Endobronchial Argon Plasma Coagulation for Treatment of Hemoptysis and Neoplastic Airway Obstruction*

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**Study objective:** To evaluate the usefulness of endobronchial argon plasma coagulation (APC) for the treatment of hemoptysis and neoplastic airway obstruction.

**Design:** Retrospective study.

**Setting:** Bronchoscopy unit of a university hospital.

**Patients:** A total of 60 patients with bronchogenic carcinoma (n = 43), metastatic tumors affecting the bronchi (n = 14), or benign bronchial disease (n = 3). Indications for intervention were hemoptysis (n = 31), symptomatic airway obstruction (n = 14), and both obstruction and hemoptysis (n = 25). Hemoptysis was stratified as a volume of > 200 mL/d (n = 6), > 50 to 200 mL/d (n = 23), or ≤ 50 mL/d but persistence for > 1 week (n = 27). The mean (± SD) duration of hemoptysis was 16.5 ± 16.1 days before intervention. Obstruction sites were the trachea (n = 8), mainstem bronchi (n = 21), and lobar bronchi (n = 30). In 24 cases, the patient had obstructions at multiple sites. The mean size of the pretreatment obstruction was 76 ± 24.9%.

**Interventions:** APC, a noncontact form of electrocoagulation, was performed via flexible bronchoscopy. Sixty patients underwent 70 procedures. Conscious sedation without endotracheal intubation was used in all patients except four, who were mechanically ventilated because of underlying respiratory failure.

**Measurements and results:** All patients with hemoptysis experienced a resolution of bleeding immediately after APC. Hemoptysis from treated sites did not recur during a mean follow-up duration of 97 ± 91.9 days. Patients with endoluminal airway lesions had an overall decrease in mean obstruction size to 18.4 ± 22.1%. All patients with obstructive lesions, except one who died of sepsis, experienced symptom improvement. In these patients, symptom control was maintained during a median follow-up period of 53 days (range, 18 to 321 days). There were no complications related to the procedure.

**Conclusions:** APC is effective for the treatment of endoluminal hemoptysis and airway obstruction. The procedure can be performed in an outpatient setting or at the bedside in the ICUs. APC provides a simpler, lower-risk alternative to other interventional endobronchial techniques.

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**Key words:** airway obstruction; argon plasma coagulation; bronchial neoplasms; bronchoscopy; electrocoagulation; endobronchial therapy; hemoptysis

**Abbreviations:** APC = argon plasma coagulation

Neoplastic airway invasion is common among patients with lung cancer and metastatic malignancies.1,2 These patients may present with symptoms caused by tracheobronchial tumor extension, such as dyspnea, bleeding, intractable cough, and postobstructive pneumonia. In selected cases, bronchoscopic interventions can prevent imminent death, offer clinical stability that will allow additional cancer treatment, or palliate symptoms.3 Endobronchial therapies can also be curative in some patients with early-stage malignancies4 or benign airway disease.5 Technical developments in the past 20 years have generated multiple types of bronchoscopic treatments.6–9 A significant portion of these techniques, however, have been out of the reach of most clinical bronchoscopists. High equipment costs, scarcity of...
training resources, cumbersome instrumentation, and operational safety concerns have prevented a more general utilization of these technologic advances.

Argon plasma coagulation (APC) is a form of noncontact electrocoagulation. It offers the simplicity and low cost of an electrocoagulator with the noncontact approach of an Nd-YAG laser. The noncontact feature of APC allows rapid coagulation with minimal manipulation of and mechanical trauma to the target tissue. The term plasma is used to describe an electrically conducting medium produced when the atoms in a gas become ionized. It is sometimes referred to as the fourth state of matter, distinct from the solid, liquid, and gaseous states. APC utilizes electrically conductive argon plasma as a medium to deliver high-frequency current via a flexible probe. The argon plasma flow transfers electricity between the probe and the target tissue (Fig 1). The basic APC system is composed of an argon gas source, a computer-controlled high-frequency electrosurgical generator, and the endoscopic probe (Fig 2). Tracheobronchial access is obtained by passing the probe through the working channel of the bronchoscope.

