Malignant Central Airway Obstruction

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KEYWORDS

• Malignant central airway obstruction • Airway tumor • Bronchoscopy • Endobronchial therapy • Airway stenting

KEY POINTS

- Malignant central airway obstruction (MCAO) is obstruction of the trachea or mainstem bronchi due to a tumor.
- The primary purpose of therapeutic bronchoscopy is palliation of symptoms.
- Multiple patient characteristics need to be taken into consideration in selecting patients who may benefit from therapeutic bronchoscopy.
- There are a variety of modalities that can be used with therapeutic bronchoscopy, dependent on local resources, expertise, and patient characteristics.
- Therapeutic bronchoscopy has high rates of successful recanalization resulting in symptom and quality of life improvement.

INTRODUCTION

Malignant central airway obstruction (MCAO) is obstruction of the trachea or mainstem bronchi by a cancerous tumor. Lung cancer is responsible for 60% to 70% of MCAO but can occur with other malignancies.[1–3] An estimated 15% off all patients diagnosed with lung cancer have MCAO at presentation and 20% to 30% will develop symptomatic MCAO within a few years.[4,5] Squamous cell lung cancer is the most common histologic type.[6,7] After lung cancer, the literature varies as to the next most common cause. In the EpiGETIF registry, which included centers from France and other Francophone countries, esophageal cancer (9%), cancer of another gastrointestinal organ (2.6%), and urothelial cancer (2.2%) were the next most common.[3] In the AQuIRE registry and another mostly North American registry, breast, colon, and renal cancers were more common.[1,2] MCAO is associated with decreased survival.[4]

MCAO can be caused by direct invasion into the airway from an adjacent primary or metastatic tumor, invasion of the airway from adjacent metastatic adenopathy, focal metastasis to the airway, or primary tumors that arise in the airway. Direct invasion is the most common and typical for lung cancer. Renal cancer, colorectal cancer, breast cancer, melanoma, thyroid cancer, and others are known to metastasize to the airway.[8,9] Primary tumors of the airway include squamous cell carcinoma, adenoid cystic carcinoma, mucoepidermoid carcinoma, and carcinoid tumors.

MCAO can be categorized by how tumor compromises the airway. Intrinsic obstruction refers to tumor that involves only the airway lumen. Extrinsic obstruction describes tumor that compresses the airway from the outside. Mixed obstruction has characteristics of both. Purely extrinsic MCAO is the least common, with intrinsic and mixed obstruction representing the majority of cases.[3,7,10]

The focus of this article is on the management of MCAO with therapeutic bronchoscopy. Therapeutic bronchoscopy is considered a palliative procedure with the primary goal of improving

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Abbreviations	
APC	argon plasma coagulation
ASA	American Society of Anesthesiology
CT	computed tomography
ECOG	Eastern Cooperative Oncology Group
ETT	endotracheal tube
HDR	high-dose rate
LDR	low-dose rate
MCAO	malignant central airway obstruction
NSCLC	nonsmall cell lung cancer
PDR	pulse dose rate
PDT	photodynamic therapy
SCLC	small cell lung cancer
SEMs	self-expandable metal stents

symptoms and quality of life. Successful recanalization of the airway may also improve a patient's functional status so they can receive adjuvant antineoplastic therapies or rarely, to liberate them from mechanical ventilation. Successful bronchoscopic management of MCAO depends on patient preferences and expectations, baseline patient and tumor characteristics, physician expertise, and local resources.

CLINICAL PRESENTATION

Symptoms of MCAO depend on baseline health status, tumor location, rate of tumor growth, and degree of airway obstruction. Dyspnea is the most common symptom and thought to require narrowing of the airway diameter to greater than 50%.[11–13] In some patients who were previously asymptomatic, respiratory infection resulting in airway swelling can worsen the obstruction and lead to obstructive symptoms.

Another common symptom is noisy breath sounds. These include inspiratory stridor, biphasic stridor, wheezing, and hoarseness. The presence and character of noisy breath sounds depend on multiple factors including comorbid obstructive lung disease, mucus retention, concomitant infection, the degree of obstruction, and the location of obstruction. Clinicians should be attentive to persistent noisy breath sounds that do not improve with bronchodilator therapy or in patients who continue to present with such symptoms despite treatment of non-malignant underlying causes. In the setting of known malignancy, noisy breath sounds should prompt further investigation. Noisy breath sounds over the area of the trachea do not reliably localize the obstruction, but unilateral sounds typically indicate an obstruction below the carina.[11]

Other symptoms of MCAO may include cough, chest pain, and hemoptysis. Those with tracheal obstruction or bilateral mainstem obstruction can present with life-threatening respiratory failure.

DIAGNOSIS

Chest Imaging

Most patients will have a chest X-ray as part of initial investigation of dyspnea or noisy breathing. Chest X-ray is not sensitive for airway obstruction, but findings can include tracheal deviation, mediastinal enlargement, lymphadenopathy, or abrupt truncation of the airway.[14] Computed tomography (CT) is 93% sensitive and 100% specific for MCAO and is the preferred imaging modality.[15] Contrast-enhanced CT chest can detail the type, degree, and length of obstruction, as well as distal airway patency and involvement of adjacent structures, which are important for procedure planning.[16]

Pulmonary Function Tests

Pulmonary function tests may show decreased peak inspiratory and expiratory flows and characteristic flattening of the flow-volume loop (**Fig. 1**).[17] However, pulmonary function tests are deranged only in more advanced obstruction and should not be used in the acute setting.

Flexible Bronchoscopy

Flexible bronchoscopy can provide additional information regarding the extent of obstruction, distance from other structures, presence of patent distal airway, and allow for tissue sampling. The role of flexible bronchoscopy without a secure airway for procedural planning alone is unclear and should be considered on a per-case basis. However, when there is severe symptomatic obstruction, flexible bronchoscopy without a secure airway may precipitate respiratory failure from sedation, uncontrolled coughing, and bleeding.[14,18]

PATIENT SELECTION

Correct patient selection for therapeutic bronchoscopy is critical for success. Patients should be counseled on the expected benefits, risks, and potential long-term complications (eg, bronchomalacia, need for stent maintenance). Bronchoscopy should only be offered if the expected outcomes align with a patient's wishes. Other important factors to consider are the likelihood of technical success, the likelihood that reopening the airway will improve symptoms, and whether alternative therapies may be more appropriate (**Fig. 2**).

