Experience With the Use of Single-Use Disposable Bronchoscope in the ICU in a Tertiary Referral Center of Singapore

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Background: **Flexible bronchoscopy is performed frequently in intensive care units (ICUs) for various indications using the reusable conventional bronchoscope (CB). Recently, "single-use disposable bronchoscope" (SB) was introduced into the health care industry. The purpose of this study was to compare the utility of SB with CB in ICU.**

Methods: **A retrospective review of medical records of patients undergoing flexible bronchoscopy in the ICUs in the year 2015.**

Results: **Ninety-three patients undergoing flexible bronchoscopy in the ICU were studied. Eighty-three bronchoscopies were performed using SB in 71 patients, and 24 using CB in 22 patients. The most common indications for using the SB were percutaneous tracheostomy [n = 37 (44.6%)] in neuro-ICU, followed by collecting specimens for microbiological evaluation [n = 20 (24.1%)] in the medical ICU. Airway inspection [8 (9.6%)], bronchial toilet [8 (9.6%)], hemoptysis [5 (6%)], and intubation [3 (3.6%)] were other indications for which SB was used. Microbiological yield of SB was 70% (14/20) versus 70% (7/10) for CB ($P = 1.0$). The median interval between identification of the need-to-start of the procedure was shorter with SB (10 min) versus CB (66 min, $P = 0.01$), whereas the cost was similar, SGD450 versus SGD472, respectively. In addition, less (3 personnel) were needed to perform bronchoscopy with SB versus 5 with CB with additional resource sparing effect in terms of nursing personnel having to wheel the CB equipment to ICU.**

Conclusions: **SB is equivalent in performance to CB in ICU. In addition, the SB may confer clinical, economic, and logistical advantages over the CB.**

Key Words: bronchoscopy, stenting, laser, central airway obstruction, tracheostomy

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Flexible bronchoscopy is a valuable tool in the management of patients in intensive care unit (ICU). It may be used in ICU to assist with intubation, perform percutaneous tracheostomy in those who require prolonged mechanical ventilation, inspect the airways for localizing the site of bleeding in patients with hemoptysis, assess endobronchial lesions in cases of central airway obstruction, remove airway secretions in mucus plugging causing atelectasis, and collect airway secretions for microbiological and cytologic examination.[1–3] It can also aid in early liberation from mechanical ventilation in patients with central airway diseases.[4] Studies conducted over 5 months to 2 years have reported hundreds of patients requiring flexible bronchoscopy in the ICU.[1,3,5]

However, bronchoscopy in an ICU not equipped with a dedicated bronchoscope requires mobilizing the bronchoscope and its accessories from the endoscopy center to the ICU. This entails wheeling the video-system and the bronchoscope by nursing personnel to the ICU, assisting with the procedure at the bedside, and then returning the equipment to endoscopy center, followed by disinfecting it before use for another patient. This not only affects timeliness of the procedure but also the ability to perform the bronchoscopic procedure in the endoscopy center for that time period, and precludes performing 2 bronchoscopies concurrently in ICU

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due to limited availability of manpower and equipment.

ICU equipped with conventional bronchoscope (CB) may not experience these issues. However, the use of CB carries the potential risk of transmission of infection across patients. Despite disinfection, residual contamination with *Pseudomonas aeruginosa*, Mycobacteria, as well has human immunodeficiency virus has been reported.[6–10] In addition, improper sterilization of the bronchoscopes after its use in the ICU, followed by the use of the same bronchoscope in outpatients carries the risk of exposing the community to multidrug resistant organism that are often encountered in the ICU.

Single-use disposable bronchoscope (SB) present an alternative to overcome abovementioned challenges associated with the reusable CB. There are several different SB devices available, however, there is a paucity of research describing the use and performance of SBs in the ICU.[11] The objective of this study is to describe our experience with use of SB in the ICU in a tertiary referral center in Singapore.

MATERIALS AND METHODS

Data Collection

Medical records of patients who underwent SB between January to December 2015 in the medical, surgical, cardiac, and neuro-ICU's of Tan Tock Seng Hospital were studied. Data were collected retrospectively from patient records and includes patient demographics, indications for procedure, and procedure outcomes. For comparison we collected data on use of CB in the medical ICU over the same time period. The current study was part of an audit as a quality-of-care initiative performed on ICU patients to assess the utility of newly introduced SB.

