Safety and Clinical Utility of Flexible Bronchoscopic Cryoextraction in Patients With Non-neoplasm Tracheobronchial Obstruction

A Retrospective Chart Review

Narin Sriratanaviriyakul, MD,†‡ Francis Lam, MD,†‡*
Brian M. Morrissey, MD,†‡ Nicholas Stollenwerk, MD,*†‡*
Michael Schivo, MD,†‡ and Ken Y. Yoneda, MD*†‡*

Background: **Airway obstruction from blood clots, airway secretions, and foreign bodies is a potentially life-threatening condition. Optimal management of this problem, whether by rigid or flexible bronchoscopy, has not been well studied. We report our single-center experience on the safety and clinical utility of cryoprobe extraction for this indication.**

Methods: **We performed a retrospective chart review from January 2006 to November 2014 of all subjects aged 18 and older who underwent flexible bronchoscopic cryoprobe extraction. Subjects with obstruction due to benign or malignant neoplasm or airway stenosis were excluded.**

Results: **A total of 38 cryotherapy sessions performed on 30 subjects were identified for inclusion. Cryoprobe extraction was successful in reestablishing airway patency in 32/38 (84%) sessions overall and in 24/26 (92%) for blood clots, 4/6 (67%) for mucous plugging, 2/4 (50%) for foreign bodies, and 2/2 (100%) for plastic bronchitis. Twenty-one of 31 (68%) sessions resulted in improvement in oxygenation or ventilation. There was 1 complication related to sedation.**

Conclusions: **We conclude that flexible bronchoscopic cryoprobe extraction of blood clots, mucous secretions, plastic bronchitis, and foreign bodies is a safe and effective option. It can be safely performed at the bedside and in many cases eliminates the need for rigid bronchoscopy.**

Key Words: cryoprobe, airway obstruction, bronchoscopy, foreign body, blood clot

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Acute airway obstruction from blood clots, airway secretions, or foreign bodies is a potentially emergent, life-threatening condition. Initial efforts at removal of blood clots and airway secretions may involve lavage, suction, baskets, and forceps extraction through a flexible bronchoscope. If unsuccessful, further management options include rigid bronchoscopy, balloon catheter dislodgment, and topical thrombolytic agents.[1–4] Nevertheless, tenacious airway secretions, and in particular blood clots, can be painstakingly difficult and time consuming to remove by any means. Furthermore, many of these patients require mechanical ventilation and monitoring in the intensive care unit, and conversion to a rigid bronchoscope and transfer to the operating room can be problematic. Relief of the obstruction should be accomplished in a safe and efficient manner. Unfortunately, there have been no prospective studies comparing the various methods and no prospective studies comparing rigid to flexible bronchoscopy for these purposes. Therefore, the decision on how to proceed is typically based on individual and institutional experience and practice. Although case series and institutional reviews of these various techniques have been published, the existing data on cryoextraction of blood clots, airway secretions, or foreign bodies are extremely limited.

The cryotherapy probe is an effective tool used by both interventional and general pulmonologists. This technique uses a compressed gas cryogen or

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From the *Division of Pulmonary, Critical Care, and Sleep Medicine; †Department of Internal Medicine, University of California, Davis, Sacramento; and ‡VA Northern California Health Care System, Mather, CA.
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Reprints: Narin Sriratanaviriyakul, MD, Department of Internal Medicine, University of California, Davis, 4150V Street, Suite 3100, Sacramento, CA 95817 (e-mail: dr.narin.s@gmail.com).

coolant (usually nitrous oxide or carbon dioxide) that is delivered under pressure through a specifically designed catheter, to the cryoprobe tip where it cools the metal tip to approximately −89°C. Direct contact with the cryoprobe tip freezes the liquid component of blood clots, airway secretions, and foreign bodies. Cryoadherence occurs, allowing for extraction times of a few seconds.[5] The catheter can be passed through a flexible bronchoscope, a rigid bronchoscope, or a combination of the 2. It has many potential clinical applications: management of endobronchial obstruction due to benign or malignant tumors,[6] tissue sampling for endobronchial tumor,[7] and tissue sampling in interstitial lung disease[8] or lung transplantation.[9] Case reports of endobronchial blood clot and foreign body extraction using a cryoprobe have been published.[5,10–14] The cryoprobe may have an additional beneficial hemostatic effect through vasoconstriction; however, evidence supporting this effect is limited.

Despite the limited publications supporting its use, cryoextraction has been proposed as the treatment of choice for removal of blood clots from the tracheobronchial tree.[5] To better define its role, we performed a systematic, retrospective, single-institution review on the clinical utility and safety of bronchoscopic cryoextraction of blood clots, airway secretions, and foreign bodies.

