Transbronchial needle aspiration: development history, current status and future perspective

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Background: Transbronchial needle aspiration (TBNA) technology was underutilized by clinicians because it is "blind". Recent development of endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) renewed the interest and confident of TBNA. TBNA without EBUS is referred as conventional transbronchial needle aspiration (C-TBNA).

Methods: This paper focuses on C-TBNA technology development history, present situation and future development to do a detailed introduction.

Results: TBNA is a simple, cost effective and minimally invasive technique for diagnosing disease of the mediastinum and lung in adult as well as children patients.

Conclusions: More improvements of TBNA technology should be made, including employing technological advances to perfect the instruments and techniques, focusing on patient comfort, optimizing yield, simplifying instruments, maximizing ease of use and minimizing training requirements for the pulmonologist. The ideal TBNA scope deserves further evaluation and study.

Keywords: Transbronchial needle aspiration (TBNA); endobronchial ultrasound (EBUS); Fujifilm; Wang needle; rapid on-site evaluation (ROSE)

Submitted Jul 29, 2015. Accepted for publication Oct 27, 2015.
doi: 10.3978/j.issn.2072-1439.2015.11.36
View this article at: http://dx.doi.org/10.3978/j.issn.2072-1439.2015.11.36

Introduction

Transbronchial needle aspiration (TBNA) was first developed in 1949 for use with the rigid bronchoscope (1), and Wang *et al.* designed a prototype needle for flexible bronchoscope in 1978 (2). TBNA has been employed in sampling beyond the wall of the central airways. It is a cost effective, safe, minimally invasive technique, performed while the diagnostic bronchoscopy being carried out, avoiding another staging procedures and additional surgical approaches (3-5). Convex probe endobronchial ultrasound (CP-EBUS), with the ability to perform real-time endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) was developed in 2002. By 2007, EBUS-TBNA had been accepted by clinicians as a safe and efficient technique for mediastinal and hilar lymphadenopathy (5,6). The TBNA without EBUS is referred as conventional transbronchial needle aspiration (C-TBNA), which is often being deemed as a blind technique for its' dependence on extremely thorough understanding of anatomy. To a great extent, the operators' abilities of anatomical location and completing the systemic training or not influenced the aspiration results, inducing the yields of TBNA varies greatly in the published literature, ranged from 14-100% (4). Although there are scholars believe that EBUS-TBNA should be the only clinicians' choice, it is undeniable that the C-TBNA with the superiorities of more convenient, less expensive, can be applied in puncturing peripheral lung nodules and children patients, and so on, which cannot be replaced by EBUS-TBNA (7). TBNA technique seems fall into a controversial situation, whether C-TBNA can break through its limitations or not? How to cope with the C-TBNA and EBUS-TBNA in clinical work? This paper will do a detailed introduction focusing on C-TBNA technology development history, present situation and future development.

Development history of TBNA

Concept of TBNA

In 1949, Dr. Eduardo Schieppati first reported the employment of TBNA, without obtaining full attention of clinicians (1). Then, in 1978, Wang *et al.* introduced this technique to North America and promoted it to the whole world, by describing TBNA in diagnosing a small cell lung cancer (2), which attracted great attention of chest physicians and pathologists. From then on, in order to make the TBNA technique be a better diagnostic tool for the clinical work, Wang *et al.* had concentrated on the development of TBNA by flexible bronchoscopy in diagnosing mediastinal and hilar lymphadenopathy. For the purpose of guiding TBNA operators, they established the "Wang map" and the systemically described the puncturing methods, which made TBNA become an effective and widely used technology.