Device

The device used for performing bronchoscopy with the SB consisted of 2 parts, the Ambu aScope 3 5.0/2.2 and Ambu aView monitor (Fig. 1). The maximum diameter of the bronchoscope is 5.0 mm requiring a minimum endotracheal tube diameter of 6.0 mm. The bronchoscope comes in 2 sizes, outer diameter of 5.0 mm, and 3.8 mm. The device contains a working channel to allow suction or the use of soft endoscopic accessories that are designed to be passed through a channel width of up to 2 mm. Active endoscopic accessories such as laser probes and electrosurgical equipment are not to be used due to the risk of ignition of the plastic. The display monitor "aView" is reusable and requires cleaning by wiping with an alcohol wipe, and it is powered by batteries. The device used for CB was diagnostic bronchoscope (BF-P190; Olympus Ltd, Tokyo, Japan) connected to the image system (Evis Exera III; Olympus Ltd) (Fig. 2).

Data Analysis

We used software (SPSS, version 17; SPSS, Chicago, IL) for all statistical analyses. The results were compared using either Wilcoxon 2-sample test or Fisher exact test. *P*-values were 2 sided and considered indicative of a significant difference if < 0.05.

RESULTS

We collected data for 83 SB in 71 patients in the 4 ICU between January and December 2015. For comparison, we also collected data on 24 CB in 22 patients, which were performed in the medical ICU over the same time period. No bronchoscopy with CB was performed in the other 3 ICU. Characteristics of patients and procedures are described in Table 1.

Most bronchoscopies using SB were performed in the neuro-ICU and the most common indication was percutaneous tracheostomy (n = 37, 44.6%). The next commonest indication was collection of microbiological sample (n = 20, 24.1%) in the medical ICU. Three patients out of these underwent bronchoalveolar lavage, and 17 patients underwent bronchial washing. When microbiological specimens were required, SB yielded positive cultures in 70% (14/20) cases. This was similar to CB group in the medical ICU where the yield was 70% (7/10, $P = 1$). One example in which the SB was extremely beneficial was in a patient with a broncho-esophageal fistula (Fig. 3). This patient required regular bronchial toileting multiple times, which was facilitated by the availability of the SB.

Six (7.2%) patients required repeat procedure with the CB after undergoing bronchoscopy with the SB. This was most commonly seen in cases of hemoptysis (4/6) where better visualization, maneuverability, and better suction of blood or blood clot was deemed critical. None of the patients required emergent conversion to CB.

Table 2 compares resource requirements for CB and SB. On average, the direct cost of performing SB was similar to that of CB; however,

FIGURE 1. Image of the single-use disposable bronchoscope (Ambu aScope 3).

if we include the cost of repair, cost of disinfection, and cost of remuneration to support staff (technicians, etc.) involved in cases done on weekends and after office hours, SB is conceivably more economical. In addition, CB took longer time, and more number of staff to organize in the ICU.

DISCUSSION

Our experience illustrates that SB is an effective alternative to CB for the indications of flexible bronchoscopy in the ICU. In addition to clinical advantage of infection control, SB may confer economic, and logistical advantages over the CB as well.

Flexible bronchoscopy is commonly used in ICU to assist with intubation, perform percutaneous tracheostomy, inspect the airways for localizing the site of bleeding in patients with hemoptysis, assess endobronchial lesion in cases of central airway obstruction, clear airway secretions in mucus plugging causing atelectasis, and collect airway secretions for microbiological and cytologic examination.[1–3] It can also be

