Journal of BUON **12:** 11-22, 2007
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REVIEW ARTICLE

Interventional pulmonology techniques for immediate desobstruction of malignant central airway obstruction

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Summary

In recent years interventional pulmonology techniques have found their place in the palliative treatment of lung cancer invading central airways (trachea and principal bronchi). The curative effect of interventional techniques is reported in a number of studies with very different success ratios, but with excellent potential and perspective. Increase in number and variety of these techniques led to the development of internationally accepted guidelines for their use. The choice of a specific interventional technique in the treatment of lung cancer patients with central airway obstruction (CAO) depends on several factors: patient's general condition and comorbidities, type and characteristics of airway stenosis, availability of techniques and trained personnel.

The aim of this review was to introduce interventional pulmonology procedures aimed at urgent desobstruction of central airways obstruction to medical oncologists who are dealing with the problem of malignant CAO. We tried to emphasize indications, contraindications, technique procedure and possible complications in the treatment of malignant CAO. At the Institute for Pulmonary Diseases of Vojvodina Nd: YAG laser resection, electrocautery, argon plasma coagulation and metallic and silicone stent insertions for immediate treatment of malignant CAO are practised.

Key words: bronchoscopy, central airway obstruction, interventional pulmonology, lung cancer

Introduction

The development of interventional pulmonology techniques in recent years has led to rapid improvement of those already established, and the development of new, more sophisticated techniques for diagnosis and treatment of lung cancer. Because of the increase in number and variety of interventional techniques, the European Respiratory Society (ERS) and the American Thoracic Society (ATS) together with the American College of Chest Physicians (ACCP) published guidelines for their potential use [1,2]. The interventional techniques can be divided into diagnostic and therapeutic. The diagnostic interventional techniques include autofluorescent bronchoscopy (AFB), endobronchial ultrasound (EBUS), electromagnetic navigation bronchoscopy and narrow band imaging bronchoscopy [3-14]. The therapeutic techniques are divided into those for imminent desobstruction of central airways and the ones with delayed effect, and they can be either curative or palliative [15,16]. In cases of carcinoma *in situ* or early invasive lung cancer interventional pulmonology can offer a variety of techniques with curative effect. Photodynamic therapy (PDT), cryotherapy, electrocautery and brachytherapy are reported to have curative potential in cases of early-stage lung cancer.

Received 22-10-2006; Accepted 08-12-2006

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Bronchoscopic treatment of early-stage lung cancer requires precise and accurate staging of the disease, using all available advanced techniques for staging, e.g. positron emission tomography, EBUS and AFB or narrow band imaging bronchoscopy to make a distinction between non invasive and invasive bronchial carcinoma and to determine nodal status with high accuracy [17-24].

Palliative interventional pulmonology techniques are aimed at relieving symptoms of malignant CAO. In cases of respiratory failure due to intrinsic, extrinsic or combined obstruction of central airways, it is absolutely necessary to restore the airway integrity in order to save the patient's life. Techniques with imminent effect are laser resection, electrocautery, argon plasma coagulation and placement of tracheobronchial stents. Other therapeutic interventions can follow, after the initial treatment and reopening of the airway [25-28]. Interventional pulmonology techniques with delayed effect can improve the control of symptoms and quality of life (QoL), and addition of specific chemoradiotherapy can have certain impact on disease-free period and survival [29-31]. Every symptomatic malignant CAO must be considered as potentially fatal. Adequate bronchoscopic evaluation can offer appropriate indication for imminent interventional technique for rapid airway desobstruction . Interventional pulmonology techniques are extremely expensive and they should be available only to top respiratory institutions. Deployment of these techniques requires a multidisciplinary team of interventional pulmonologists, anesthesiologists, thoracic surgeons, radiologists and oncologists. Institutions where interventional techniques are implemented need to have appropriate facilities, well-trained personnel and a variety of interventional techniques available at any time. This is why the cost of these interventions is very high [1,2,27]. Below described are the major indications, contraindications, technique procedures and possible complications of interventional pulmonology techniques with immediate effect on airway desobstruction.