Origin of TBNA needle

A flexible needle was designed for flexible bronchoscope to perform the TBNA technology in 1983 (8). Later, in 1984, TBNA was successfully employed in the diagnosing peripheral pulmonary lesion (9). In 1985, Wang *et al.* designed the needle for the flexible bronchoscope for obtaining histological specimen (10), and then in 1989 they published the usefulness of TBNA in obtaining histological diagnosis of sarcoidosis (11). After 30 years development, there are various kinds of C-TBNA needles available to be employed inflexible bronchoscope. Recently, Wang *et al.* has designed a new series of TBNA needles (DT new Wang needle, DeTian Medical, Changzhou, China) on the basis of modifying the original Wang needles. DT new Wang needle special for EBUS scope was developed and has been proven it can be successfully used in EBUS-TBNA (12).

Establishment of Wang map

Despite efforts to perfect the TBNA technique, a 1991 survey indicated that it was remained underutilized in clinical work and in systemic training (13). A standard lymph node (LN) map (*Figures 1-11*) was first proposed by Wang *et al.* in 1994, which was widely accepted as "Wang map" by TBNA operators. Wang map described the most common LN locations in the mediastinum and hilar areas, based on computed tomography (CT) LN location with corresponding endobronchial puncture sites (14). Different from International Association for the Study of Lung Cancer (IASLC) map, Wang map identified the 11 LNs stations by the endobronchial landmarks (carina, main right/left bronchus, both upper lobes and the bronchus intermedius), which has facilitated the TBNA localization. Interestingly, the puncture sites defined by Wang map were verified by CP-EBUS in 10 years later (5).

Clinical application of TBNA

Since the application of C-TBNA technology, it revolutionized the bronchoscopy examinations. In the past 30 years, C-TBNA technology has been developing in all aspects and become a simple and practical procedure for diagnosing mediastinal and hilar adenopathy.

Indications of C-TBNA

(I) Sampling of LNs and lesions beyond the airway, but adjacent to the tracheobronchial tree; (II) diagnosis and staging of lung cancer, including abnormal mediastinum shown in CT or PET needs pathological diagnosis, and parenchymal lesion needs pathological staging of the mediastinum, even with normal mediastinum on CT and or PET; (III) others: cystic mediastinal lesions, granulomatous lesions, inflammatory lesions and infectious lesions.

Advantages of C-TBNA

C-TBNA can obtain a satisfactory result in trained hands, with sufficient cytology and histology specimens for diagnosis. In fact, for a skilled expert, C-TBNA is not "blind", because CT and endobronchial landmarks could navigate the operator to the appropriate puncture sites. C-TBNA could be completed by regular bronchoscope without

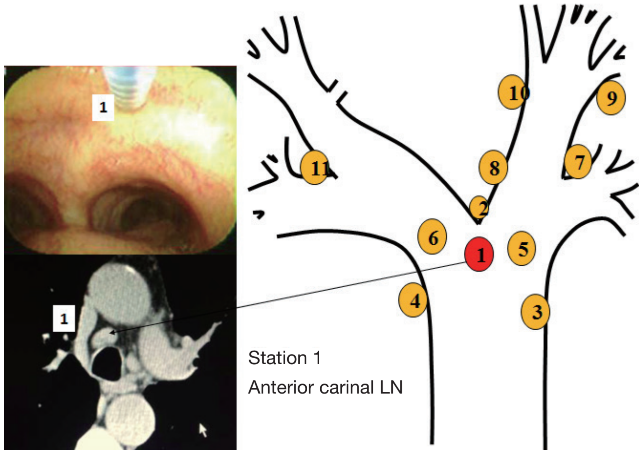

Figure 1 Station 1: anterior carina LNs are defined as LNs in front of the carina. LN, lymph node.