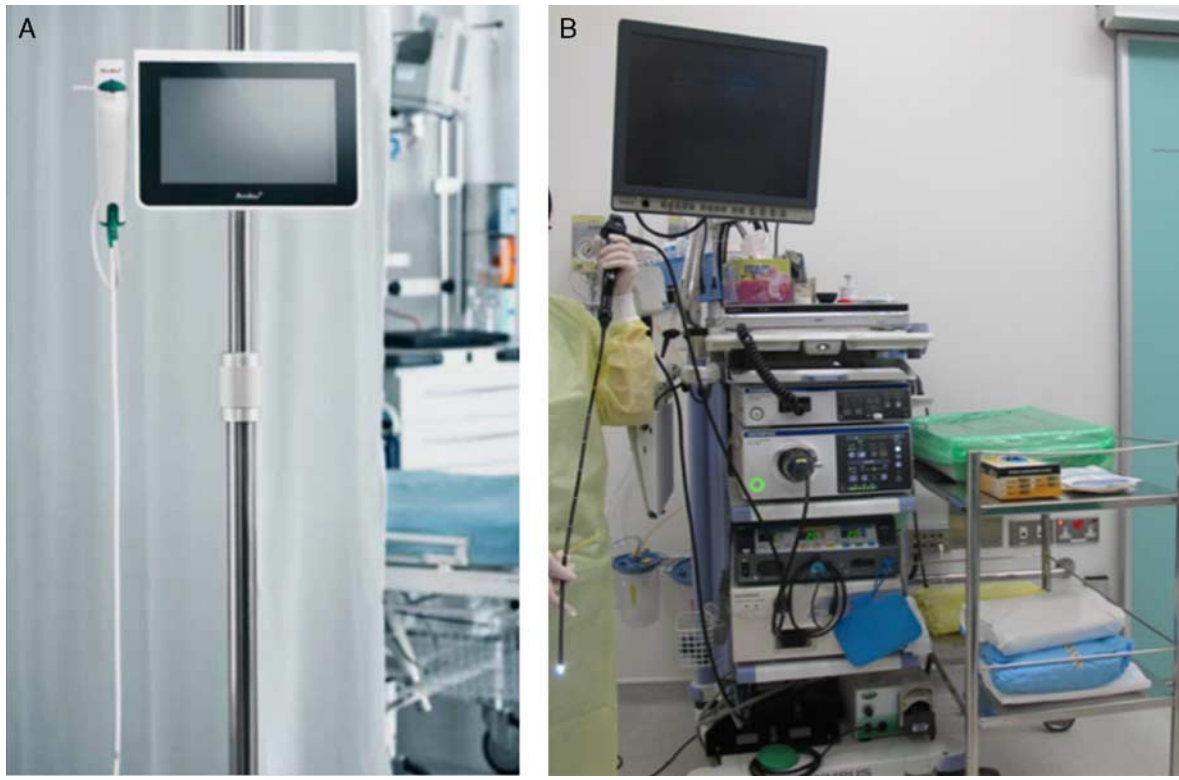

FIGURE 2. Comparison of the single-use disposable bronchoscope and the reusable conventional bronchoscope. A, Single-use disposable bronchoscope. B, Reusable conventional bronchoscope.

used to aid in early liberation from mechanical ventilation in patients with central airway diseases.[4]

Clinical Aspect

In terms of the use of SB (Ambu aScope 3) for obtaining microbiological samples in the ICU, microbiological cultures were positive in 70% of cases. These rates were identical to our sample of CB that are consistent with a systematic review from 23 studies, which reported a mean sensitivity of bronchial alveolar lavage of 73%.[12] In addition, a clinical trial is underway comparing the utility of the SB with the CB for performing BAL in research settings.[13]

For intubation, previous studies have found SB to be comparable with CB. A randomized controlled trial of the Ambu aScope 2 (the earlier version of the Ambu aScope 3 without a suction channel), found the performance similar to CB.[14] Similar findings for difficult intubations were reported by Kristensen and Fredensborg and are supported by research in manikins.[15–17] SB has been recommended by the UK National Institute for Clinical Excellence (NICE) for use in unexpected difficult airways.[18] Consistent with these findings, SB was used for intubation in 3 patients successfully in our cohort.

In case of percutaneous tracheostomies, the earlier version of the Ambu aScope 3, that is Ambu aScope 2, which did not have a suction channel posed difficulty. As a result, in a case series by Reynolds et al,[19] patients required careful selection before a SB could be used. However, the Ambu aScope 3 has a suction channel and it is, therefore, suitable in patients who have significant secretions or bleeding. Our experience showed that percutaneous tracheostomy is the most common indication of SB with the success rates of 100%. It is noteworthy though that, as percutaneous tracheostomies are performed electively in a planned manner, the interval between identification of the need-to-start of the procedure may be similar between SB and CB for this indication.

