions when immediate results desired

Electrocautery and APC
- Caution in patients with pacemakers
- Wide array of specialized catheters
- Electrocautery achieves similar results to Laser and is more economical

Photodynamic therapy
- Intense photosensitivity to sunlight
- Results may take days to weeks
- Repeat bronchoscopy required to remove sloughed tissue
- Only applicable in patients with tumors that have significant blood flow

Cryotherapy
- Results are delayed
- Able to be performed with any inspired level of oxygen
- Time consuming

Brachytherapy
- Additional radiation may be delivered to areas that have received maximal external beam radiation
- Can be delivered to long lesions or lesions that are external to and compressing the airway
- Expensive and requires special facilities

Figure I.
This series of figures depicts the effects of laser fiber therapy in endotracheal malignant disease. The upper left tile demonstrates a near complete occlusion of the distal trachea with a malignant growth emanating from the right tracheal wall. The upper right tile demonstrates the growth immediately after laser therapy with the large escar over the lesion. The lower left tile demonstrates the growth after debulking the escar; note the recanalization of the distal trachea after one laser treatment. The lower right tile shows the distal trachea 10 days after laser treatment.

Figure II.
This figure depicts three common laser fibers. The top two fibers are different sizes of non-contact laser fibers. The smaller fiber is generally used through flexible bronchoscopes whereas the larger fiber is generally used through rigid bronchoscopes. The bottom fiber is a contact laser fiber.

Figure III.
Figure III A: A narrow benign subglottic stenosis.
Figure III B: The same lesion after electrocautery knife treatment at the 9 o'clock, 12 o'clock, and 3 o'clock positions. The incisions allow the tissue to relax and dramatically increase the lumen of the airway.
Figure III C: The same lesion treated with the electrocautery probe to remove the redundant stenotic tissue.

A B C

Figure IV
Figure IV A: A polypoid mass lesion emanating from the distal left mainstem bronchus.
Figure IV B: An electrocautery snare being placed over the polypoid mass lesion.
Figure IV C: The distal left mainstem after removal of the polypoid lesion. The base of the polypoid lesion required treatment with the electrocautery probe. Patency was restored to the left mainstem.

A B C

Figure V
This figure depicts the four commonly used electrocautery instruments. The instrument on the left is the electrocautery knife which is best used to desiccate through tissue and provides precise cuts. The instrument second from left is the electrocautery probe. This probe is a contact probe that provides coagulation and at high energy settings will carbonize and vaporize tissue.

Table 1 – Comparison of different Endobronchial Ablative Therapies

Variable	Laser	Electrocautery	Argon Plasma Coagulation	Cryotherapy	Brachytherapy	Photodynamic
Rapidity of improvement	+++	+++	+/-	-	-	-
Hemoptysis Control	+++	+++	+++	-	-	-
Tumor Specifics	-	-	-	-	+	+
Depth of penetration	Variable, dependent on power settings	Variable, dependent on power settings	3mm	3mm	Variable, dependent on radiation dose	3mm
Expense	++	+	++	++	+++	+++

The above table compares and contrasts different Endobronchial Ablative Therapies.

Table 2. Indications and Contraindications for Endobronchial Ablative Therapies

Indications:

1. Endotracheal or endobronchial lesion occupying more than 50% of the airway with symptoms of dyspnea on exertion or shortness of breath
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Table 3 Complications of Endobronchial Ablative Therapies

Type of Endobronchial Therapy	**Airway Perforation**	**Hemorrhage**	**Air Embolism**	**Respiratory failure**	**Myocardial Infarction**	**Arry**
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Electrocautery	Possible	Possible	No	Possible	Unlikely	Unli
Argon Plasma Coagulation	Unlikely	Unlikely	No	Possible	Unlikely	Unli
Cryotherapy	No	No	No	Possible	Unlikely	Unli
Photodynamic therapy	No	No	No	Possible	Unlikely	Unli
Brachytherapy	No	Unlikely	No	Possible	Unlikely	Unli

*Rates of complication vary significantly among pulmonologists, airway centers, and patients. The above table is provided to guide describing complications to patients.