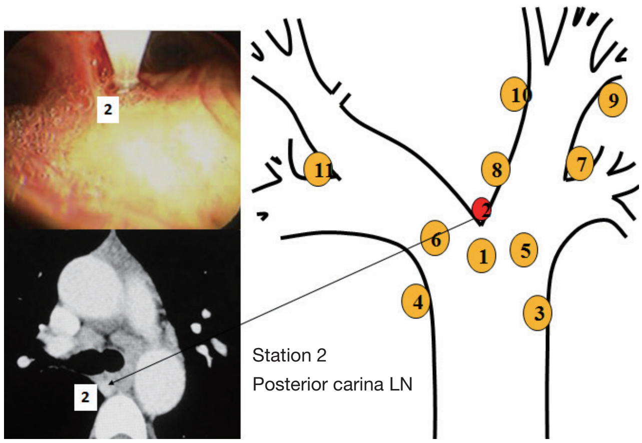

Figure 2 Station 2: posterior carina LNs are defined as LNs behind of the carina. LN, lymph node.

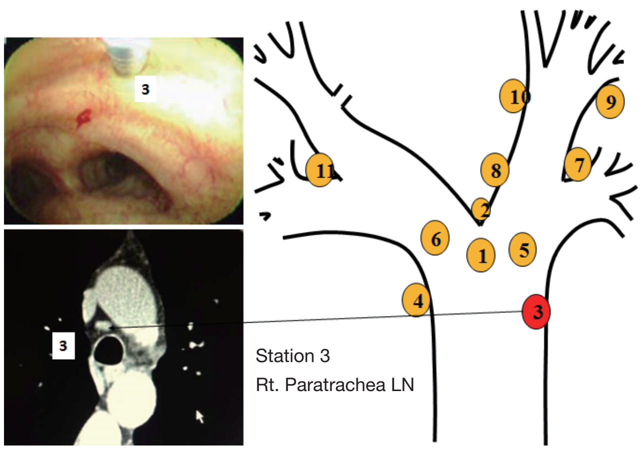

Figure 3 Station 3: right paratracheal LNs are defined as LNs above the azygos arch and more superior and lateral to the anterior carina LN. LN, lymph node.

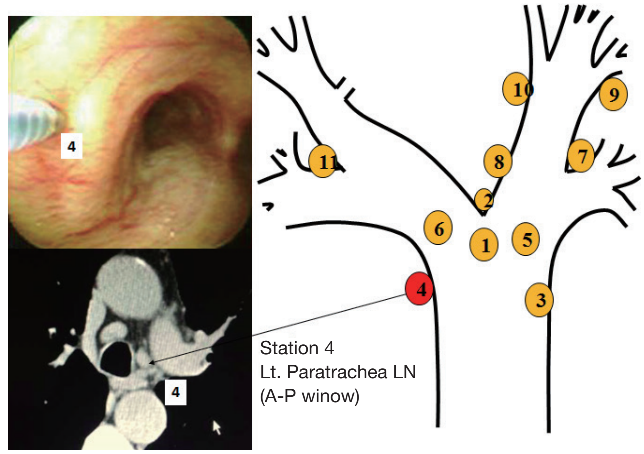

Figure 4 Station 4: left paratracheal LN is defined as the LN lateral to the left lower trachea. LN, lymph node.

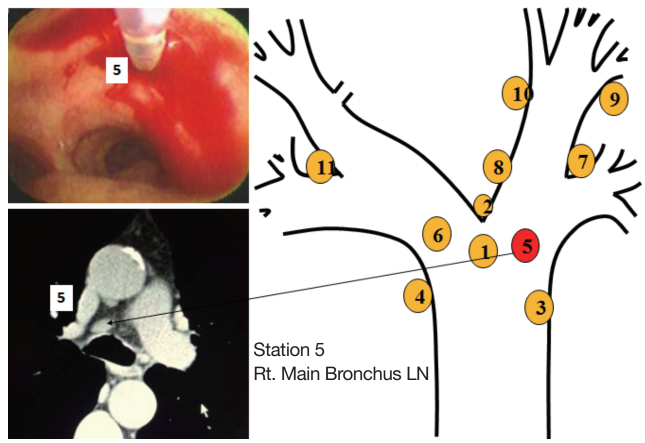

Figure 5 Station 5: right main bronchus LNs are defined as LNs inferior and lateral to the anterior carina, the puncture space should be between the first two bronchial cartilage rings anteriorly. LN, lymph node.