The usefulness of APC has been documented in numerous studies of hemostasis and ablation of lesions in GI endoscopy.\textsuperscript{10,11} Publications in the field of otolaryngology have reported the effectiveness of APC for the treatment of epistaxis\textsuperscript{12} and upper airway papillomatosis.\textsuperscript{13} We studied the effectiveness of APC in therapeutic bronchoscopy for patients with hemoptysis and/or symptomatic endoluminal airway obstruction. We also studied the feasibility of using this technique through the flexible bronchoscope in the bronchoscopy suite or as a bedside procedure in ICUs.

**Materials and Methods**

For this study, endobronchial therapy with APC was indicated for patients with hemoptysis or symptomatic endoluminal airway obstruction. Patients with hemoptysis were eligible for this study if they met all of the following criteria: (1) bleeding originated within the tracheobronchial tree; (2) the site of bleeding was identifiable during flexible bronchoscopy; and (3) there was an absence of coagulopathy or other medically correctable causes of hemoptysis. Patients with obstructing airway neoplasms were included in this study if they met all of the following criteria: (1) symptoms were related primarily to airway obstruction and not to systemic disease; (2) the tumor was located within the lumen of the airway; (3) the margins between tumor and normal airway were identifiable; (4) tumor length was $\geq 3.5$ cm; and (5) there was functional lung distal to the obstruction or relief of postobstructive pneumonia was feasible.

All endobronchial APC procedures were performed with a flexible bronchoscope. Except in those patients who required mechanical ventilation because of respiratory failure owing to their underlying disease, all procedures were performed transanally or transorally in the bronchoscopy suite. Local anesthesia and conscious sedation with IV midazolam and fentanyl were administered before and during the procedure. Oxygen was supplemented via nasal prongs. Pulse oximetry saturation, BP, and pulse were monitored during bronchoscopy. Patients who were receiving mechanical ventilation in the ICUs underwent endobronchial APC procedures at bedside through an oral-tracheal tube. These patients were already receiving continuous sedation with IV propofol and/or midazolam as part of critical-care sedation protocols for patients receiving mechanical ventilation.

Endobronchial APC was performed with an argon plasma coagulator unit (APC 300 and ERBOTOM ICC 200; ERBE USA Inc; Marietta, GA) via a flexible bronchoscope (model BF-1T10; Olympus America Inc; Melville, NY). Energy at 30 to 40 W and
argon flow at 1.6 L/min were applied through a 2.3-mm diameter, 220-cm length APC monopolar probe. The probe was inserted through the working channel of the bronchoscope. The target tissue was endoscopically visualized and then coagulated, and the devitalized tissue was mechanically removed with grasping forceps. Patients who had incomplete lesion debulking after one treatment or who developed evidence of endobronchial mucus plugging underwent a second bronchoscopic procedure for removal of devitalized tissue after 48 to 72 h. Additional endobronchial APC treatments were performed on patients who met study entry criteria if they developed recurrent or new airway disease. Patients who had residual or additional disease not amenable to further APC interventions were considered for other forms of local or systemic therapy. Patients who had APC treatments for benign lesions were followed up with surveillance bronchoscopy 3 months after therapy and as clinically indicated.