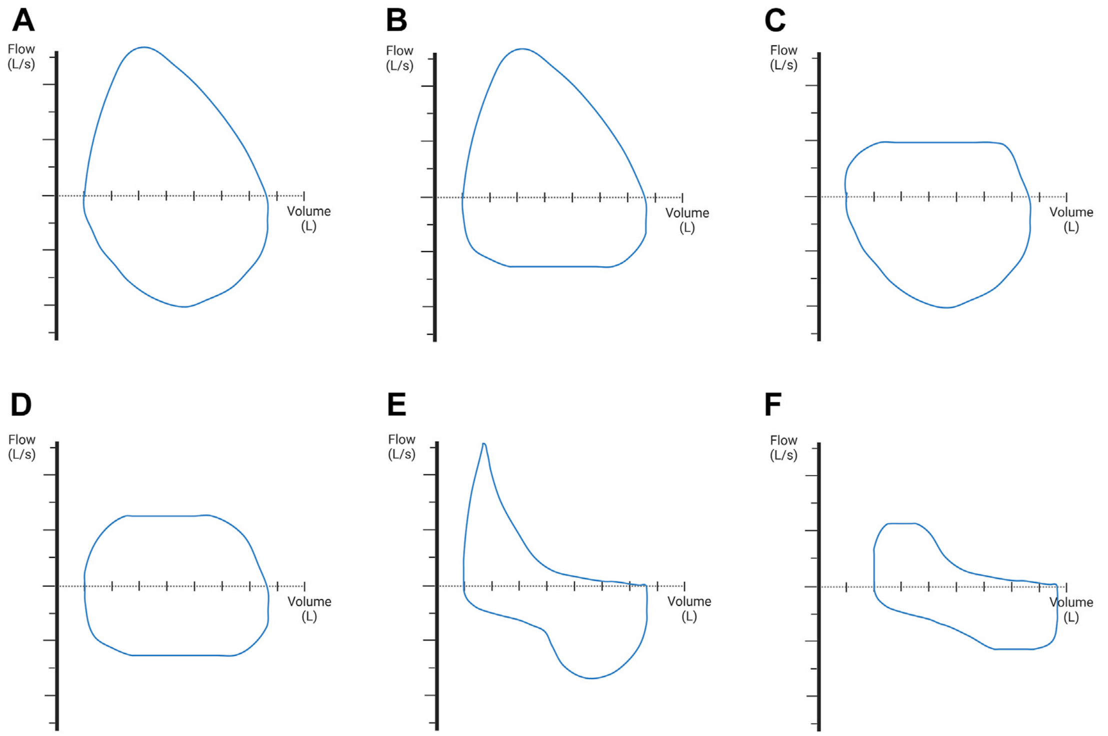

Fig. 1. Flow-volume loops for different types of central airway obstruction: (*A*) normal flow volume loop (*B*) variable extrathoracic upper airway obstruction (*C*) variable intrathoracic upper airway obstruction (*D*) fixed upper airway obstruction (*E*) unilateral mainstem obstruction (*F*) bilateral mainstem obstruction. (*Created in* BioRender. Thornton, C. (2025) https://BioRender.com/y95s892.)

Technical Feasibility

Technical success is typically defined as reopening the airway to greater than 50% of the original luminal diameter (ie, ≤50% residual stenosis).

Of the 1115 procedures recorded in the AQuIRE registry, technical success was achieved in 1039 (93%).[1] Factors independently associated with success include the presence of endobronchial tumor (odds ratio [OR] 2.62, 95% confidence interval [CI]: 1.56–4.39, *P* = .0003), placement of a stent (OR 11.90, 95% CI 5.1–27.8, *P*<.0001), American Society of Anesthesiology (ASA) score greater than 3 (OR 0.55, 95% CI: 0.33–0.9, *P* = .18), renal failure (OR 0.17, 95% CI: 0.04–0.66, *P* = .011), primary lung cancer (OR 0.45, 95% CI: 0.23–0.88,pP = .19), left mainstem disease (OR 0.51, 95% CI: 0.31–0.83, *P* = .007), and presence of a tracheoesophageal fistula (OR 0.03, 95% CI: 1.56–4.39, 95% CI 0.0003, *P*<.0001).

In the EpiGETIF registry, which included 2118 procedures, total success was achieved in 1158 (55%) and partial success in 511 (25%).[3] Total success was defined as reopening of the airway to greater than 50% and partial success was determined by the clinician in cases where significant residual obstruction remained, but the primary goal of the intervention was achieved.[3] An analysis of factors associated with technical success was not performed.

A high percentage of technical success is also reported by individual centers, ranging from 85% to 94%.[1,19] In those studies, factors associated with technical success include the degree of endobronchial obstruction (OR of success for every 10% increase in severity of obstruction 0.36, 95% CI: 0.34–0.39, *P*<.0001),[19] radiographic distal airway patency (OR 11.97, 95% CI:2.56–55.69, *P*=.002)[19] or absence of distal patency (OR 0.013, 95% CI: 0.002–0.076; *P*<.001),[20] and time from radiographic identification of MCAO to therapeutic bronchoscopy (OR 0.96 per day, 95% CI: 0.92–1.00, *P*=.048).[19]

Other factors include proximity of the obstruction to the vocal cords, carina, or lobar airways that may complicate stent insertion, length of obstruction, and the residual integrity of the involved airway and adjacent structures.