One patient in our cohort was diagnosed with broncho-esophageal stump fistula following esophagectomy for carcinoma of the esophagus (Fig. 3). Flexible bronchoscopy using SB revealed a fistula located in the medial wall of left main bronchus, communicating with the residual esophageal stump. Because of continuous ongoing

TABLE 1. Patient and Procedure Characteristics

Characteristics	Single-use Bronchoscope (n = 71)	Conventional Bronchoscope (n = 22)
Demographic		
Age [median (IQR)] (y)	62 (48-68)	67 (63-73)
Female [n (%)]	17 (23.9)	11 (50.0)
ICU [n (%)]		
Medical ICU	22 (31.0)	22 (100.0)
Surgical ICU	10 (14.1)	—
Neuro-ICU	36 (50.7)	—
Coronary care unit	3 (4.2)	—
Admitting diagnosis [n (%)]		
Respiratory failure	31 (43.7)	18 (81.8)
Neurological disorder	29 (40.8)	0 (0.0)
Cardiac disorder	4 (5.6)	1 (4.5)
Sepsis	2 (2.8)	1 (4.5)
Surgical disorder (inc. trauma)	5 (7.0)	2 (9.1)
No. bronchoscopies	83	24
Primary indication [n (%)]		
Airway inspection	8 (9.6)	4 (16.7)
Percutaneous tracheostomy	37 (44.6)	0 (0.0)
Bronchial toilet	8 (9.6)	2 (8.3)
Intubation	3 (3.6)	1 (4.1)
Hemorrhage	5 (6.0)	6 (25.0)
Microbiology	20 (24.1)	10 (41.7)
Culture positive	14	7 (29.2)
Culture negative	6	3 (12.5)
Other	2 (2.4)	1 (4.1)
Required subsequent conventional bronchoscopy [n (%)]	6 (7.2)	—

ICU indicates intensive care unit; IQR, interquartile range.

aspiration of esophageal stump contents into the bronchial tree, this patient had developed aspiration pneumonia. Ongoing aspiration through the fistula into the bronchial tree prevented recovery and perpetuated copious purulent secretion in the airways requiring bronchial toilet multiple times, which was not feasible with the CB due to lack of its immediate availability; however, could be done successfully using the SB due to ease of repeatability at short intervals.

On 2 occasions when bronchoscopy was repeated using the CB, the reason was ineffective clearance of the thick and purulent nature of secretions. However, patient did not require immediate conversion from SB to CB, rather the repeat bronchoscopy was performed the next day to achieve better clearance. Similarly, in 6 patients with hemoptysis, the bronchoscopy was repeated electively the next day using the CB. Where part of the reason for repeating the bronchoscopy the next day using the CB was better maneuverability and suction of the scope, part of it was the greater familiarity, and confidence in CB among the physicians.

Logistical Aspect

Logistically, it would be most desirable to perform flexible bronchoscopy in the ICU as soon as its need is identified instead of a day or hours later. Such a strategy would save time, confer safety by enabling resolution of the problem indicating the need for bronchoscopy promptly such as difficult intubation or suction of mucus plug, prevent spread of infection, and allow the bronchoscopy service to be provided to multiple patients if needed.

Practically, there are significant problems with the use of the CB in the ICU. Many ICUs (including our own) do not maintain a dedicated CB, and it is easier to sterilize and store bronchoscopes safely in the "endoscopy center/suite" where the relevant expertise to maintain this equipment is always available. Hence, making the CB available in an ICU requires multiple steps such as: informing the endoscopy suite of the requirement of the flexible bronchoscopy in the ICU, matching the time of bronchoscopy in the ICU with the time of availability of the equipment and nursing or respiratory staff from endoscopy center, inability to perform bronchoscopy at night when the endoscopy center is closed, procuring the equipment which entails wheeling the video-system and the bronchoscope manually by the 2 nursing personnels to the ICU, and then returning it to the endoscopy center. This is followed by disinfection before its use for the next patient.

This process requires effective interdepartmental communication, and time, making the use of CB less ideal for the time-sensitive, and often unplanned indications of bronchoscopy in the ICU. It interrupts the ability to perform the bronchoscopic procedure in the endoscopy center for that time period, and also makes performing 2 bronchoscopies concurrently in ICU difficult due to limitations of manpower and equipment. In addition, the process carries a risk of damage to the equipment during transfer.