Nd: YAG laser photoresection

"Light amplification of stimulated emission of radiation" or LASER is one of the most explored techniques in interventional pulmonology. Laser beam delivers energy in the form of heat to the target tissues resulting in vaporization, coagulation and necrosis of the targeted tissue. There are several types of lasers used in practice (Nd: YAG, CO_2, argon, dye, diode, YAP: Nd), however only Nd: YAG (neodymium: yttrium aluminum garnet) is widely used in pulmonology. The effects of laser beam depend on several factors such as power density, absorption and scattering ratio of soft tissues and delivery system but one of the most important factors determining the biological effect of laser on soft tissues is the wavelength of the laser light [27,30,32] that determines the absorption and, hence, the effect of the delivered heat energy on the tissue. CO_2 laser is the most precise laser usually used by ENT (ear, nose and throat) surgeons and its precision can be compared to the scalpel. However, the wavelength of CO_2 laser is 10600 nm and it cannot be delivered via the quartz monofilament of the fiberoptic bronchoscope. On the other hand, argon laser has wavelength of only 488-514 nm and it can be delivered via flexible bronchoscope, but its penetration depth is only 1-2 mm. The light of argon laser is absorbed by hemoglobin and any bleeding represents serious limitation to its effectiveness. The wavelength of Nd: YAG laser is 1064 nm, it is in the invisible range of the infrared region and needs a pilot light (usually red) for its guidance (Figures 1-3) [15,27].

The major indication for laser photoresection is malignant or non malignant CAO due to intraluminal growth of malignant or benign tissue. Lesions most suitable for laser resections are those situated centrally (trachea and mainstream bronchi), short in length ($\leq$ 4 cm), with visible distal bronchial lumen and functional lung distal to the obstruction [15].

Nd: YAG laser resection can be carried out via flexible bronchoscopy or the combination of rigid and flexible bronchoscopy under general anesthesia. The initial power setting is usually about 40 W, with pulse

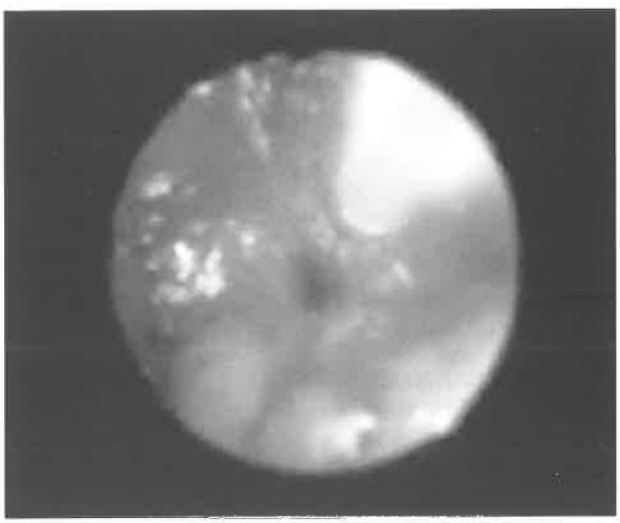


Figure 1. Nd: YAG laser resection of malignant tumor in the left main bronchus.

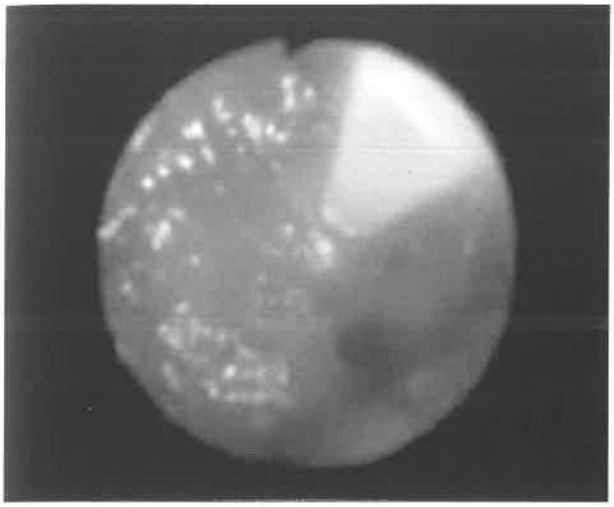


Figure 2. Red pilot light of laser, pointing the place for resection.

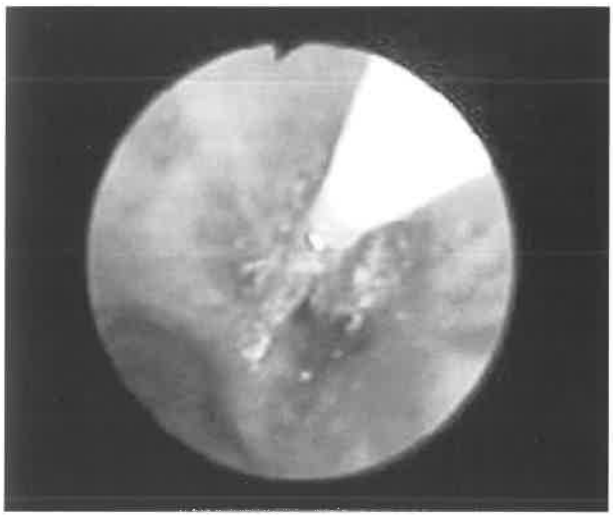


Figure 3. Nd: YAG laser resection of squamous cell carcinoma in the upper right lobe bronchus.

duration of 0.5-1 sec. The tip of the probe is aimed 1 cm proximally and parallel to the lesion. Tissue effect of Nd: YAG laser can be adjusted either by increasing the power setting or by moving the tip of the probe further or closer to the target lesion. The result will be vaporization, coagulation or necrosis of the tissue. The depth of penetration of the laser beam is not immediately visible, so frequent reanalysis of the lesion is advisable. Laser resection is usually performed under general anesthesia; as a precaution oxygen concentration should be kept under 40% in order to prevent airway fire.