Table 4 Practical consideration of Endobronchial Ablative Therapies

“Hot” Therapies (Laser, Electrocautery, APC)
- Keep FiO2 less than 40% to prevent or reduce the risk of airway fires.
- Consider the use of a rigid bronchoscope when available and appropriate to limit the risk for airway fires.
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- Electrocautery achieves similar results to Laser and is more economical

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- Time consuming

Brachytherapy
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- Can be delivered to long lesions or lesions that are external to and compressing the airway
- Expensive and requires special facilities

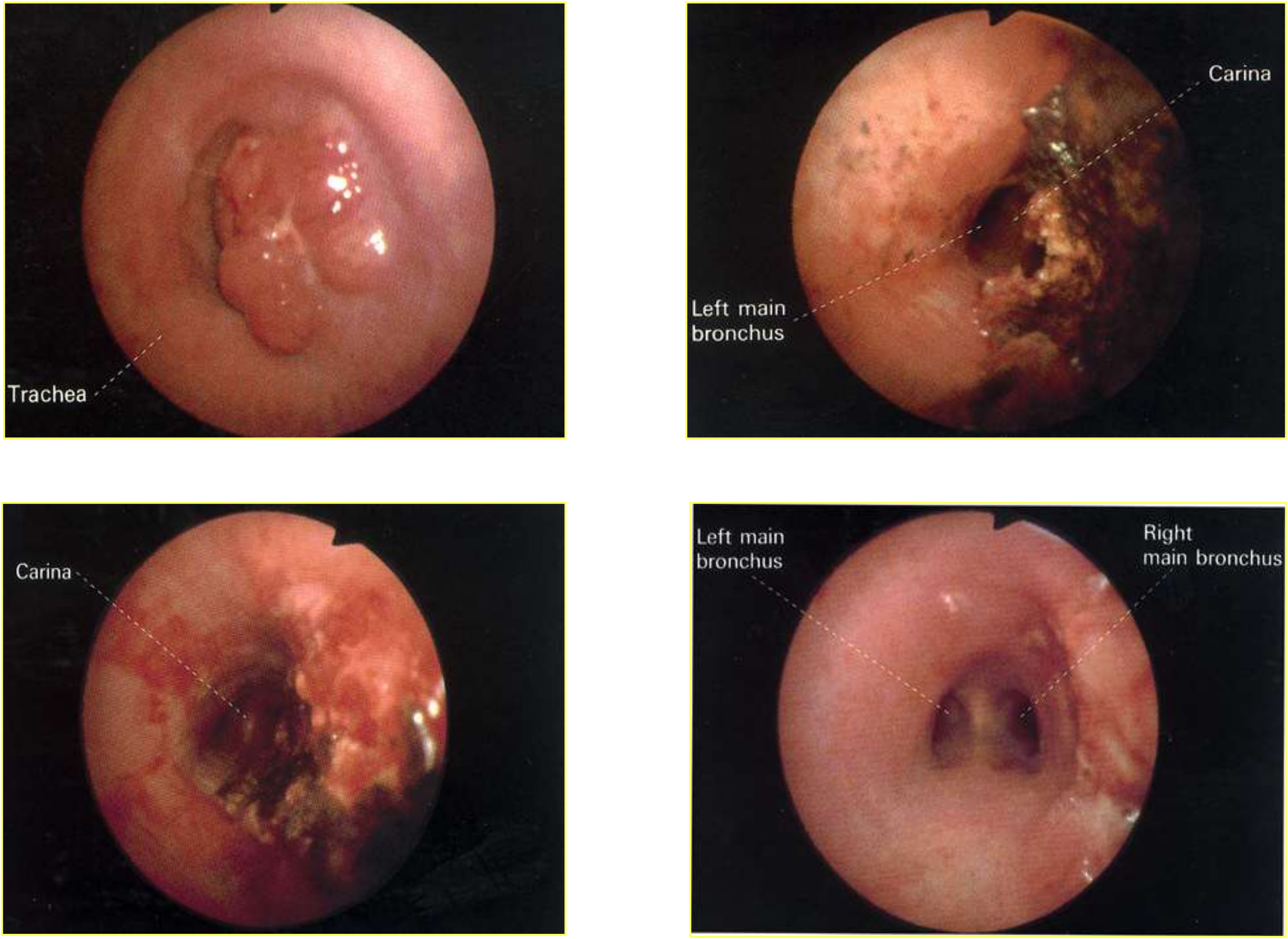
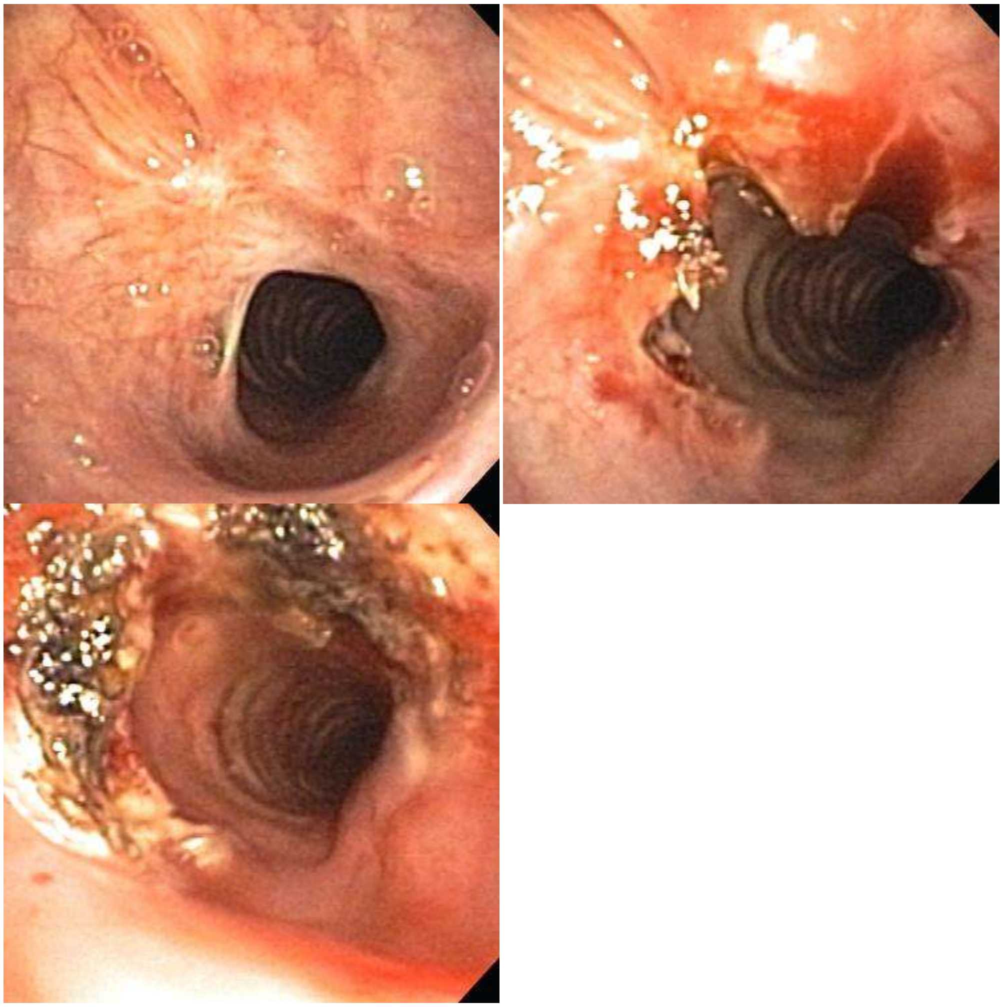