Likelihood of Symptomatic Benefit

When the chance of technical success is favorable, clinicians should also consider whether reopening the airway will lead to meaningful

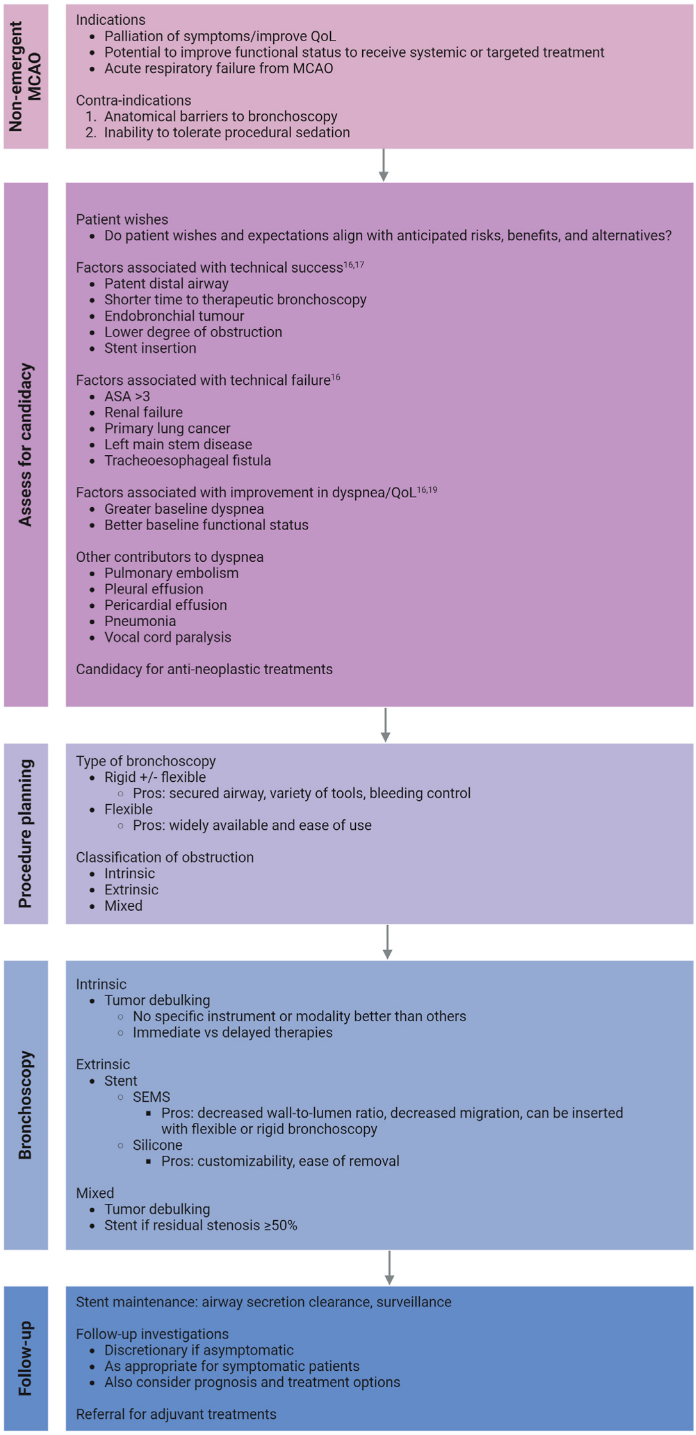

Fig. 2. Framework for management of MCAO. QoL, quality of life (*Created in* BioRender. Thornton, C. (2025) https://BioRender.com/q30w696.)

benefit in symptoms and/or quality of life. The most important factors are the degree of current dyspnea, how this compares to baseline dyspnea, and to what degree symptoms are attributable to MCAO.

In the AQuIRE registry, therapeutic bronchoscopy was associated with a mean change in Borg score of -0.9 ± 2.2, $P<.0001$.[1] Those who had more dyspnea before therapeutic bronchoscopy had greater improvement in dyspnea after intervention. For every 1 unit increase in baseline Borg score (ie, more dyspnea), there was a 0.63 unit decrease in the mean difference in Borg score (ΔBorg) before and after bronchoscopy (error 0.05, P<.0001).[1] Similarly, Ong and colleagues found a one unit increase in baseline Borg was associated with a 0.52 unit decrease in ΔBorg postprocedure at 7 days (95% CI: −0.66 to −0.40, P<.001).[21] There is overlap in patients between the AQuIRE registry and Ong and colleagues's study, but Ong and colleagues included unique patients spanning at least 16 months. In the EpiGETIF registry, the mean ΔBorg was comparatively larger in magnitude at -4.1 ± 2.1 at 48 hours postprocedure.[3]

Perfusion to the lung distal to the obstruction is also important. If the blood supply is compromised by malignant infiltration of the pulmonary artery, thrombus, or other obstruction, recanalization of the obstructed airway may lead to an increase in dead-space ventilation.

Symptoms may not improve with recanalization if there are other causes of dyspnea, such as a pleural effusion, pulmonary embolism, pericardial effusion, pneumonia, vocal cord paralysis, and others.

Antineoplastic Treatment

Bronchoscopy should be deferred if other antineoplastic treatments are more appropriate and available. In treatment-naïve patients without significant symptoms, radiation or systemic treatments may be more suitable. This is especially true for cancers with high treatment response rates, such as small cell lung cancer (SCLC).[22] In patients who have already received treatment, the likelihood that additional lines of treatment will be successful should be considered.

Radiation therapy alone can improve obstruction, with studies in lung cancer (nonsmall cell lung cancer [NSCLC] and SCLC) showing tumor response ranging from 52% to 79%, and symptomatic improvement ranging from 61% to 73%.[23,24] Nihei and colleagues included only patients with NSCLC and found 54% tumor response.[25] Two of these studies defined tumor response as radiographic improvement in obstruction[24,25] and one used the *Response Evaluation Criteria in Solid Tumors* criteria.[23] Factors associated with tumor response include the radiation biologically effective dose ≥39 Gy (P<.01) and an obstructive lesion < 6 cm (P = .04).[23] However, tumor response to radiation takes time, with 1 study showing a median time to tumor response of 24 days (range 11–44 days).[25]

CONTRAINDICATIONS

Reduced cardiopulmonary reserve may be a contraindication to general anesthesia or sedation. Anatomic barriers to intubation with a rigid bronchoscope are an absolute contraindication. These can include an unstable cervical spine, severe kyphoscoliosis, and oral/maxillofacial deformities or trauma.[26] Flexible bronchoscopy under moderate sedation should be avoided in patients at high risk for bleeding and upper airway obstruction.