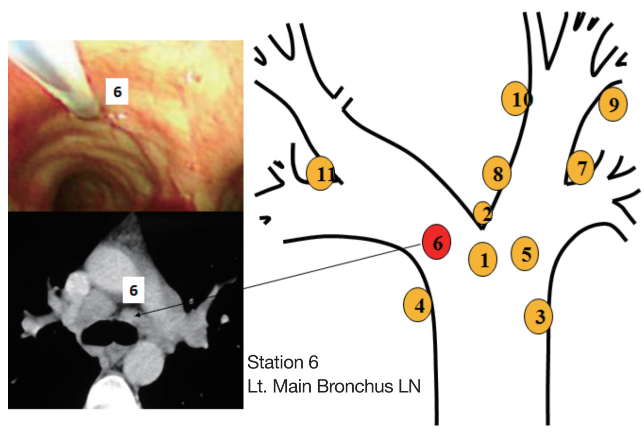

Figure 6 Station 6: left main bronchus LN is defined as anterior to the left main bronchus. LN, lymph node.

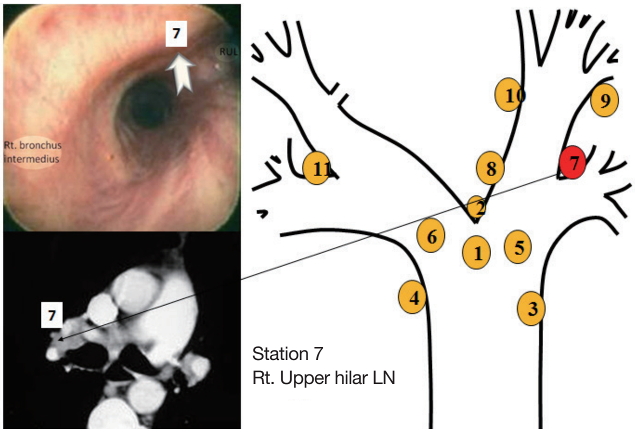

Figure 7 Station 7: right upper hilar LN is defined as in front of and between the right upper lobe and main bronchus. LN, lymph node.

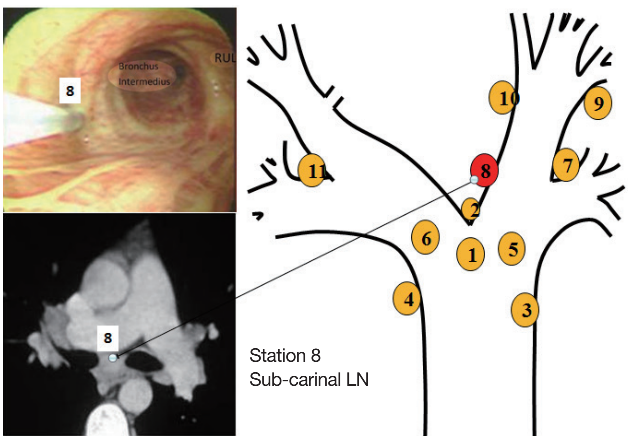

Figure 8 Station 8: sub-carina LN is defined as the LN next to the medial wall of the right main bronchus. LN, lymph node.

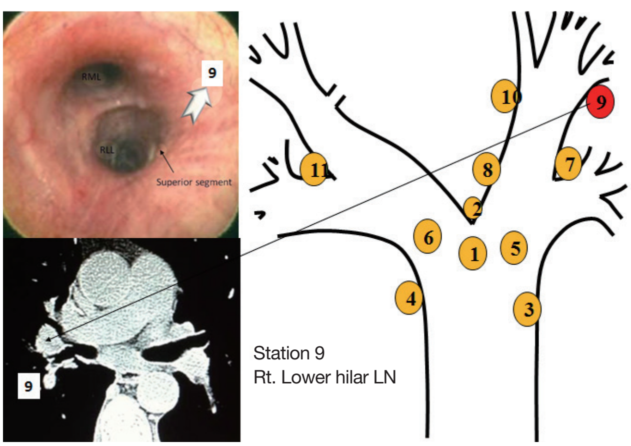

Figure 9 Station 9: right lower hilar LN is defined as the LN at the anterior lateral aspect of the bronchus intermedius. LN, lymph node.