Figure I.

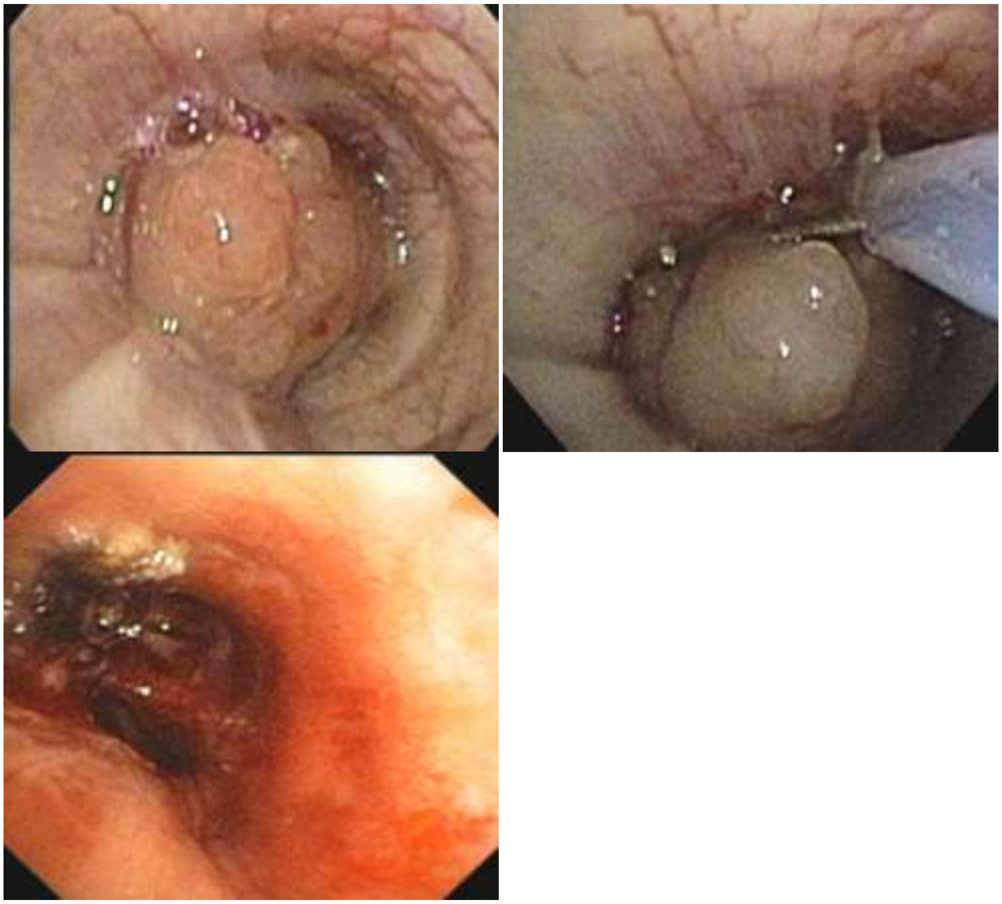
This series of figures depicts the effects of laser fiber therapy in endotracheal malignant disease. The upper left tile demonstrates a near complete occlusion of the distal trachea with a malignant growth emanating from the right tracheal wall. The upper right tile demonstrates the growth immediately after laser therapy with the large escar over the lesion. The lower left tile demonstrates the growth after debulking the escar; note the recanalization of the distal trachea after one laser treatment. The lower right tile shows the distal trachea 10 days after laser treatment.

Figure II.
This figure depicts three common laser fibers. The top two fibers are different sizes of non-contact laser fibers. The smaller fiber is generally used through flexible bronchoscopes whereas the larger fiber is generally used through rigid bronchoscopes. The bottom fiber is a contact laser fiber.



A. B. C.

Figure III.
Figure IIIA: A narrow benign subglottic stenosis.
Figure IIIB: The same lesion after electrocautery knife treatment at the 9 o'clock, 12 o'clock, and 3 o'clock positions. The incisions allow the tissue to relax and dramatically increase the lumen of the airway.
Figure IIIC: The same lesion treated with the electrocautery probe to remove the redundant stenotic tissue.



A. B. C.

Figure IV
Figure IVA; A polypoid mass lesion emanating from the distal left mainstem bronchus.
Figure IVB: An electrocautery snare being placed over the polypoid mass lesion.
Figure IVC:The distal left mainstem after removal of the polypoid lesion. The base of the polypoid lesion required treatment with the electrocautery probe. Patency was restored to the left mainstem.

Figure V
This figure depicts the four commonly used electrocautery instruments. The instrument on the left is the electrocautery knife which is best used to desiccate through tissue and provides precise cuts. The instrument second from left is the electrocautery probe. This probe is a contact probe that provides coagulation and at high energy settings will carbonize and vaporize tissue. The instrument third from the left is the electrocautery snare. The snare is used to loop over polypoid lesions and cinches around the base of the lesion to provide a clean excision. The last instrument is the electrocautery forceps which can be used to grasp tissue and provides coagulation at low settings and can carbonize and vaporize tissue at high settings.