Poor performance status alone is not an absolute contraindication to therapeutic bronchoscopy. However, higher Eastern Cooperative Oncology Group (ECOG) scores and higher ASA scores are associated with reduced technical success,[1] lower quality-adjusted survival,[21] cumulative survival,[12] and increased hazard of mortality.[7] Therapeutic bronchoscopy should, therefore, be offered with caution in this patient population.

TYPE OF BRONCHOSCOPY AND MANAGEMENT CONSIDERATIONS

The most common goal of therapeutic bronchoscopy is to improve quality of life by restoring airway patency. Therapeutic bronchoscopy may also improve a patient's functional status so they can receive adjuvant antineoplastic therapy and, in rare cases, liberate them from the ventilator.[27–29] Many bronchoscopic techniques are available and the choice depends on patient-level factors, tumor characteristics, local expertise, and available resources. Therapeutic bronchoscopy can be performed using a rigid bronchoscope, a flexible bronchoscope, or both.

Rigid bronchoscopy with or without flexible bronchoscopy is advantageous because the airway is secured with the rigid bronchoscope, mechanical ventilation occurs directly through the bronchoscope during debulking or stent insertion,[30,31] is compatible with the greatest number of therapeutic instruments, and allows for greater control of bleeding (increased suction capacity, ability to tamponade bleeding with the scope, ease of inserting an endobronchial blocker).

Flexible bronchoscopy alone is more widely available and can be performed in a mechanically ventilated patient with a secure airway (endotracheal tube or laryngeal mask airway) or in a spontaneously breathing patient under moderate sedation. Debulking instruments are limited to those that fit the working channel of the bronchoscope and silicone stents cannot be placed.[31] Insertion of metallic stents may also be limited by the size of the deployment catheter and the diameter of the endotracheal tube or other airway. Compared with a rigid bronchoscope, the flexible bronchoscope obstructs ventilation when inside the airway. When performed without a secure airway, physicians need to be mindful of the potential loss of airway control and select cases with low risk of bleeding and respiratory failure. In the AQuIRE registry, only 14% of patients had a therapeutic procedure with flexible bronchoscopy under moderate sedation.[1] Patients had similar outcomes to those that underwent rigid bronchoscopy, but presumably, were carefully selected.[1]

Additional planning should include procedure timing, location, need for hospital admission, and consultation with other specialist services, as necessary. Procedures should be performed as soon as safe since the odds of success are improved the shorter the duration between radiographic diagnosis of MCAO and therapeutic bronchoscopy.[19,21] It is unlikely that performing the procedure in an operating room versus an endoscopy suite will result in different outcomes, so long as the appropriate equipment and expertise are available. In the AQuIRE registry, 33% of procedures were performed as inpatients with outcomes similar between inpatients and outpatients.[1]

Reopening the airway may require tumor debulking, airway dilation, stent placement, or a combination of these. The type of MCAO provides information on which treatments are likely necessary. For extrinsic compression, dilation and stenting are favored. For intrinsic obstruction, tumor debulking alone may be sufficient. Mixed obstruction usually requires a combination of techniques depending on the results of debulking and residual extrinsic compression.

ENDOLUMINAL THERAPIES

There are many bronchoscopic modalities available to manage the many types of MCAO (**Fig. 3**). However, there is a lack of randomized control trials comparing modalities due to the nature of MCAO. Registry data and single center studies suggest that no specific modality is superior but that high rates of technical success are achieved when patients are carefully selected and when the procedure is performed by experienced operators.[1,3,19]

Endoluminal therapies can be broadly divided into mechanical therapies and ablative therapies. Ablative therapies may provide immediate or delayed effects. Delayed-effect ablative therapies should only be offered when the risk of critical airway stenosis is low and sufficient time is available for delayed-effect therapies to take effect. In practice, a combination of 2 or more therapies is common.

Mechanical Debulking

Tumors can be debulked mechanically using the rigid scope itself, specialized debridement tools, forceps, rigid suction catheters, or other instruments. Mechanical debulking can remove large amounts of tumor in a short amount of time and can be done at high oxygen concentrations. The rigid bronchoscope has a beveled leading end that can be used to core out the tumor by applying forward pressure and gently twisting the barrel of the bronchoscope. The specialized microdebrider is a long hollow metal tube with a small rotating blade coupled with suction and saline irrigation. The suction evacuates blood and debris during debridement, which maintains visualization, and the saline keeps the suction channel clear.[32] Allowing the suction to suck loose tumor into the blades also decreases the risk of damaging normal airway. The largest retrospective review of microdebrider in combination with other therapies for MCAO reported high rates of technical success and no major complications.[33] In the EpiGETIF registry, 67% of patients had some form of mechanical debulking with or without other therapies.[3]

Ablative Therapies

Heat denatures protein and evaporates cellular water leading to a spectrum of tissue injury from coagulation (>60–80°C) to desiccation (>100°C) to carbonization (>200°) to vaporization (>300°C), depending on the modality and technique.[34] Cold leads to cell death by ice crystal damage, local vasoconstriction causing ischemia, and immune-mediated pathways.[35] **Table 1** summarizes available tumor ablative therapies.

Any ablative therapies that result in an open spark or flame require low FiO_2 during ventilation to prevent airway fire. However, the FiO_2 below which ablative therapies are safe is not known. Two animal studies found no flame with electrocautery with an FiO_2 less than 50%.[36,37] In our experience, temporarily holding ventilation to wash out excess O2 or reducing the FiO_2 on the ventilator to less than 40% are the most common approaches. Electrocautery and argon plasma coagulation (APC) can interfere with pacemakers/defibrillators. APC and cryotherapy can also cause air embolisms.[38,39]

Ablative Therapies with Immediate Effect

Electrocautery

Electrocautery uses an electric current to generate heat and cause tissue destruction. There are multiple tools through which electrocautery can be applied, including a simple probe, a hollow probe with suction, wire snare, knife or filament, and forceps. In the largest retrospective study where electrocautery was used as the primary ablative