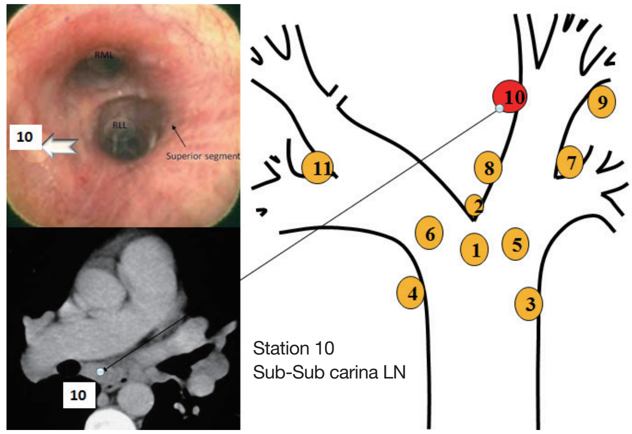

Figure 10 Station 10: sub-subcarinal LN is defined as medial to the bronchus intermedius. LN, lymph node.

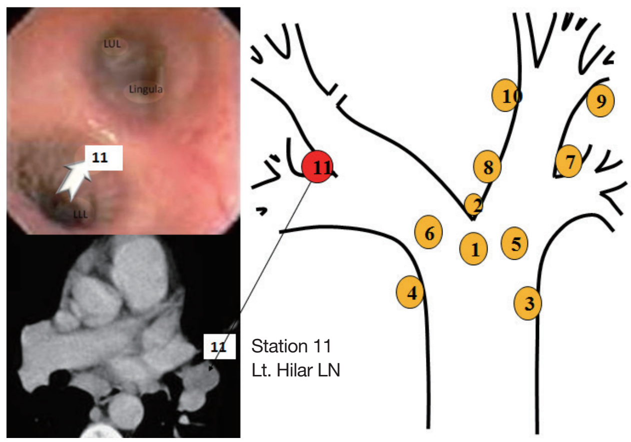

Figure 11 Station 11: left hilar LN is defined as the LN in between the left upper and lower lobe bronchi. LN, lymph node.

additional equipment, and it is relatively comfortable for the patient under local anesthesia. Compared with CP-EBUS equipment, there were more types of regular bronchoscopes could be chose for C-TBNA, for example a relatively smaller external diameter bronchoscope could be employed in C-TBNA in children or tracheobronchial stenosis patients, which were impossible for EBUS-TBNA (7). In addition, many types and variations of C-TBNA needles have been developed for puncturing central and peripheral area lesions. EBUS-TBNA requires its special CP-EBUS equipment, which is costly and may be unaffordable for some hospitals. Due to the addition of ultrasound probe, EBUS scope is less flexible compared with the regular bronchoscope, which required higher skill of scope handling and caused more invasiveness. Usually a second

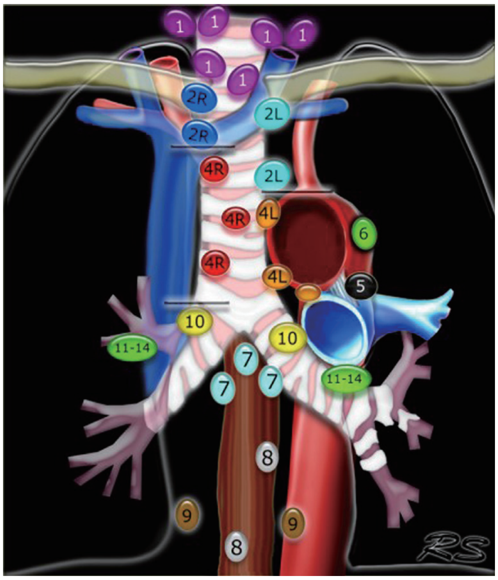

Figure 12 IASLC LNs map in 2009. IASLC, International Association for the Study of Lung Cancer; LN, lymph node.