Absolute contraindication is extraluminal disease; relative contraindications include recent myocardial infarction, ventricular arrhythmias, conduction abnormalities, hypotension, decompensated heart failure, severe obstructive lung disease, extensive tumor involvement, unresolved coagulopathies and sepsis.

The first larger study on the therapeutic value of Nd: YAG laser resection was published by Dumon et al. in 1982 [33], revealing that the best results can be obtained in the treatment of malignant disease. Several studies followed, and the Cavaliere's group published one of the largest series on 1000 patients, 649 of whom had malignant CAO. In their study the success rate depended on the location of the tumor, with the best results for malignancies of the trachea, right main and intermediary bronchi - 97.94 and 90%, respectively. The success rate for the left main bronchus was 86% and for the bronchi of the left upper lobe 58% [34]. Čanak and associates published a larger scale study on the effects of Nd: YAG laser resection, brachytherapy and external beam radiotherapy (EBRT) compared with brachytherapy and EBRT alone. In that study they found significant improvement in the group treated with addition of laser for all investigated parameters: cough, dyspnoea, hemoptysis, thoracic pain, performance status, body weight loss, atelectasis, postobstructive pneumonia, endoscopic findings and lung function parameters. Time to progression and survival were significantly better when compared to the group that received only radiation therapy [35]. A similar study was published by Shea and colleagues [36], but since these studies were non randomized it is impossible to conclude that the better survival or time to progression can be attributed to Nd: YAG laser resection. The conclusion of most studies could be that Nd: YAG laser resection resolves CAO, which is in connection with high mortality [37,38]. Some of the important studies concerning laser resection [34,36,39,40] are stated in Table 1.

The overall complication rate of Nd: YAG laser resection is generally low. Possible complications include hypoxemia intraoperatively and postoperatively, hemorrhage, airway perforation, airway fire (burns), pneumothorax and fistulae formation [41]. After treatment the patient should be observed in the recovery room for a reasonable period of time because of the possibility of bronchospasm or laryngospasm. With adequate precaution measures taken the complication rate is usually less than 5%. In the largest Cavaliere's study the complication rate was 2.3%. In hands of experienced bronchoscopists Nd: YAG laser resection is a safe and successful procedure for urgent airway debulking [42]. Table 2 presents the 10 Dumon's commandments for safe YAG laser resection [32].

Table 1. Results of laser therapy in the treatment of malignant CAO

Author	*Patients, n*	*Indication*	*Therapy*	*Results*
Cavaliere [34]	1000	Malignant CAO	Nd: YAG	The success depends on tumor localization: trachea, right main, intermediary bronchi, left main and LUL 97, 94, 90, 86, 58%, respectively.
Shea [36]	46	Malignant CAO	Nd: YAG vs. Nd: YAG + brachytherapy	Significantly longer survival in the combined group: 40 vs. 16 wks (p=0.001)
Cavaliere [39]	1585	Malignant CAO	Nd: YAG	Bronchoscopic and radiologic improvement in 93%.
Venuta [40]	273	Malignant CAO	Nd: YAG ± stent	Significant improvement in oxygenation, lung function tests, QoL, 3-yr survival 52-59%.

CAO: central airway obstruction, Nd: YAG: neodymium: yttrium aluminum garnet, LUL: left upper lobe, QoL: quality of life

Table 2. Dumon's ten commandments for safe Nd: YAG laser resection

1. Know the anatomic danger zones: aortic arch, pulmonary artery and esophagus being the main hazard areas.
2. Have a well-trained laser team, including anesthesiologist specialized in light general anesthesia and two assistants drilled in emergency response procedures.
3. Screen patients carefully: Any endoluminal growth is amenable to laser resection, but purely external compression is beyond the reach of the technique.
4. Use the rigid bronchoscopic technique (custom-made open tube, light general anesthesia, straight telescope and two suction catheters) for any high-grade obstruction, especially if malignancy is involved.
5. Monitor blood gases and cardiac performance. At the least sign of hypoxemia , interrupt treatment long enough to oxygenate the patient, if necessary under closed circuit conditions.
6. Fire the laser parallel to the wall of the airway; never aim directly into it.
7. Coagulate at will but avoid using the laser at high power settings; mechanical resection after laser coagulation is preferable to laser resection alone whenever possible.
8. Do not neglect hemorrhage, for even slow bleeding will lead to hypoxemia if left unattended.
9. Terminate each procedure with a thorough laser irradiation of the resected area and perform tracheobronchial toilet to remove all secretions and/or debris.
10. Keep the patient under observation in a specially outfitted recovery room for a reasonable period of time.