PATIENTS AND METHODS

Subjects

The protocol for this clinical study was approved by University of California, Davis Medical Center, Sacramento, CA (IRB # 601340-1). Written informed consent was waived in this study as the data were analyzed in a de-identified manner. Subjects were identified by a retrospective chart review covering January 2006 to November 2014 of all subjects aged 18 and older who underwent flexible bronchoscopic cryoextraction. Patients with obstruction due to benign or malignant neoplasm or airway stenosis were excluded.

Bronchoscopy

All bronchoscopies were performed by pulmonary attendings or fellows following standard institutional operating and monitoring procedures. Patients were administered intravenous sedation by certified registered nurses under the direction of a pulmonologist. One of 2 cryoprobes of either 2.4 or 1.9 mm outer diameter and a length of 90 cm each (ERB USA Inc.; Marietta, GA) was used for all procedures. The bronchoscopes used with the smaller diameter cryoprobe had a working channel of 2 or 3 mm (BF-P180 or BF-1T180; Olympus America, Melville, NY). The cryoprobe with the larger diameter was always used with the bronchoscope with a working channel of 3 mm (BF-1T180; Olympus America). The bronchoscope was introduced orally or by means of an endotracheal or tracheostomy tube. The cryoprobe tip was advanced and maintained at least 4 to 5 mm beyond the end of the bronchoscope to avoid damage to the bronchoscope. Under bronchoscopic visualization, the cryoprobe tip was placed in direct contact with blood clots, airway secretions, or foreign bodies in a tangential manner or directly into the body of the lesion. At the end of each freeze cycle lasting 20 to 120 seconds, the cryoprobe was removed together with the bronchoscope. None of the patients underwent rigid bronchoscopy.

Outcome Measures

Reestablishment of airway patency was considered successful if the blood clot, mucous secretion, or foreign body was completely removed from the visible airway. Improvement in oxygenation and/or ventilation was defined by achieving and sustaining any of the following for 24 hours after the procedure: (1) successful liberation from mechanical ventilation; (2) decrease in PEEP of 5 or more; (3) decrease in FiO_2 of 25% or more or 2 LPM or more; and (4) reversal of lobar collapse. Subjects who were on extracorporeal membrane oxygenation (ECMO) were excluded from analysis for improvement in oxygenation and/or ventilation outcome.

Clinical Data

Clinical data were extracted by retrospective chart review independently by 2 of the authors (N.S., F.L.); any disagreement was resolved by consensus discussion between authors (N.S., F.L., and K.Y.Y.).

RESULTS

During the study period, we identified a total of 89 cryotherapy sessions performed on 73 subjects. Forty-seven sessions of neoplasm-related obstruction and 4 sessions of tracheal stenosis were excluded from analysis. A total of 38 cryotherapy sessions performed on 30 subjects were included for analysis. Subject characteristics are summarized in Table 1. The mean age was

52.6 years, 20 (66.7%) were male. The indications were acute airway obstruction from blood clots (26), mucous plugging (6), foreign bodies (4), and plastic bronchitis (2). The locations of the lesions are summarized in Table 2. All sessions were performed at the bedside with flexible bronchoscopy in the inpatient setting. Thirty-three of 38 sessions were performed on patients on mechanical ventilation, one through a tracheostomy tube, the remainder through an oral endotracheal tube.

Clinical and safety outcomes are summarized in Table 3. Reestablishment of airway patency was successful in 32/38 (84.2%) sessions. Blood clot extraction was successful in 24/26 (92%) sessions with the failures occurring in the setting of continued and excessive airway bleeding. In no case did removal of blood clots lead to significant or persistent airway bleeding. Improvement in oxygenation and/or ventilation occurred in 21/31 (68%) sessions. Mucous plugging extraction was successful in 4/6 (66.7%) sessions. Foreign body extraction was successful in 2/4 (50%) of sessions. The patient with plastic bronchitis underwent 2/2 (100%) successful extraction sessions.

During the study period, there was only one complication of transient hypotension related to sedation that resolved with an intravenous fluid bolus. No procedure was aborted prematurely. One patient underwent four separate cryoprobe sessions for hemoptysis occurring while on ECMO for hypoxemic respiratory failure due to ARDS. Cryotherapy temporarily relieved the obstruction, but the family decided to withdraw care after seventeen days of ECMO with little improvement.