scope was employed for regular examinations, inducing less convenience and more cost. EBUS-TBNA needle is more complex than the Wang C-TBNA needles. Completely removing the inner stylet is needed before applying suction, which complicated the procedure and added the contamination risk (12). Certain studies indicated that EBUS-TBNA performs better in terms of diagnostic yield and safety, while other studies reported that C-TBNA was comparable to EBUS-TBNA (15).

Limitations of C-TBNA

Because C-TBNA is performed without real-time ultrasound guidance, systemic training is the key important step. Poor training has resulted in lower yields and decreased use by general clinicians (4). Limitations to the practice of C-TBNA included operators' lack of systemic training, technical inadequacies, unfamiliarity with Wang needles, less confidence in C-TBNA, absence of trained pathologist in TBNA, and so on. Therefore, emphasis on anatomy, C-TBNA techniques, and specimen preparation may help to improve diagnostic yield. With more and more clinicians being skilled in C-TBNA, the less invasive, low-cost and safe procedure will be widely used (16). However, EBUS-TBNA is more sensitive in detecting small lesions, for beginners with low confidence EBUS-TBNA is a better choice, especially for lesions adjacent to vessels with higher risk of bleeding.

Operation of C-TBNA technology

Selection of the appropriate puncture site of C-TBNA

For beginners, learning LN anatomy is important and difficult. TBNA will not be effective unless the needle is aspirated into the desire lesion. Usually, CT examination, intraluminal landmarks and fluoroscopy are used to help choose puncture sites. Endobronchial location of common mediastinal and hilar LN chains could be easily recognized by experienced bronchoscopist. In 1994, Wang *et al.* selected 11 mediastinal and hilar LN stations which could be sampled easily and safely with the C-TBNA technique, and they systemically described the total 11 LN stations with CT and intraluminal landmarks correlations in Wang map (11), which made the TBNA biopsy of the mediastinal and hilar LNs from the airways accessible and simplified.

In order to help memory Wang map, 11 LNs can be summarized into three groups. Briefly, carina region is consist of station 1 (anterior carina) (*Figure 1*), 3 (right paratracheal) (*Figure 3*), 4 (left paratracheal or AP window) (*Figure 4*), 5 (right main bronchus) (*Figure 5*) and 6 (left main bronchus) (*Figure 6*); sub-carina region includes station 2 (posterior carina) (*Figure 2*), 8 (sub-carina, right upper lobe bronchus level) (*Figure 8*) and 10 (sub-subcarinal, right middle lobe bronchus level) (*Figure 10*); hilar region includes station 7 (right upper hilar) (*Figure 7*), 9 (right lower hilar) (*Figure 9*) and station 11 (left hilar) (*Figure 11*).

The latest IASLC map in 2009 (*Figure 12*), reformulate the anatomy boundaries of each LN station on basis of Naruke map and Mountain-Dresler modification of ATS map, making it more practical for TBNA procedure and TNM staging (17). Obviously, both Wang map and IASLC map are well documented and widely accepted system, it is absolutely imperative for bronchoscopists to fully understand these two maps for obtaining a better TBNA yield and accurate TNM staging.