Electrocautery (EC)

Electrocautery was introduced into respiratory medicine in the early 1930s, however it was soon abandoned because of severe side effects for the patients and the bronchoscopist. The most common ones were burns and electric shocks. In 1980s Hooper and Jackson popularized its use in combination with flexible bronchoscope [43].

EC represents a contact form of electrosurgery (Figures 4,5). Electron flow between the tip of the probe and the tissue is a result of voltage difference between these two surfaces. Electrons are then transmitted through a tiny gap of air between these two surfaces. The electrical current created is affecting the target tissue in the form of heat, causing its coagulation, carbonization or vaporization [44]. The current leaves the body through a grounding plate, usually applied on the patient's arm. The effects of

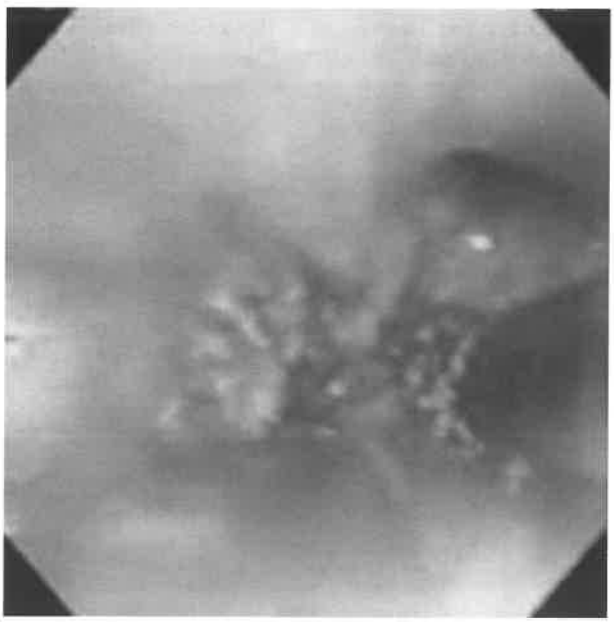


Figure 4. Coagulative effect of electrocautery on the tumor tissue.

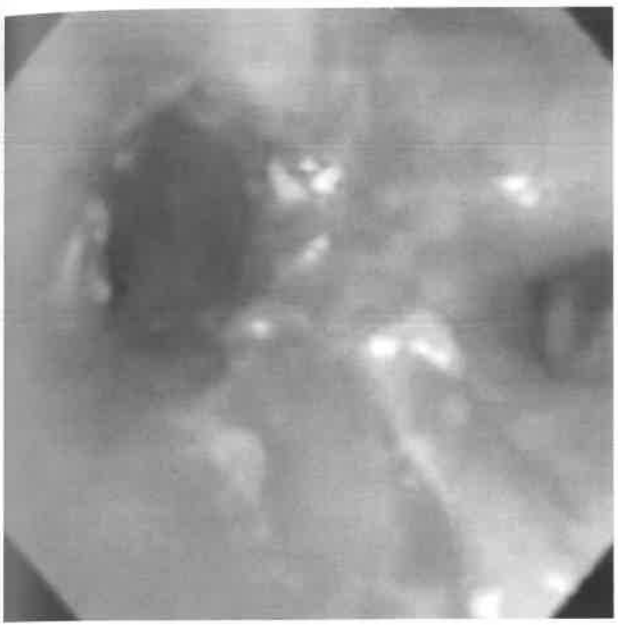


Figure 5. Reopening of the airway after electrocautery.

EC depend on power setting, tissue resistance, time of application and the applied mode of EC. Low voltage, low power and high amperage will cause coagulation. High voltage, high power and low amperage will cause carbonization. There are a "cut" mode and a "blended" mode of EC, the latter being preferred for its ability to combine cutting and coagulation. Some authors divide EC coagulation in 3 types: soft - to avoid carbonization, hard - for deeper tissue penetration and spray - for surface hemostasis. Indications for EC are the same as for laser resection, and often EC is used as a cheaper alternative to laser resection. Intraluminal obstruction of major airways due to benign or malignant tissue proliferation is the most common indication for its use. Absolute contraindications are extraluminal disease and a pacemaker susceptible to electrical interference [45].