TABLE 1. Patient Data

Characteristic	Sessions	Patients
Patient population		
Total sessions and patients	38	30
Age range, y (mean)		28-73 (52.6)
Male/female		20/10
Airway		
Nonintubated	5	5
Endotracheal tube	32	24
Tracheostomy	1	1
Indication		
Blood clots	26	20
Mucous plugging	6	5
Foreign body	4	4
Plastic bronchitis	2	1

TABLE 2. Location of Lesions

Location of Endobronchial Obstruction	Sessions	Patients
Trachea	11	8
Right mainstem	9	8
Right upper lobe	8	5
Right bronchus intermedius	12	10
Right middle lobe	8	5
Right lower lobe	7	5
Left mainstem	16	13
Left upper lobe	11	8
Left lower lobe	16	14

DISCUSSION

This study demonstrates that cryoprobe extraction of blood clots, airway secretions, and foreign bodies can be safely, reliably, and efficiently accomplished in the inpatient setting and on patients receiving mechanical ventilation. Acute airway obstruction due to endobronchial blood clots, airway secretions, or foreign bodies is not uncommon and is potentially life-threatening. A variety of other bronchoscopic techniques have been used to manage this problem, yet there is no bronchoscopic method that has been established as the gold standard. Important aspects to any procedure are reducing the degree of invasiveness and time to completion, while maintaining or improving efficacy and safety. Cryoextraction with flexible bronchoscopy offers several potential advantages over rigid bronchoscopy, including ready availability, patient comfort, and ease of use in the intensive care unit in patients on mechanical ventilation.

Our study reported 1 complication of transient hypotension related to sedation that resolved with an intravenous fluid bolus. We had no other identified complications, suggesting that cryoextraction with flexible bronchoscopy can be performed safely at the bedside in a

TABLE 3. Clinical Outcome by Session

Indication	Airway Patency* (%)	Improvement in Oxygenation/ Ventilation* (%)	Complications* (%)
Blood clots	24/26 (92)	14/21 (66.7)	1/26 (3.8)
Mucous plugging	4/6 (66.7)	4/6 (66.7)	0 (0)
Foreign body	2/4 (50)	3/4 (75)	0 (0)
Plastic bronchitis	2/2 (100)	NA	0 (0)
Total	32/38 (84.2)	21/31 (67.7)	1/38 (2.6)

*Number of sessions.
NA indicates not available.

controlled manner without general anesthesia. Although we did not identify any immediate complications related to the use of the cryoprobe, the relatively small number of subjects and the retrospective nature of the study limit these findings. In a study performed by Mathur et al,[6] a cryoprobe was used to manage endobronchial obstruction due to tumor. Two cases were complicated by bronchospasm and 1 by cardiopulmonary arrest. It was unclear how the complications were related to the procedure. Nevertheless, from the available data and our experience, we believe that cryoprobe extraction is a safe method of airway clearance of blood clots, airway secretions, and liquid-based foreign bodies.

Airway obstruction from blood clots (Fig. 1) was relieved with cryoextraction in >90% of sessions, with failure seen only in the setting of continued and excessive airway bleeding, supporting the opinion that it should be considered the method of choice for removal of blood clots in the airway.[6] This recommendation has been made on the basis of the adherent properties of cryotherapy and the personal experience of the authors Homasson and Vergnon.[5] It is also supported by several case reports[10–14] but no other case series. The cryoprobe appears to be particularly useful in removing blood clots that are otherwise difficult and time consuming to remove by flexible bronchoscopy. Cold promotes coagulation and the cryoprobe seems to firmly solidify and strengthen blood clots, facilitating extraction of large bronchial casts compared with suction, biopsy forceps, and basket extraction where clots easily fragment. Probe contact time varied by case and by bronchoscopist. Although not specifically studied, our subjective impression is that longer contact times of 1 to 2 minutes promote removal of large airway casts while helping to control focal bleeding. Our perception is supported by the large casts we removed and by the fact that we had no incidence of significant bleeding after removal of blood clots. It must be noted, however, that it is our general approach to wait 24 hours after an acute bleed before attempting clot removal, and early removal was attempted only in cases in which it was believed that the potential benefit of clot removal outweighed the risks of inciting new or increased airway bleeding.

FIGURE 1. Airway cast of a case with hemoptysis.

Extraction of mucous secretions was successful in 4 of 6 cases. We must add that the mucous extraction was not nearly as dramatic as the large airway casts that were removed with blood clot extraction. In addition, it was used only for removal of extremely tenacious secretions when conventional bronchoscopy failed.