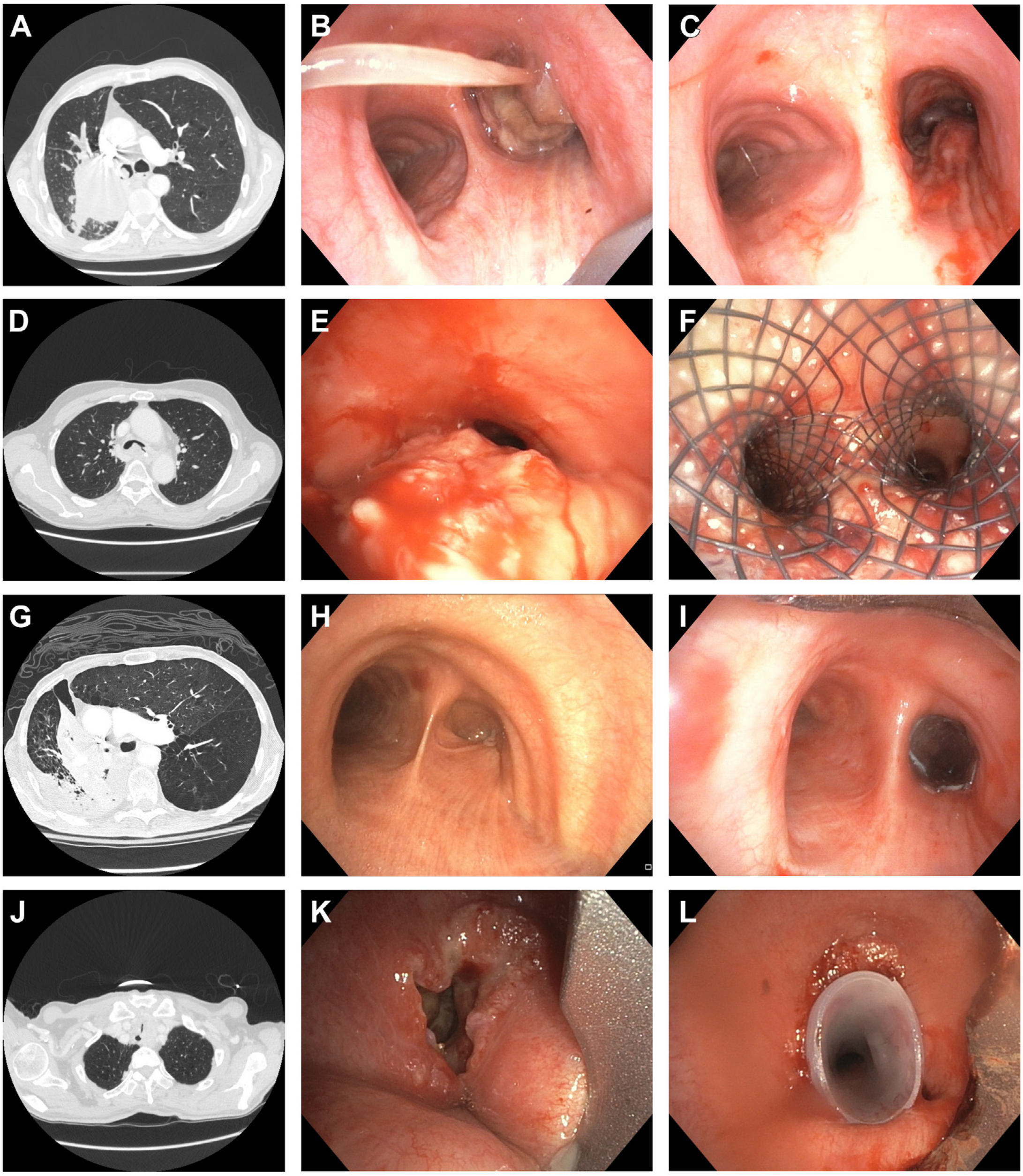

Fig. 3. MCAO preintervention and postintervention: (*A*) endoluminal tumor in the right mainstem bronchus seen on chest CT (*B*) bronchoscopy (*C*) the tumor was removed using a microdebrider and the tumor base treated with APC; (*D*) mixed obstruction of the trachea with a bronchoesophageal fistula seen on CT chest (*E*) bronchoscopy (*F*) improvement after SEMS Y stent; (*G*) extrinsic compression of the right mainstem bronchus seen on CT chest (*H*) bronchoscopy (*I*) improvement after balloon dilation then SEMS stent insertion; (*J*) mixed obstruction of the trachea seen on CT chest (*K*) bronchoscopy (*L*) improvement after silicone stent insertion. (*Created in* BioRender. Thornton, C. (2025) https://BioRender.com/e80c288.)

therapy, technically success was achieved in 94% without any major complications.[40]

Argon plasma coagulation

Argon plasma coagulation is a noncontact form of electrocoagulation, where electric current flows through ionized argon gas ejected from the catheter tip toward tissue with the lowest electrical resistance (ie, tissue with a high water content). APC is flexible and provides excellent superficial coagulation, making it useful for hemostasis and debulking vascular lesions. However, cycles of

Table 1
Properties of ablative therapies

	Tissue Penetration	Hemostasis/ Coagulation	Settings	Advantages	Disadvantages	Safety Considerations
Electrocautery	• 1-2 mm, variable depending on application duration	• Yes	• 10–40W, <5s per pulse	• Cost friendly • Easy to use	• Repeated cleaning • Perforation • Airway fire	• FiO_2 <40% • Interference with PM/defibrillator
APC	• 2-3 mm	• Yes, highly effective	• Gas flow 0.3–0.8LPM, 10–30W	• Good for airways with acute angles	• Slow debulking • Perforation • Air embolism • Airway fire	• FiO_2 <40% • Interference with PM/defibrillator
Laser	• Varies depending on specific laser, up to 10 mm	• Yes, highly effective	• 20–40W, 0.5-1s	• Efficient for de-bulking and coagulation	• Difficult in airways with acute angulation • Perforation • Air embolism • Airway fire • Cost	• FiO_2 <40% • Eye protection
Cryotherapy	• 2-3 mm	• No	• Universal, duration variable	• Low perforation risk • no O2 limitations	• Bleeding risk • Air embolism	• May require serial bronchoscopy for removal of sloughed tissue • Cryospray: passive venting during cryospray
PDT	• 5–10 mm	• Yes	• 100–200 J/cm^2	• Low procedure risk	• Delayed effect • Fistula • Skin photosensitivity • Cost	• May require serial bronchoscopy for removal of sloughed tissue
Brachytherapy	• Depending on dosage	• No		• effective	• Delayed effect • Hemorrhage • Radiation bronchitis • Airway stenosis • Fistula • Cost	

coagulation and debridement are onerous, given the shallow depth of penetration, and make APC alone a poor choice for tumor debulking. One retrospective study of endobronchial lesions managed with APC and mechanical debulking found good success with 99% of patients reporting improvement in dyspnea.[41] A rare but dangerous complication from APC is an air embolism, which can occur when there is prolonged release of argon gas directly into a vessel.[38,42] Avoiding activation of APC when the catheter tip is not visualized and limiting activation time to a few seconds substantially reduces this risk.