EC can be carried out via rigid or flexible bronchoscopy, or combination of these two techniques. When rigid bronchoscopy is performed, EC is performed under general anesthesia. Analgosedation can be used in flexible bronchoscopy EC. A specially isolated ceramic-tip flexible bronchoscope is used for EC, and the patient is electrically grounded with a pad or a plate. Limiting inhaled oxygen fraction and avoiding flammable materials (plastic endotracheal tube or tracheobronchial stents) are necessary precaution measures. There are several types of EC probes designed to achieve the desired effects on the target tissue. Blunt probe is usually used for coagulation and carbonization, knife causes coagulation and blend, and snare is designed for blend. The coagulative effect of EC significantly correlates with the histologic tissue damage effect on the targeted tissue [46].

The curative intent of EC on early-stage lung cancer is reported in several studies. Van Boxem et al. reported their treatment results with EC in 13 patients (15 lesions); they achieved complete response in 80% (10 patients, 12 lesions), and survival range of 16-43 months with a mean follow up of 21 months [45]. Vonk-Noordegraaf et al. reported use of EC in 32 patients, with complete response in 97% and median survival of 60 months (range 21-120) [47]. There is a case report of curative resection of endobronchial fibroma with electrocautery [48]. However, controlled, prospective, randomized trials have not been published.

The palliative effect of EC is well established and proven by a number of studies. In the study published by Sutedja and coworkers [49] intraluminal malignant airway obstruction has been treated with EC (the majority of patients had NSCLC, 4 of them had benign obstruction) with a success rate of 70%. Homasson [50] reported 75% success rate in hemoptysis control, and 67% in airway debulking. A comparative study of Van Boxem et al. [51] with Nd: YAG laser vs. EC revealed success rate of 70% for both procedures, and cost-effectiveness ratio in favor of EC.

Possible complications of EC include airway perforation, electrical shocks and hemorrhage, however only mild hemorrhage has been reported in the published studies. Precaution measures for application of EC include limited power setting (40 W), low inspired oxygen concentration ($\leq$ 40%), short burst time ($\leq$ 2 sec) and the use of isolated bronchoscope [1,2,27]. EC seems to be good alternative to laser resection; it is cheap and safe technique for urgent airway debulking.

Argon plasma coagulation (APC)

APC is a form of non-contact electrosurgery (Figures 6-9) that uses ionized argon gas transformed into plasma in order to create electrical current. When high voltage spark (5000-6000 V) ignites argon gas, the gas is ionized into plasma. Monopolar current of ionized plasma affects the target tissue in the form of heat, producing coagulative and necrotic effects on the target tissue. Plasma seeks the way of least resistance, targeting directly wide surface of tissue. Closed current circuit is necessary for argon plasma to flow; the tip of the probe must therefore be situated



Figure 6. Argon plasma coagulation on model tissue.



Figure 7. Argon plasma burst on model tissue.



Figure 8. Argon plasma burst in bronchi to stop hemoptysis.

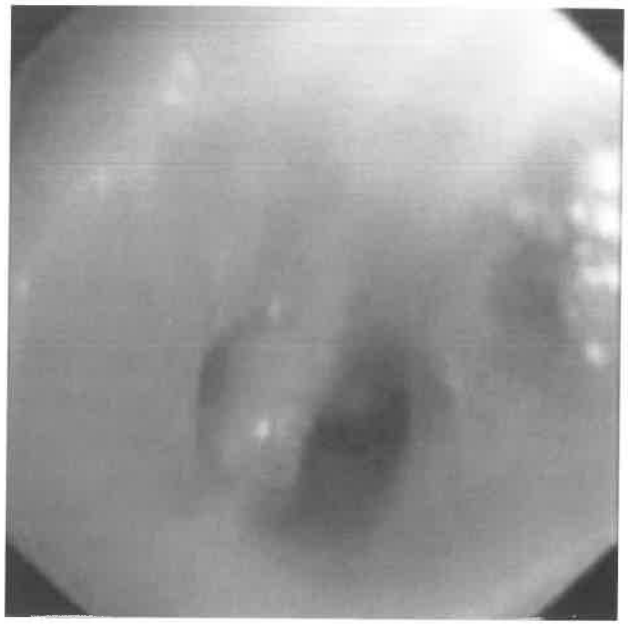


Figure 9. Argon plasma coagulation effect in bronchi.

less-than-centimeter from the tissue. If the distance between the tip of the probe and the tissue is more than 1 cm, the circuit will be open and the effect will be lost. The current leaves the body through a grounding plate, usually situated under the patient's lower back.