Patients’ demographic characteristics, underlying diagnoses, severity and duration of hemoptysis and/or dyspnea, and clinical or roentgenographic manifestations of obstruction or infection were recorded. The location of the airway lesions, the degree of obstruction, the immediate response to therapy, and any complications were documented at the completion of the endobronchial therapy session. The percentage of airway obstruction was estimated by visual comparison between the area of stenosis and the healthy proximal airway. Improvement of dyspnea after APC therapy was classified as excellent if, based on patients’ estimations, the dyspnea resolved or was at least reversed to the level of the dyspnea present before the onset of the airway obstruction. Improvement was classified as moderate if the dyspnea improved without complete resolution and the improvement was less than it existed before the onset of airway obstruction. After bronchoscopic interventions, patients’ outcomes were monitored at 24 h or roentgenographic manifestations of obstruction or infection were recorded. The location of the airway lesions, the degree of obstruction, the immediate response to therapy, and any complications were documented at the completion of the endobronchial therapy session. The percentage of airway obstruction was estimated by visual comparison between the area of stenosis and the healthy proximal airway. Improvement of dyspnea after APC therapy was classified as excellent if, based on patients’ estimations, the dyspnea resolved or was at least reversed to the level of the dyspnea present before the onset of the airway obstruction. Improvement was classified as moderate if the dyspnea improved without complete resolution and the improvement was less than it existed before the onset of airway obstruction. After bronchoscopic interventions, patients’ outcomes were monitored at 24 h and thereafter as clinically indicated (median, 22 days; range, 5 to 67 days).

**RESULTS**

From November 1998 to April 2000, 60 patients underwent 70 endobronchial APC treatments. Patients’ demographic characteristics, diagnoses, and locations of endoluminal airway lesions are shown in Table 1.

Conscious sedation without endotracheal intubation was used in all patients except four, who were receiving mechanical ventilation in the ICUs because of respiratory failure caused by their underlying disease. The first author performed all the bronchoscopic interventions. Fifty-seven treatments (81%) were conducted on ambulatory patients. These patients were discharged home on the day of the procedure after remaining in stable condition during a period of observation in the bronchoscopy recovery area. In the remaining 13 cases, the patients were hospitalized because of their primary clinical conditions. No patient was hospitalized because of the bronchoscopic intervention.

Indications for APC therapy were hemoptysis (31 patients), symptomatic endoluminal airway obstruction (14 patients), and both obstruction and hemoptysis (25 patients) (Table 2). The onset of hemoptysis occurred at a mean (± SD) of 16.5 ± 16.1 days before endobronchial intervention. Bleeding was severe (> 200 mL/d) in 6 patients, moderate (> 50 to 200 mL/d) in 23 patients, and mild (< 50 mL/d) but persistent for > 1 week in 27 patients (mean onset, 19.3 ± 14.1 days). Endoluminal airway bleeding was completely controlled in all patients immediately after APC. No recurrence of hemoptysis from a treated site was noted during a mean follow-up period of 97 ± 91.9 days. Three patients were treated with APC for a second episode of hemoptysis that originated from a new endobronchial site at 53, 87, and 101 days after the initial treatment. One patient required arterial embolization after APC for management of bleeding that originated from a peripheral lung mass beyond the reach of the bronchoscope. Except for two patients who had benign conditions, all patients with hemoptysis had malignant diseases. Bleeding from benign lesions occurred in areas of dilated vascular proliferation and bronchiectasis associated with prior external-beam irradiation.