Puncture techniques of C-TBNA

Four puncture technique methods of C-TBNA were described, including Jabbing method, Pushing method (piggy back method), Hub against the wall method and Cough method. Before the procedure, the operator should review CT to locate lesions for TBNA, using the LN map to choose appropriate puncture sites. Beginners often obtained lower TBNA yield because of some common mistakes, including failure in penetrating the bronchial wall completely and inappropriate aspiration angulation of the needle, and lesion missed despite adequate penetration and angulations. Besides, in order to protect the scope from damage, operator shouldn't be allowed to insert the needle into scope until confirm the needle tip inside the metal hub. When the needle is safely inserted and metal hub is visualized, operator advanced the needle and locked it. Then operator withdrew the whole catheter until only the distal tip of the needle being visible and advanced the scope to the target area. For peripheral lesions, after needle being located in proper puncture sites, X-ray is recommended to guide the TBNA.

Preparation of C-TBNA specimens and pathological reading

It is not a successful C-TBNA until satisfactory pathological results were obtained. There should no delay in preparation of specimens. In order to obtain qualified specimens and satisfactory pathological results, good communications should be developed between TBNA operator and pathologists. Rapid on-site evaluation (ROSE) of cytological specimens during TBNA is a useful ancillary technique, but is not a widespread technique, because of lack of time and resources. Furthermore, a board-certified cytopathologist was deemed as the gold standard to perform ROSE, however, recent study showed that a bronchoscopist could evaluate the adequacy of TBNA specimens on-site to diagnose hilar/mediastinal adenopathies/masses after receiving training in cytopathology (18).

New progress of TBNA technology

It is unwise to suggest that EBUS-TBNA replace C-TBNA as a standard initial examination for the diagnosis of mediastinal/hilar adenopathy. Improvements have been made to make C-TBNA fill clinical demand better, and further investigation is ongoing.

Application of DT new Wang needle

Original Wang needle has three types: Type I (single lumen fixed), Type II (double lumen retractable), and Type III (single lumen fixed, & mini trochar). Type I is convenient to use and has better flow, but less protection of the scope (by rounded tip guide wire). Type II has better protection of the scope but inconvenient because the guide wire needs to be completely removed for suction. Type III can avoid plug of the needle but less safer for the scope (by flat tip needle bevel tip guide wire). Modifications have been made to make DT new Wang needle simpler to use, safer and with a maximal flow. DT new Wang needle Type I (single lumen retractable), its suction is through the space between the wire and outer tube and transmitted to the tip of needle through a side cut hole at the proximal end of the needle. DT new Wang needle Type III, it is similar in principle as the original Wang Type II needle, which is double lumen retractable except the guide wire is attached to the plunger of a syringe. As suction is applied the tip of the wire is moved into the wider portion of the inner tube for flow. It is most easy to use and safe. DT new Wang needle Type IV is similar to needle 3 except the guide wire is attached to a hub with a Y two way adapter at the proximal end. The guide wire only needs to be partially retracted for suction. The flow of DT new Wang Needle Type III and IV is between the space of wire and inner tube, lesser then needle one but adequate to create a negative pressure immediately at the tip of the needle and obtain and keep the specimen at the distal end of the inner tubing rather than sucking it all the way up to the syringe. The Olympus EBUS needle using medal inner tube is stiffer and easier to control. The length of needle catheter can be adjusted and is the needle working length. The tip of the needle is treated for better US visualization. However, in fact, all these three changes are not that necessary, which makes the needle complicated and difficult to use. DT new Wang needle was designed able to be used for EBUS-TBNA and has been proven it can be used in the Olympus 2.2 mm EBUS scope. As for Fujifilm and Pentax scope because of the smaller lumen and more angle of the opening it need special attention, DT EBUS specific needle (Type V) has been developed. For Fuji scope, nitinol 522 needle was the best.

Addition of adapter in C-TBNA procedure

To improve the instrument and technique, a hybrid method is developed by using an adapter (*Figure 13*) as a third hand to hold the catheter onto the scope (19). Common mistakes for beginner will be avoided to some extent. The employment of "fixer" makes the pushing technique of C-TBNA more dependable and easier by ensure the complete penetration and proper perpendicular angle of the needle.