Laser

Laser, light amplification by simulated emission of radiation, destroys tissue when the light energy is converted to thermal energy in the tissue. There are multiple types of lasers: Nd:YAG, Nd:YAP, CO2, KTP, and holmium:YAG, each with their own advantages and disadvantages.[43] The effect of laser on tissue also depends on the distance of the laser from the tissue and the duration of laser activation, with closer range and longer activation resulting in increased thermal injury and depth of penetration.[43] Like APC, laser is effective for hemostasis but is comparatively more effective for tumor ablation given its deeper penetration. The ideal lesions for laser are shorter tumors with visible distal lumen and centrally located.[44] The laser should be directed parallel to the airway wall to decrease the risk of incidental damage to deeper structures, especially vessels. The largest retrospective study of Nd:YAG laser resection reported a 93% success rate and 2.3% complication rate.[44]

Cryotherapy

Cryotherapy uses extreme cold to cause tissue trauma, both immediate and delayed. There are 2 commercialized forms of cryotherapy, the cryoprobe and cryospray. With the cryoprobe, a frozen tip contacts and adheres to the tumor, which is then pulled off piece meal. Maiwand and colleagues reported symptomatic improvement in 86% of patients where cryoprobe was the main modality for recanalization, with a complication rate of 3.5%.[45] With cryospray, liquid nitrogen is applied to the tumor in a noncontact fashion. This causes flash freezing in which ice crystals cause immediate and delayed cell death.[35] Cryospray may cause barotrauma and air embolism due to rapidly expanding nitrogen gas.[39,46] Due to the potential for delayed cell death, repeat bronchoscopy may be required to remove slough. A small retrospective multicenter study demonstrated 99% recanalization with cryospray and mechanical debridement in a cohort with high ASA scores.[46] The complication rate was 19.3%, although most complications were minor.[46] A more recent single center study reported fewer complications (3.8%), believed to result from adequate venting of nitrogen gas.[47]

Ablative Therapies with Delayed Effect

Photodynamic therapy

Photodynamic therapy (PDT) starts with injection of a photosensitizing agent that is preferentially absorbed by malignant cells. After 48 to 72 hours, a light source is placed adjacent to the tumor, which for MCAO would be applied bronchoscopically. The light source is of a specific wavelength that activates the photosensitizing agent, which causes cell death from the release of oxygen free radicals. As with cryotherapy, repeat bronchoscopy is recommended to manage sloughing. One retrospective study demonstrated 81% recanalization and 74% symptom improvement with PDT.[48] Photosensitivity is a complication, with 3% of patients developing skin burns in 1 retrospective study; so, patients need to avoid sun exposure.[48]

Brachytherapy

Brachytherapy requires insertion of a catheter into the airway just distal to the tumor and advancing radioactive seeds. The catheter must be temporarily fixed to allow radiation delivery over time. Once treatments are completed, the catheter and seeds are removed. There are 3 types of brachytherapy, low-dose rate (LDR), high-dose rate (HDR), and pulse dose rate (PDR). LDR delivers a low hourly dose given over days and thus patients require hospitalization and significant radiation precautions, whereas HDR delivers higher hourly doses given in shorter, recurrent sessions. Benefits are usually seen between 1 and 3 weeks posttreatment. An advantage of brachytherapy is the ability to target lesions in the distal or upper lobe airways that may not be amenable to other therapies. A retrospective study that compared LDR to HDR at a single institution found a comparable clinical response (72% vs 85%, $P>.05$). Complications include radiation bronchitis, bronchial stenosis, and catheter displacement during the procedure.[49]

Airway dilation

Dilation of the airway can be done via rigid bronchoscopy or flexible bronchoscopy. With a rigid bronchoscope, advancing the bronchoscope past the obstruction dilates the obstruction and can tamponade bleeding at the same time. Different barrel diameters can be used with some rigid bronchoscopy sets to dilate to a larger size. With flexible bronchoscopy, a balloon can dilate the airway (balloon bronchoplasty). Airway dilation can be performed alone or before stent deployment to dilate the airway to the desired size. Dilation balloons can also be used to fully dilate a metal stent after deployment, but this is not always necessary with self-expanding stents.

STENTS

Airway stents can also be used alone or in combination with other techniques. Stents can be helpful in several clinical scenarios. They can be used to join healthy airway through a malignant stricture, support severely damaged or diseased airways, or be used prophylactically to prevent critical stenosis before radiation.[50] In AQuIRE, stents were placed in 39% of procedures, and in 54% of patients in EpiGETIF.[1,3] Stents are most useful when there is pure extrinsic compression or when there is residual extrinsic compression after tumor debulking in mixed obstruction. While the incidence of radiation induced laryngeal edema is common (44%),[51] tracheal edema after radiation is rare, with description limited to case reports.[52] Nevertheless, prophylactic stenting may still be offered since the potential consequences of postradiation airway edema can be life threatening.

Sizing

If the decision is made to place a stent, both the size (length and diameter) and type are important. There are multiple methods to estimate an appropriate stent size. The most common are measurements made from the chest CT and measurements made during bronchoscopy. Other options include sizing devices, balloon dilators, the diameter of obstruction compared with the diameter of the bronchoscope, rigid forceps, and visual estimation by an expert.[53] Ideally, the length of the stent should be 5 mm longer than the obstruction at each end. The stent should be of an adequate diameter to minimize migration and apply sufficient radial pressure to withstand extrinsic compression, but not an excess of pressure to affect microcirculation and tissue integrity. Oversized stents may also buckle or fold in the airway, limiting their effectiveness.