The effect of APC depends on power setting, application time and conductivity of the tissue. Coagulated tissues have higher resistance and higher resistance lowers conductivity and limits penetration. At power setting of 40-120 W and burst time less than 2 sec, the penetration depth is limited to less than 5 mm. One of the major benefits of APC is the fact that lesions situated laterally to the probe or lesions "around the corner" can be successfully treated, in contrast to laser or electrocautery. Disadvantages of APC include low penetration ability; therefore APC is not recommended in bulky tumor masses. In that case other interventional techniques usually must follow APC. Repeated bronchoscopic checkups are also usually required in order to remove all the necrotic debris from the airways [27,44,52].

The indications for APC are similar to EC or laser resections. They include intrinsic airway obstruction due to proliferation of malignant or benign tissue. Most suitable lesions are those having large endobronchial component with visible distal bronchial lumen and functional pulmonary tissue. The major indication for APC is hemostasis in hemoptysis. Since APC affects wide surface it is a recommended technique for hemoptysis control. APC is success-

fully used in the resection of granulomatous tissue proliferating through the pores of metallic stents [52]; there are also reports of use in the treatment of respiratory papillomatosis and posttransplantation benign tracheobronchial stenosis [53-55]. There are no absolute contraindications for APC use, except extraluminal disease. Relative contraindications are the same as for laser resections and EC.

APC can be carried out via flexible bronchoscopy alone (Figures 8,9); however, the combination of flexible and rigid bronchoscopy allows better control of bursts and adequate removal of debris during the intervention. The technique is usually performed under general anesthesia and requires all the necessary precautions for safe general anesthesia. Oxygen concentration should be under 40% and all flammable materials e.g. silicone stents or endotracheal tube, should be avoided. Initial settings for application of APC include power at 30-80 W, burst time of 2-3 sec, argon gas flow 0.3-2 L/min. The flexible probes for APC are 1.5 or 2.3 mm in diameter and up to 220 cm long. Probes can easily pass through the working channel of the flexible bronchoscope. The tip of the probe must protrude at least 1 cm off the tip of the bronchoscope making the visualization of the field clear and preventing possible burning of the bronchoscope. The probe must be kept 1 cm from the target tissue in order to keep the flow of plasma. During the procedure the debris should be removed with forceps or with suction.

The effectiveness of APC in the palliative treatment of lung cancer has been reported in several studies. Morice et al. [56] used APC to treat hemoptysis and CAO; prompt relief of symptoms was achieved in all but one patient and the mean follow up for hemoptysis was 97±92 days and for dyspnoea 53 days. The major indication for APC in a study conducted by Reichle et al. [52] was airway obstruction (186 patients; 51%) and hemoptysis (119 patients; 33%). They performed 482 interventions, with overall success rate of 67% (full or partial recanalization, hemostasis, or both). A success rate of 92% in the treatment of airway obstruction and hemoptysis was reported from Crosta et al. [57], however this rate required 3.5 interventions per patient.

Possible complications include airway perforation (pneumomediastinum or pneumothorax), airway fire and damage to the bronchoscope. The incidence of these complications is less than 1%. Limitation of oxygen concentration less than 40% and keeping power settings under 80 W with application time less than 5 sec minimizes the probability of these complications. In conclusion, APC is an advisable technique for the management of hemoptysis and for removing of CAO.

Tracheobronchial stents

Tracheobronchial stents have 4 major indications in interventional pulmonology; 1) extrinsic compression from tumors or enlarged lymph nodes; 2) stabilizing the airway patency after removal of endobronchial malignancy; 3) sealing of tracheo-oesophageal fistulas; and 4) treatment of benign CAO [15,58]. Tracheobronchial stents are divided into 2 large groups: silicone and metallic stents (Figures 10-12). Metallic stents can be balloon-expandable and self-expanding. Baloon-expandable metallic stents are currently out of date and rarely used. Both types of stents have certain advantages and disadvantages, also both types of stents have specific indications and complications. Commonly used in these days are hybrid stents, made of metal wire mesh and covered with silicone [Ultraflex® (Boston scientific), Aero stent® (Alveolus)] [59,60]. Major advantages and disadvantages of both types of stents are stated in Tables 3 and 4. As shown in Table 3, silicone stents are adjustable to the airway architecture, easily removed, with no ingrowth of granu-