In contrast, the SB can be stored in the ICU. The monitor is easy and light to carry by hand from the storage area to the bedside by a single person, usually a respiratory therapist who is also located in the ICU. After completion of the procedure, the bronchoscope is discarded, and the monitor is placed back in the storage area in

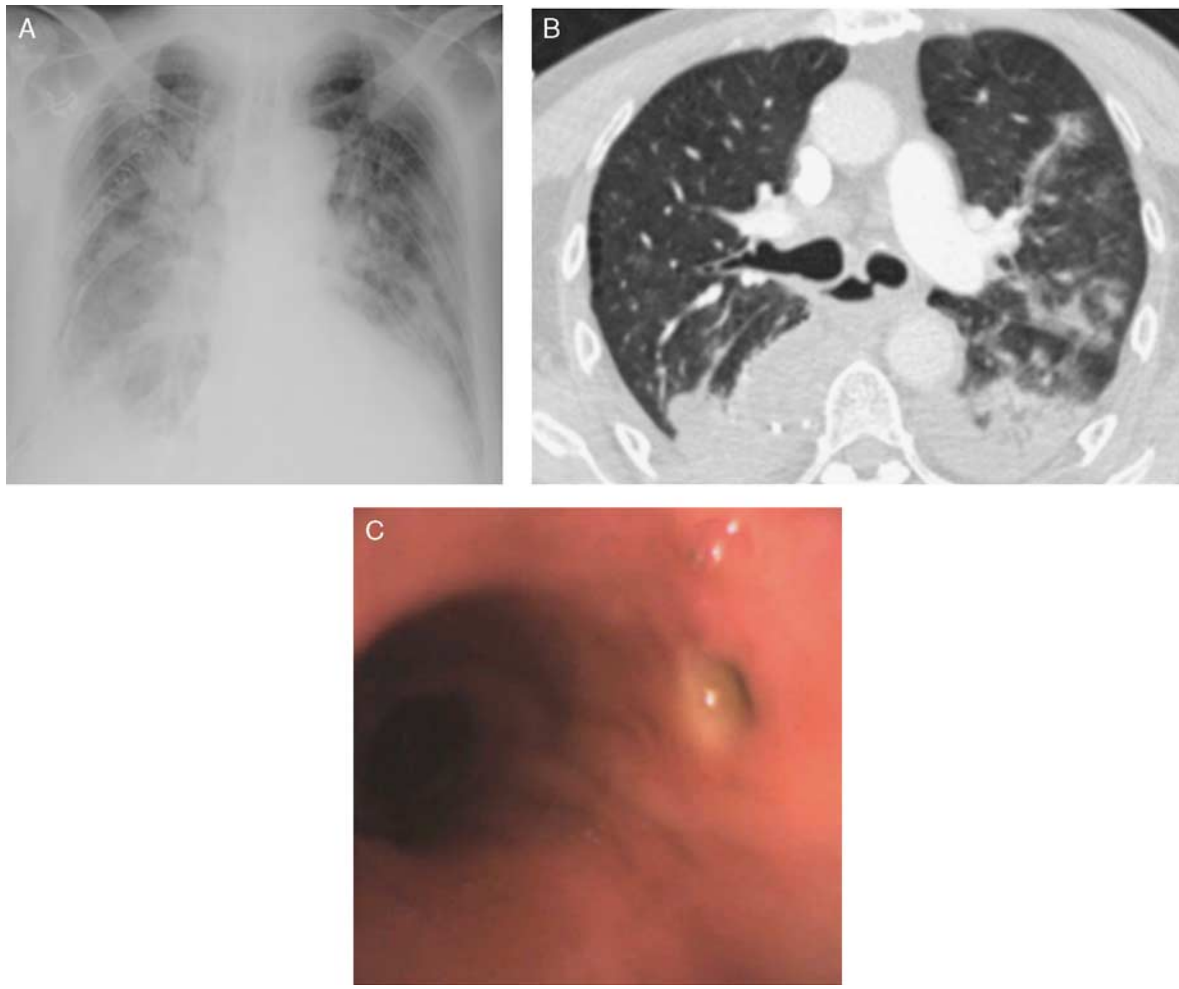

FIGURE 3. A representative case of broncho-esophageal stump fistula. A, Bilateral aspiration pneumonia. B, Computed tomographic scan showing fistulous communication between the left main bronchus and esophageal stump. C, Bronchoscopic appearance of left main bronchus fistula using the single-use disposable bronchoscope.