Silicone Stents

Silicone stents can be customized by cutting, stitching, or ordering customized stents from vendors. They are easy to remove should the stent no longer be needed or due to a complication. Disadvantages include the increased wall-to-lumen ratio (ie, decreased inner diameter) and need for insertion with a rigid bronchoscope. Compared to metal stents, they apply less radial pressure resulting in a greater tendency to migrate.[54]

Self-expandable Metal Stents

Self-expandable metal stents (SEMSs) are available uncovered and covered. The metal knitting is made of nitinol, a nickel titanium alloy that expands with body temperature. They can be inserted over a guide-wire with flexible bronchoscopy and fluoroscopy, or under direct visualization through a rigid bronchoscopy. Uncovered SEMSs are not recommended for malignant airway obstruction because tumor will grow into the stent. Covered SEMSs apply less radial pressure to the airway compared to uncovered SEMSs.[54] Some SEMSs have the metal knitting on the outside (Micro-Tech, Nanjing Co., China), others have short, uncovered segments on the ends (Ultraflex, Boston Scientific, Natick, MA, USA) designed to further reduce migration, though may make removal more challenging.

Y Stents

Y-stents come in both silicone and SEMS forms. The main indication is obstruction near the carina. Sizing of a Y stent is more complex, since the lengths and diameters of the tracheal limb and bilateral mainstem bronchi must all be considered.

Outcomes with Airway Stents

For extrinsic compression, stents have consistently been demonstrated to improve symptoms and quality of life. A large retrospective review of patients who had stents for central airway obstruction demonstrated symptom improvement in 95% of patients.[55] Another retrospective study of 72 patients found a significant improvement in Medical Research Council (MRC) dyspnea scale from 4.40 to 3.29 postoperatively (P<.01) and ECOG from 3.36 to 2.32 postoperatively (P<.01).[13] In the setting of intrinsic obstruction after tumor debulking, Dutau and colleagues demonstrated that silicone stents maintain benefits for dyspnea and obstruction recurrence over 1 year (HR 0.32, 95% CI: 0.14–0.75, P = .005), but have no effect on quality of life.[56]

Complications from Stents

Although stents provide an attractive option for maintaining airway patency, they are not without risk. Between 30% and 60% of patients develop symptoms or a complication directly related to their stent.[55,57,58] Most complications will occur within 3 months of placement.[57] These include cough, stent migration, tumor ingrowth, proliferation of granulation tissue that obstructs the ends of the stent, mucus plugging, infection, and halitosis. Airway perforation is described but rare, with 1 retrospective study of 309 stent insertions reporting an incidence of 1%.[55]

Airway Secretion Clearance

After stent insertion, patients require a regimen to optimize airway clearance because stents interrupt mucociliary transport by covering the airway surface. There is a lack of standardized recommendations for airway clearance regimens but nebulized solutions and mucolytics are prescribed most often. Popular nebulized solutions include 0.9% normal saline, 3% or 7% hypertonic saline, N-acetylcysteine, and bronchodilator nebules. Mucolytics can be also taken orally.[53,59]

Stent Surveillance and Removal

There is also no consensus on fixed surveillance intervals after insertion or stent revision/replacement protocols. Follow-up investigations with chest imaging and/or flexible bronchoscopy are usually performed on a per-case basis and depend on patient preferences, symptoms, fitness for additional procedures, prognosis, and others. Patients who are asymptomatic may not require specific investigations.[59]

In the case of decreased obstruction due to antineoplastic therapy, intolerability, infection, or other indication, stents can be removed. Removal of silicone stents requires reinsertion of a rigid bronchoscope. Removal of SEMS can be done with a flexible bronchoscope but should be done with an endotracheal tube (ETT) on mechanical ventilation.

EMERGENCY MANAGEMENT OF CRITICAL MALIGNANT CENTRAL AIRWAY OBSTRUCTION

When patients present with acute respiratory failure from MCAO, the standard approach to any respiratory failure should be taken. In patients with advanced cancer, their preferences for aggressive interventions should be clearly understood. Early involvement of appropriate specialists, such as critical care, anesthesiology, interventional pulmonology, thoracic surgery, and otolaryngology is recommended.

Heliox is a helium oxygen mixture with a lower density than ambient air. Breathing Heliox can improve laminar flow of air through the airways and thus decrease work of breathing and dyspnea.[60] However, the ratio of helium to oxygen in Heliox 80:20 is similar to ambient air and may not be appropriate for hypoxic patients. Heliox 60:40 has a greater percentage of oxygen but at the price of increased density. Heliox is best suited for patients with airway obstruction and hypercarbic respiratory failure to help with ventilation and dyspnea.[61]

There is insufficient evidence to know whether steroids for MCAO are helpful. Theoretically, steroids decrease peritumoral edema and thus the degree of airway obstruction. A case series of 3 patients with MCAO showed improvement in stridor with a short course of IV corticosteroids.[62] However, steroids should be considered only as an adjunctive therapy.

For impending respiratory failure, the airway should be secured. Options include an ETT, surgical airway, or rigid bronchoscopy. Tracheostomy or cricothyrotomy may be appropriate for very proximal tracheal lesions[63] An ETT can be placed when tumors are more distal and allows time for further investigations and expert consultation. When intubating for MCAO, excessive sedation and muscle relaxant may result in critical hypoxia/hypercapnea and should be used cautiously.[64] Additional considerations include intubating with the patient seated upright and using videoscopic assistance. In some circumstances, a small diameter ETT can pass a proximal tracheal obstruction without causing excessive trauma and allow for ventilation. Rigid bronchoscopy has the benefit of both securing the airway and allowing for therapeutic intervention. When available, rigid bronchoscopy has been recommended as first-line treatment in those with critical airway compromise from MCAO.[14,30]

COMPLICATIONS

Complications from therapeutic bronchoscopy include pneumothorax, pneumomediastinum, infection, bleeding, hypoxia, and death. However, major complications are uncommon. The complication rate in the AQuIRE registry was 4% and there was significant variability across centers (0.9%–11.7%, $P = .002$).[65] In the EpiGETIF registry, 11% of patients had a complication, with about half of all complications Calvien-Dindo grade 3 or higher.[3] Therapeutic bronchoscopy related mortality is reported between 0.5% and 1%.[7,65] An increased risk of complications has been associated with the use of moderate sedation, high ASA, urgent/emergent bronchoscopy, and repeat therapeutic bronchoscopy.[65]