Application of Fujifilm EBUS scope

The bigger viewing field and external diameter of CP-EBUS scope make it is difficult to manipulate and unusable for

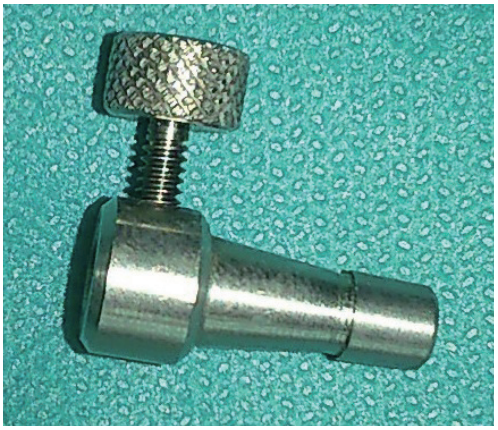

Figure 13 Adapter used in C-TBNA. C-TBNA, conventional transbronchial needle aspiration.

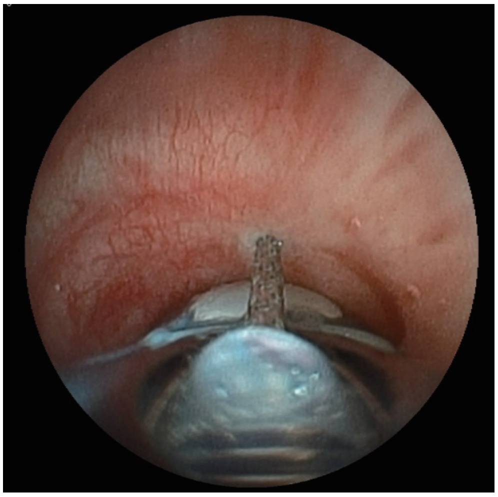

Figure 14 Endoscopic view of Fujifilm EBUS-TBNA. EBUS-TBNA, endobronchial ultrasound-guided transbronchial needle aspiration.

routine airway examination and biopsy. Adding more discomfort for the patient, often requiring general anesthesia, and usually being preceded by a regular bronchoscopy promoted the demand for improvement of EBUS scope. Fujifilm EBUS scope (EB-530 US) has a relatively smaller forward oblique view (10 degrees) and external diameter, which ensure a better endoscopic view while performing TBNA technology (*Figure 14*). Fujifilm EBUS scope decreases the need for a second scope and simplifies the TBNA with or without EBUS. Xiang *et al.* has successfully applied the Fujifilm EBUS scope to the patient (20).

Future of C-TBNA

C-TBNA has been a simple, economic useful technique for minimally invasive biopsy of mediastinal LNs and masses for decades, which has been widely applied in adult as well as children patients in the whole world. In consideration of past 30 years' insufficient use by clinicians, systemic training needs further improvement, and EBUS equipment may provide learning models for TBNA beginners. By using DT new Wang needle and fixer as a third hand in C-TBNA practice, common mistakes could be avoided, and a higher yield may be obtained. For years, lots of exciting new technologies such as (EBUS, ENB, virtual bronchoscopy) have refocused clinicians on TBNA and every bronchoscopists should receive high quality of systemic training for C-TBNA as well as EBUS-TBNA. In future, more improvements of TBNA technology should be made, including employing technological advances to perfect the instruments and techniques, focusing on patient comfort, optimizing yield, simplifying instruments, maximizing ease of use and minimizing training requirements for the pulmonologist. The ideal TBNA scope should be more like the new Fujifilm EBUS scope. Although it is under the guidance of ultrasound, it is still easy to operate as conventional bronchoscope. That will definitely simplify EBUS-TBNA and deserve further evaluation and study.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Cite this article as: Yang H, Zhang Y, Wang KP, Ma Y. Transbronchial needle aspiration: development history, current status and future perspective. J Thorac Dis 2015; 7(Suppl 4):S279-S286. doi: 10.3978/j.issn.2072-1439.2015.11.36