TABLE 2. Summary of Average Resource Requirement for 1 Procedure Using a Single-use Bronchoscope (SB) Compared With a Conventional Bronchoscope (CB)

	SB	CB	*P*
Time to start bronchoscopy [median (range)] (min)			
Identification of need to start of the procedure time	10 (5-15)	66 (8-253)	0.01
Time to perform bronchoscopy	25 (8-30)	25 (8-55)	1.0
Turn-around time	0	120	0.01
Resource utilization			
No. assisting personnel per procedure	3	5	—
Equipment used per procedure			
Swivel connector	1	1	—
Video-system	0	1	—
Ambu monitor	1	0	—
Bronchoscope carrying trolley	0	1	—
Disinfection equipment	0	1	—
Cost			
SGD	450	472	1.0

the ICU. This instant availability reduces the interval between identification of the need-to-start of bronchoscopy with the potential to translate into clinical benefits of bronchoscopy as soon as possible. Because of its lack of reliance on the video-system, endoscopy personnel, and turn-around time associated with the disinfection of the bronchoscope, it may allow performing bronchoscopy on multiple patients concurrently. In addition, as bronchoscopy has been reported as a major risk factor for patients acquiring multidrug resistant *Pseudomonas* or *Stenotrophomonas maltophilia* infection in ICU, SB reduces the risk of cross-infection.[20,21]

Economic Aspect

Performing flexible bronchoscopy using CB in the ICU is more resource intensive. The procedure requires 5 personnel; 1 intensivist, 2 endoscopy nurses, 1 ICU staff nurse, and 1 respiratory therapist. In terms of equipment, it requires swivel connector, video-system, a trolley to transfer the CB, a CB, and equipment for disinfection of the bronchoscope. In our hospital, when CB is needed in the ICU, 2 endoscopy nurses, 1 to wheel the Olympus video-system tower (heavy equipment), and 1 to wheel the trolley carrying the CB and accessories) are involved in the process. In terms of cost, the billing cost of performing each flexible bronchoscopy using CB in the ICU was SGD472 in our hospital.

In contrast, the use of SB only requires 3 personnel; 1 intensivist, 1 ICU staff nurse, and 1 respiratory therapist, and a swivel connector with a SB, and the portable Ambu aView monitor for performing the procedure. In terms of direct cost, 1 procedure using a SB costs SGD450, similar to 1 procedure using a CB. However, if the indirect cost such as; the cost of CB repair, cart equipment repair, cost associated with remuneration of on-call technicians for performing bronchoscopy after office hours or weekends, and the cost of staff utilization for cleaning and maintenance of the bronchoscope is taken into account, the cost of CB is conceivably higher than the cost of SB for relatively lesser clinical and logistical benefit derivable from it. Average cost per repair has been reported to range from average of 74 to 2985 USD in 1 study.[22] In another study from Europe, the average repair cost/damage occurrence ranged from 213 to 5956 EUR.[23] There have also been reports of concern about the cost of the SB. Previous reports have suggested that SB are significantly more expensive and are only cost-effective in centers where very few bronchoscopes are performed in the ICU.[24] However, the relative costs vary between centers, in 1 recent report Aïssou et al[25] concluded that the cost difference was marginal and may be outweighed by the benefits of SB. In our center the respective procedure costs between SB and CB are similar.

This study has a few limitations. First, the study was a retrospective observational study reporting the experience of a single center. Second, our sample size is small and not powered to detect any statistically significant differences in success rates between single-use and reusable bronchoscopes in the ICU. Third, the therapeutic bronchoscopy such as stenting or use of a laser will require the use of CB to be performed safely. Fourth, the image quality with CB may be better than the image quality of the SB. However, progressive improvement in technology may be able to overcome this limitation in the future. Fifth, in patients with hemoptysis or copious respiratory secretions, CB may be preferable over SB. In addition, it is foreseeable that the frequent use of a disposable device may raise concerns about the environment.

In conclusion, SB is an effective alternative to CB in the ICU for intubation, bronchial toilet, suction of mucus plug, and airway inspection. Microbiological yield (70%) was also similar to the yield with CB, and the reported yield in the literature, with low requirement for a subsequent conventional bronchoscopy. In addition, the interval between identification of the need-to-start of the procedure was shorter, and the cost was similar, with a potential for resource sparing effect in terms of sparing the interruption of the bronchoscopy procedure at the endoscopy center, nursing personnel having to wheel the equipment to ICU, and number of staff needed to perform the procedure. Future studies with larger cohorts conducted at multiple institutions will help to validate these findings.

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