OUTCOMES

Dyspnea and Health-Related Quality of Life

Therapeutic bronchoscopy has been shown to improve both dyspnea and health-related quality of life. In the AQuIRE registry the mean ΔBorg was -0.9 ± 2.2 and the mean Δutility was 0.023 ± 0.107 utiles. A prospective study of 102 patients, of which a subset were also part of the AQuIRE registry, found a mean ΔBorg at 7 days of -1.8 (95%CI: -2.2 - -1.3, $P<.0001$) and HRQOL mean Δutility at 7 days of 0.047 utiles (95%CI: 0.023–0.071, P = .0002).[21] In a study by Mohan and colleagues,[66] 65 patients with symptomatic MCAO underwent 83 interventional procedures with therapeutic bronchoscopy. The median baseline dyspnea, measured on the visual analog scale, improved from 7.5 at baseline to 2.6 at 48 hours, 1.4 at 4 weeks, and 1.0 at 12 weeks, $P<.01$. The median total St. George's Respiratory Questionnaire improved from 69.4 ± 16.5 at baseline to 40.0 ± 13.9 at 48 hours, 30.7 ± 14.1 at 4 weeks, and 26.1 ± 11.7 at 12 weeks, $P<.01$. Another prospective study of 34 patients with MCAO who underwent bronchoscopy found an improvement in dyspnea and quality of life using the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire.[67] The mean baseline dyspnea improved from 79 ± 26 to 35 ± 34 at 1 week, and 39 ± 39 at 15 months ($P<.05$). The mean global heath score improved from 42 ± 28 at baseline to 64 ± 18 at 1 week, and 57 ± 26 at 3 months ($P<.05$). Worse dyspnea at baseline is associated with a greater improvement in dyspnea after bronchoscopy.[1,21]

Bridge to Adjuvant Therapies

Per the American Cancer Society of Clinical Oncology guidelines, systemic and targeted therapies should not be offered to patients with ECOG performance status of ≥3.[68] In select patients, restoration of airway patency with therapeutic bronchoscopy may result in sufficient improvement in functional status to be eligible for systemic or targeted therapy. Overall, 45% to 80% of patients who undergo therapeutic bronchoscopy are well enough to undergo additional therapy.[7,9,20,69–71] The largest retrospective study included 224 patients with MCAO who were treatment naïve and found that 69% received adjuvant therapies after therapeutic bronchoscopy.[7] However, for most studies, it is not clear whether pateints were eligible for treatment before they had bronchoscopy. More convincingly, Lee at al. found a significant improvement in ECOG performance score after therapeutic bronchoscopy regardless of baseline performance status ($P<.00001$).[27] In that study, 27/77 (35%) patients had a baseline ECOG performance score of ≥3 and 70% of those patients improved sufficiently to receive treatment.[27]

Liberation from Mechanical Ventilation

Data from single centers with small numbers of patients suggest that in select patients intubated for acute respiratory failure secondary to MCAO, therapeutic bronchoscopy may liberate them from mechanical ventilation and result in meaningful improvement in survival. For example, Murgu and colleagues reported on 12 patients intubated with inoperable MCAO from NSCLC, where rigid bronchoscopy restored airway patency in 11 (91%) and resulted in liberation from mechanical ventilation in 9 (75%).[28] The median survival for all 12 patients was 228 days (range 6–227) and 313 days (6–927) for the 9 who came off ventilation.[28]

Survival

Median survival after therapeutic bronchoscopy is measured in months, with the majority of retrospective studies showing a median survival between 3 and 8 months[7,9,20,58,69,71,72] and a 1 year survival of 30% to 40%.[7,9,72] Factors associated with improved overall survival after therapeutic bronchoscopy include intrinsic MCAO,[7,9,21] lower baseline ECOG,[7,21] naïve to prior radiation or systemic antineoplastic treatments,[7,21,70,71] and receiving adjuvant antineoplastic treatments.[7,9,21,70,71] This highlights the somewhat indirect effect bronchoscopy can have on survival compared with other antineoplastic therapies. For example, Chhajed and colleagues found that patients with NSCLC and MCAO who underwent therapeutic bronchoscopy and adjuvant chemotherapy had similar survival compared to those with advanced and inoperable NSCLC without MCAO.[10]

SUMMARY

MCAO may present with a variety of symptoms, including life-threatening respiratory failure. Therapeutic bronchoscopy can be performed with rigid bronchoscopy and/or flexible bronchoscopy. There are multiple bronchoscopic instruments and techniques available, including mechanical debulking, ablative therapies, and stents. The use of these therapies is dependent on availability, operator experience, and patient characteristics. When selected appropriately, therapeutic bronchoscopy improves symptoms and quality of life and can help bridge patients to antineoplastic therapies that can improve survival.

CLINICS CARE POINTS

- In select patients, therapeutic bronchoscopy can improve dyspnea, improve quality of life, and provide a bridge to adjuvant antineoplastic therapies that can improve survival.
- It is important to identify other potential causes of symptoms such as pleural effusion, pulmonary embolism, pericardial effusion, infection, pulmonary edema, and vocal cord paralysis.
- Patients who are more symptomatic, have a good performance status, and are naïve to antineoplastic treatments are the most likely to benefit from therapeutic bronchoscopy.
- CT imaging is essential for the diagnosis of MCAO and procedure planning.
- Factors associated with improved technical success include placement of a stent, intrinsic compression, radiographic distal airway patency, and a shorter time from radiographic identification of MCAO to therapeutic bronchoscopy.
- Factors associated with reduced technical success include a greater degree of obstruction, renal failure, lung cancer, American Society of Anesthesiology score greater than 3, left mainstem disease, and the presence of a tracheoesophageal fistula.
- Tumor debulking can be performed using a variety of instruments and techniques with similar success, so long as they are performed by an experienced operator.
- Stents are most helpful in patients with extrinsic MCAO.

DISCLOSURE

The authors have no conflicts of interest to disclose.

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