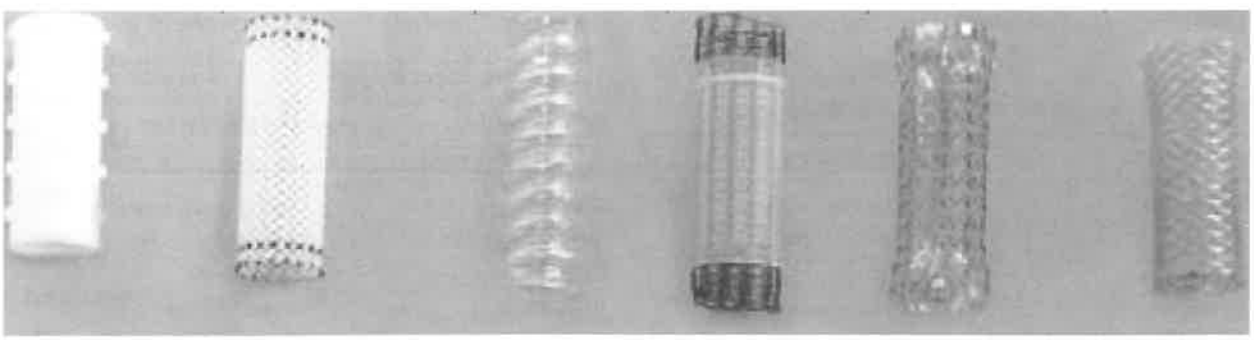


Figure 10. Silicone stents. From left: Dumon stent, Polyflex stent, Noppen stent, covered Ultraflex stent, Alveolus Aero stent and covered Wallstent.

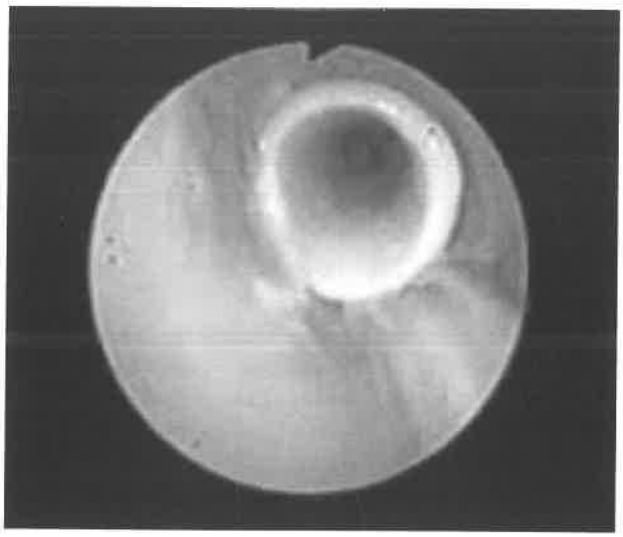


Figure 11. Silicone stent in place in the distal part of the trachea.

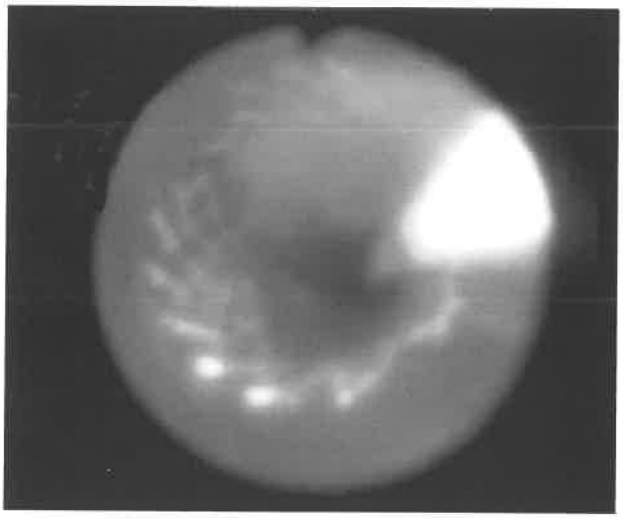


Figure 12. Metallic uncovered stent (Wallstent) in place for treatment of severe extraluminal compression (thyroid cancer compression on upper part of the trachea).

lomatous or tumor tissue, unreactive in the means of mucosa irritation, their expansion is easily controlled and they are cheaper than metallic stents. However, placement of silicone stents requires rigid bronchoscopy under general anesthesia, the placement is rather complicated, and one of the most common problems is dislocation. Some authors complain that the decreased inner diameter leads to impaired mucus clearance and formation of mucus plugs. Metallic stents (Table 4) are easily placed via flexible bronchoscope, stable in place and the position of the stent is confirmed on fluoroscopy. On the other hand, once placed, these stents are permanent, the position of the stent can not be adjusted and their removal is dangerous because it may cause perforation of the airway, serious bleeding and trauma. Confirmation of stent position requires fluoroscopy; tissue (benign or malignant) grows through the stent requiring additional resections and these stents are expensive [59]. As stated earlier there are combinations of both types of stents combining all the advantages of both groups. There are also stents like Polyflex® made of polyester wire mesh covered with silicone layer, with strong elastic recoil, but the problem of migration remains. The best solution for the treatment of obstruction with carinal involvement is Y-shaped dynamic stent. The dynamic stent has been developed by Freitag and basically it is a hybrid stent made of silicone with steel claps [60].