**Table 1—Characteristics of Patients, Diagnoses, and Location of Airway Lesions**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>43</td>
</tr>
<tr>
<td>Female</td>
<td>17</td>
</tr>
<tr>
<td>Median age, yr</td>
<td>63 (range, 29–84)</td>
</tr>
<tr>
<td>Diagnoses</td>
<td></td>
</tr>
<tr>
<td>Lung cancer</td>
<td>42</td>
</tr>
<tr>
<td>Non-small cell</td>
<td></td>
</tr>
<tr>
<td>Small cell</td>
<td>1</td>
</tr>
<tr>
<td>Metastatic</td>
<td></td>
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<tr>
<td>Renal</td>
<td>12</td>
</tr>
<tr>
<td>Thyroid</td>
<td>1</td>
</tr>
<tr>
<td>Melanoma</td>
<td>1</td>
</tr>
<tr>
<td>Benign</td>
<td></td>
</tr>
<tr>
<td>Telangiectasia</td>
<td>1</td>
</tr>
<tr>
<td>Bronchiectasis</td>
<td>1</td>
</tr>
<tr>
<td>Fibrous web</td>
<td>1</td>
</tr>
<tr>
<td>Location of airway lesions†</td>
<td></td>
</tr>
<tr>
<td>Trachea</td>
<td>10</td>
</tr>
<tr>
<td>Main bronchi</td>
<td></td>
</tr>
<tr>
<td>Right mainstem</td>
<td>20</td>
</tr>
<tr>
<td>Left mainstem</td>
<td>23</td>
</tr>
<tr>
<td>Lobar bronchi</td>
<td></td>
</tr>
<tr>
<td>Right upper lobe</td>
<td>17</td>
</tr>
<tr>
<td>Bronchus intermedius</td>
<td>9</td>
</tr>
<tr>
<td>Right middle lobe</td>
<td>2</td>
</tr>
<tr>
<td>Right lower lobe</td>
<td>2</td>
</tr>
<tr>
<td>Left upper lobe</td>
<td>18</td>
</tr>
<tr>
<td>Left lower lobe</td>
<td>16</td>
</tr>
</tbody>
</table>

*Values are presented as No. of patients. †Thirty-eight patients had airway lesions at more than one location. Values include all sites of endoluminal airway obstruction and/or bleeding.
In the group of patients who had symptomatic obstruction, the endoluminal airway lesions were located in the trachea in 8 cases, in the mainstem bronchi in 21 cases, and in the lobar bronchi in 30 cases. In 24 of these cases, the patient had an obstruction at more than one site. Except for one patient who had a symptomatic bronchial web-like stenosis, all patients with bronchial obstruction had malignant disease. Patients with endoluminal masses had a pretreatment reduction of the healthy airway lumen that averaged $76 \pm 24.9\%$. Immediately after APC and mechanical debulking, the obstruction decreased an average of $26 \pm 30.5\%$. Seven patients required an additional bronchoscopic procedure for the removal of devitalized tissue 48 to 72 h after the initial APC treatment. This second intervention further decreased the overall posttreatment bronchial obstruction to a mean value of $18.4 \pm 22.1\%$ (Fig 3). There were no complications directly related to endobronchial therapy.

Symptoms improved immediately after tumor destruction in all patients except for one, a patient who was receiving mechanical ventilation who died within 48 h owing to neutropenic sepsis and underlying pneumonia. Improvement of dyspnea immediately after endobronchial tumor debulking was excellent in 37 cases (53%) and moderate in 32 cases (46%) (Fig 4). Two patients underwent a second APC intervention for mechanical debulking of recurrent endoluminal obstruction 149 and 210 days after the initial treatment. Twenty-one patients also received high-dose-rate endobronchial brachytherapy after APC for a boosting effect or ablation of the residual tumor. Relief of dyspnea related to obstruction was maintained for a median follow-up period of 53 days (range, 18 to 321 days).

**DISCUSSION**

APC has been used for > 10 years in open surgery, laparoscopy, and GI endoscopy. This is the first study (to our knowledge) that reports on the feasibility and effectiveness of APC for hemostasis and debulking of endoluminal tracheobronchial lesions through the flexible bronchoscope. The excellent safety profile, readiness of use, and relatively low

| Table 2—Indications for APC Therapy and Patients’ Manifestations of Endoluminal Airways Disease* |
|--------------------------------------------------|------------------|
| **Variables** | **Values** |
| Indications |  |
| Hemoptysis | 31 |
| Hemoptysis and obstruction | 25 |
| Obstruction | 14 |
| Clinical manifestations |  |
| Dyspnea |  |
| Severe | 9 |
| Moderate | 42 |
| Mild | 19 |
| Hemoptysis |  |
| > 20 mL/24 h | 6 |
| > 50–200 mL/24 h | 23 |
| < 50 mL/24 h | 27 |
| Pneumonia | 5 |
| Cough |  |
| Severe | 18 |
| Moderate | 43 |
| Mild | 9 |

*Values are presented as No. of patients.