Our experience with foreign body cryoextraction is limited but was successful in only 2 of 4 cases. Cryoadherence and extraction relies on the freezing of liquid within or surrounding a foreign body. Therefore, whereas most organic materials are reliably adherent, inorganic materials are not. Nevertheless, there are exceptions, and it has been recommended that, when feasible, identical objects should be tested for cryoadherence before the attempt is made in the patient.[15] In addition, within the airway there may be sufficient moisture on the surface of the foreign body or liquid can be sprayed on the foreign body to facilitate cryoadherence and extraction.[12]

Our single case of plastic bronchitis (Fig. 2), with a successful outcome using cryoextraction combined with inhaled fibrinolytic and rhDNase therapy as previously reported,[16] supports its use for this indication. While a rare occurrence, plastic bronchitis can be life-threatening and extremely difficult to manage by any means. Therefore, although there are no other case reports on the use of cryoextraction for plastic bronchitis and commentary on its utility for this indication is necessarily limited, we found it extremely useful for this indication and recommend it be considered.

We would like to summarize some pitfalls of using flexible cryoprobe. First, although the cryoprobe is effective in removing organized blood clots, it may not adequately control

FIGURE 2. Airway cast of a case with plastic bronchitis. a+

airway bleeding; the local and systemic causes of bleeding should be explored and addressed. Second, for foreign body cryoextraction in intubated patients, the operator must consider the size of the foreign body and the size of the endotracheal tube, as the foreign body might be difficult to extract through smaller-sized tubes, leading to dislodgement of the foreign body or requiring endotracheal tube removal. Foreign bodies larger than the endotracheal tube orifice can be extracted by withdrawing the foreign body, bronchoscope, and endotracheal in concert. Third, the cryoprobe could potentially damage the endobronchial mucosa and potentially perforate the bronchus,[17] thus the operator must maintain direct visualization of the airway during its use. Fourth, liquid can freeze within the bronchoscopy channel in the small space surrounding the catheter and fracture the inner lining of the channel, resulting in an air leak. To avoid this problem, the tip of the cryoprobe should be at least 4 to 5 mm distal to the tip of the bronchoscope, and complete thawing should occur before withdrawal of the probe through the bronchoscopy channel. Fifth, although the smaller 1.9 mm diameter cryoprobe initially fit through the 2 mm diameter bronchoscopic channel, after several uses it no longer did. A replacement cryoprobe manifested the same defect. Sixth, although we did not encounter this problem, removal of blood clots can lead to recurrent or worsening of airway bleeding. Therefore, on a case by case basis, the potential benefit of clot removal must be carefully weighed against the risk of inciting or aggravating airway bleeding. Lastly, the operator must be aware that clinical deterioration may occur during the procedure, thus the procedure should be performed in an environment that has adequate staffing and an appropriately equipped room.

Our study is limited by its relatively small size, retrospective nature, and limitation to a single institution. Also, cryoextraction was generally applied in cases in which blood clots and airway secretions could not be effectively removed by conventional flexible bronchoscopy. Therefore, it is difficult to know the optimal indications for its use.

CONCLUSIONS

We conclude that flexible bronchoscopic cryoextraction of blood clots, airway secretions, and foreign bodies is a safe and effective technique. It can be safely performed at the bedside and may eliminate the need for rigid bronchoscopy.

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Announcement

AABIP 2015 Recipient of the Geoffrey McLennan Memorial Award for Advancements in Interventional Pulmonology

The American Association for Bronchology and Interventional Pulmonology (AABIP) is pleased to announce that the 2015 recipient of the Geoffrey McLennan Memorial Award for Advancements in Interventional Pulmonology is **Dr. Roberto F. Casal**.

Dr. Casal is a graduate of the Buenos Aires Medical School, Argentina. He completed his training in internal medicine, pulmonary and critical care medicine at the Texas Health Science Center–Houston. Dr. Casal also did a dedicated interventional pulmonology fellowship at the University of Texas M.D. Anderson Cancer Center. He currently directs the interventional pulmonology clinical and research program at the Baylor College of Medicine.

Dr. Casal is a well-known academician, respected teacher, prolific writer, and productive scientist. He has designed and conducted highly regarded clinical trials published in the *American Journal of Respiratory and Critical Care Medicine* and *CHEST*.

His contributions to medicine and science extend beyond U.S. borders. He serves on the scientific committee of the World Association for Bronchology and Interventional Pulmonology (WABIP), which develops global guidelines to enhance patient safety and outcomes. Under the auspices of WABIP, Dr. Casal played a key role in formulating guidelines on endobronchial ultrasound-guided transbronchial needle aspiration sample acquisition and processing. He is also the chief editor of the WABIP online library.

Dr. Casal is a member of the AABIP board of directors. He chairs and serves on several key AABIP committees. His tireless efforts and dedication to interventional pulmonology have earned him an international reputation as a respected thought leader in his field.

Please join us in congratulating Roberto on this distinguished award.

Ali I. Musani MD