One of the techniques for urgent airway debulking usually precedes stent insertion in malignant and benign CAO. With laser resection, EC or APC the intraluminal component can be easily removed and stent application can follow. In such a situation one usually decides to place silicone or hybrid stent. In cases when extraluminal compression is a major component of CAO, application of metallic (covered) stent is favorable [61-63]. Benign conditions like postintubation, posttransplantation or postresection tracheal stenoses or endobronchial tuberculosis [64] are treated with silicone stents. There are reports of successful metallic stents use in the treatment of extrinsic compression in postpneumonectomy syndrome [65-67]. There are many studies confirming the effectiveness of stenting in the treatment of benign and malignant CAO, and some of the most recent studies are stated in Table 5.

Table 3. Advantages and disadvantages of silicone stents

Advantages	*Disadvantages*
Adjustable	Rigid bronchoscopy
Removable	Difficult placement
No ingrowths	Dislodgement
Unreactive	Decreased inner diameter
Controlled expansion	
Inexpensive	

Table 4. Advantages and disadvantages of metallic stents

Advantages	*Disadvantages*
Flexible bronchoscopy	Permanent
Easy delivery	Difficult adjustment
Stable placement	Need fluoroscopy
Confirmation	Granulation
Epithelization	Tumor ingrowths
Easy ventilation	Erosion
	Expensive

Table 5. Recently published studies on the effectiveness of tracheobronchial stenting

Author	*Year*	*No of patients*	*Stent material*	*Indication*	*Comment*
Eisner [68]	1999	9	Metal	Benign CAO	Pulmonary function tests improved. Median follow up 23 mo.
Noppen [69]	1999	46	Silicone	Benign and malignant CAO	Very effective in palliative treatment; in cases of benign CAO migration was more often.
Miyazava [70]	2000	34	Metal	Malignant CAO	Effective palliation of dyspnoea, improvement in QoL, mean survival 12 wks, extrinsic and intrinsic obstruction.
Vergnon [71]	2000	13	Silicone	Inoperable benign tracheal stenoses	No migration, easy removal, mean follow up 23 mo.
Vonk-Noordegraf [72]	2001	14	Mixed	Malignant CAO	Great palliative effect, mean survival 11 wks.
Wood [73]	2003	82	Metal	Mixed CAO	95% clinical success, 42% overall complication rate, 5% migration, 9% granulation, metallic stents avoided in benign CAO.
Saad [74]	2003	143	Silicone and metal	Mixed CAO	Successful extubation in 88% of patients requiring mechanical ventilation, migration in 5%.
Čanak [75]	2006	10	Silicone	80% benign, 20% malignant CAO	Significant improvement in lung function tests, relief of dyspnoea 100%, average stent placement 13.7 mo.

The largest study on silicone stenting was published by Dumon et al. in 1996 [76]; over 7 years 1574 stents were placed in 1058 patients (698 malignant and 360 benign stenoses). In 9.5% of malignant CAO cases the major complication was migration, in 8% granulomatous tissue formation appeared and secretion obstruction was seen in 15%. In the benign group of patients these rates were 15%, 18% and 8%, respectively. Other studies reported overall migration rate of silicone stents ranging from 5 - 28%. Granulomatous tissue growth was reported in 1-20% of the cases and secretion obstruction in 6-17% [58,77,78].

The ideal stent of the future should be easy to insert and remove, with low possibility of migration, rigid enough to support the airway and flexible enough for adaptation to the airway structure. It should be biologically inert to minimize granulomatous tissue formation, available in different sizes and not too expensive. There are some feasibility studies going on in order to investigate the success of tracheobronchial stents made of bioabsorbable materials. Saito et al. recently published a feasibility study of poly-L-lactic acid made stent (PLLA stent) on a dog model with satisfactory preliminary results and a conclusion that further investigation is necessary before any clinical use [79].

Conclusion

Interventional pulmonary techniques are extremely expensive and they require the presence of well-trained personnel and a variety of techniques available any moment, any time. Multidisciplinary approach is necessary for the interventional team to work properly, and appropriate facilities must be available for prompt action. That's why it is recommended that only highly specialized centers for respiratory medicine should have interventional pulmonology teams. The variability of the techniques should be synchronized with the needs of each center; at least one technique for urgent debulking must be available. It is recommended that also at least one technique with delayed effect should be implemented in the center at the same time. Guidelines for the use of interventional pulmonology techniques are published and they should be recognized, implemented and synchronized in the national pulmonary societies (or guidelines). Guidelines for training and practice of interventional pulmonology [80] and interventional pulmonology competency standards [81] are dealing with the expertise of personnel. It is also advisable to recognize and accept these guidelines in order to maintain high levels of proficiency.

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