Figure 3. Diagram indicating the degree of endoluminal obstruction before treatment (*left, A*) and after treatment (*right, B*). Values are presented as the mean percent reduction of the healthy airway lumen. The numbers correspond to 1 SD of the mean values.
cost make APC most suitable for therapeutic applications through the flexible bronchoscope in the outpatient setting. This study also attests to the operational simplicity and portability of equipment that allows expansion of the range of therapeutic interventions to bedside use in the ICUs. The non-contact approach offers advantages over other forms of electrocoagulation. Avoiding tissue contact and probe adhesion to friable tissues decreases the risk of bleeding. It also allows the bronchoscopist to treat a larger area very quickly.

Proper patient selection for therapy with endobronchial APC is crucial. For patients with hemoptysis, the bleeding source must be endobronchial and within the reach of the bronchoscope for APC to be effective. Patients with severe bleeding and respiratory compromise should be stabilized before any intervention. Endobronchial therapy in these patients is aimed at preventing recurrence once the acute episode of massive hemoptysis has decreased or subsided. The selection of rigid vs flexible bronchoscopy to assess or treat massive hemoptysis most likely reflects the user’s experience and the clinical circumstances. The rigid bronchoscope allows better suctioning and airway control, while the flexible bronchoscope permits easier access and visualization of distal airways.\textsuperscript{17} Flexible bronchoscopy was used in all patients enrolled in this study.

The ablation of obstructive airway lesions should be done with the purpose of regaining significant lung function or relieving postobstructive pneumonia. In the absence of postobstructive pneumonia, no benefit from endobronchial therapy will be gained if the lung distal to the obstruction is nonfunctional, for example in patients with extensive parenchymal tumor invasion or postradiation fibrosis. Patients selected for endobronchial APC should have primarily respiratory rather than systemic symptoms of widespread malignancy. Airway lesions that are most suitable for treatment with APC are those measuring \( \leq 3.5 \) cm in length. To obtain the best results, these tumors should protrude within the lumen and not extend beyond the cartilage of the airway. Ideally, the bronchoscopist would be able to identify the

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure4.png}
\caption{An example of tumor debulking using APC for the treatment of an airway obstruction in a patient with non-small cell carcinoma. \textit{Top left, A}: a pretreatment endoscopic examination shows an 80\% occlusion of the distal trachea by an endoluminal mass. This tumor originated in the right upper lobe and extended through the right mainstem bronchus into the trachea. \textit{Top right, B}: a pretreatment flow-volume loop tracing that is indicative of a severe, fixed central airway obstruction. \textit{Bottom left, C}: a complete reopening of the trachea and right mainstem bronchus immediately after APC and tumor removal. \textit{Bottom right, D}: normalization of the flow-volume loop tracing 48 h after bronchoscopic intervention.}
\end{figure}
The latter use has been reported for APC applica-
tion best suited for the removal of a tumor that may
grow over stents without damage to the stent.

Some patients may require a combination of end-
bronchial therapies. APC can be used to control
bleeding before brachytherapy or to reestablish the
adequate opening of an occluded airway for subse-
quent passage of a catheter for brachytherapy. The
electroconductive properties of APC make this tech-
nique best suited for the removal of a tumor that may
have grown over stents without damage to the stent.
The latter use has been reported for APC applica-
tions in GI endoscopy. Our study also documented
the usefulness of APC therapy for hemostasis of
bleeding associated with benign vascular proliferation
in central bronchiectasis and for the ablation of
an endoluminal web.

APC devitalizes tissue gradually by producing
temperatures that coagulate and desiccate tissue. As
the target surface becomes less electrically conduc-
tive, APC will automatically seek adjacent tissue with
less electrical resistance. This results in a homoge-
neous but limited depth of penetration (approximately
3 mm). Thus, APC offers uniform coagulation and
good protection against airway perforation. When
debulking tumors with the APC, the visible surface
of the mass is sprayed with the argon beam. This
decreases the risk of bleeding and causes a variable
degree of tumor shrinkage by dehydration. The
tumor is removed through sequential cautere
tation followed by peeling of tissue as it becomes crust-
or coagulated. Tissue is removed with a grasping for-
ceps or suction. The extraction of devitalized tissue
in large pieces is desirable to shorten the duration of
the procedure. Pieces that do not fit through the
working channel of the bronchoscope are removed
by simultaneously withdrawing the bronchoscope
with the tissue attached to the biopsy forceps.

Although the APC is a noncontact method, the
bronchoscopist must hold the tip of the probe close
to the target tissue, usually within 3 to 5 mm.
Because the current follows the path of least resis-
tance, holding the tip of the probe in proximity to
the side of the bronchial wall or the lesion will allow
current to flow laterally rather than on a straight
path. To prevent trauma to friable tissues, the tip of
the probe should be extended past the end of the
working channel of the bronchoscope only after the
target tissue has been properly identified. During
procedures performed with the patient under con-
scious sedation, the bronchoscopist also should ant-
icipate unexpected movement of the target tissue
because of the patient’s cough. Use of the APC with
a therapeutic channel bronchoscope is recom-
mended to facilitate the suction of secretions, blood,
and smoke.

The Nd-YAG laser is another noncontact thermal
device. It differs from APC in that it can generate
higher temperatures capable of tissue vaporization
and deeper penetration. In combination with rigid
bronchoscopy under general anesthesia, the Nd-
YAG laser has been the method used most often for
the rapid removal of large tumors. Although it
offers less penetration, the argon plasma beam has
the advantage of not having to follow a straight path
like the Nd-YAG laser. Because APC seeks electro-
conductive areas, it can more easily access targets
located laterally, radially, or around anatomic cor-
ners. APC also does not generate a direct thermal
reaction with airway devices that do not conduct
electricity. Thus, the risks of igniting endotracheal
tubes or other airway catheters are much lower with
APC than with the Nd-YAG laser. Similarly, the
known risk of Nd-YAG laser-induced retinal injury to
the operator and technical personnel does not exist
during APC instrumentation.

Despite the safety features of APC, care must be
taken to reduce risks inherent to any thermal device.
The APC probe should extend 0.5 to 1.0 cm beyond
the tip of the bronchoscope to avoid collateral
thermal damage to the bronchoscope. Supplemental
oxygen should be kept at the minimum safe level. In
general, maintaining inspired concentration of sup-
plemental oxygen at ≤ 40%, or intermittently reduc-
ing it to this level, is recommended during APC
application. No fires or technical complications oc-
curred during the interventions reported in this
study. There have been isolated case reports of
intestinal wall emphysema and pneumoperitoneum
after APC in GI endoscopy. Systemic air emboli-
sms have also been reported during bronchoscopic
Nd-YAG laser interventions. In our patients, we
did not observe gas exchange impairment, broncho-
pulmonary barotrauma, or clinical manifestations of
gas embolism associated with the introduction of
low-flow, inert argon gas into the airway.

Patient selection for endobronchial tumor ablation
with APC requires the understanding that the mere
presence of endobronchial disease does not in itself
constitute an indication for endobronchial therapy.
Standard surgical, medical, and radiation treatments
remain the primary therapeutic modalities for pa-
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context of multidisciplinary management of these
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context of multidisciplinary management of these
patients. Procedures such as APC that can be per-
formed in an outpatient setting or at the bedside in the ICUs augment the therapeutic options available to the clinical bronchoscopist. These techniques help to transform the traditional role of the pulmonologist from diagnostic bronchoscopist to active participant in cancer therapy within multidisciplinary programs.

REFERENCES