TECHNOLOGICAL NOTE

Intrabronchial display of hilar-mediastinal lymph nodes by virtual bronchoscopic navigation system

Xiaodong Wu[1*] (ORCID), Lingzhi Shi[2*], Yang Xia[3], Ko-pen Wang[4] & Qiang Li[1]

1 Department of Respiratory and Critical Care Medicine, Shanghai General Hospital, Shanghai Jiao Tong University, Shanghai, China
2 Department of Respiratory Medicine, Wuxi People's Hospital, Nanjing Medical University, Wuxi, China
3 Department of Respiratory and Critical Care Medicine, Second Affiliated Hospital of Zhejiang University School of Medicine, Hangzhou, China
4 Division of Pulmonary and Critical Care Medicine, Johns Hopkins University, School of Medicine, Baltimore, Maryland, USA

Correspondence

Ko-pen Wang, Division of Pulmonary and Critical Care Medicine, Johns Hopkins University, School of Medicine, 733 N Broadway, Baltimore, MD 21025, USA.
Tel: +1 443 691 7696
Fax: +1 443 691 7696
Email: kopenwang@yahoo.com

Qiang Li, Department of Respiratory and Critical Care Medicine, Shanghai General Hospital, Shanghai Jiao Tong University, No. 100 Haining Road, Shanghai 200080, China.
Tel: +86 21 6324 0090 (Ext. 3142)
Fax: +86 21 6324 0090 (Ext. 3142)
Email: liqressh@hotmail.com

*These authors contributed equally to this work.

Abstract

The description of precise intrabronchial positions for the sampling of mediastinal-hilar lymph nodes is critical to successfully perform conventional transbronchial needle aspiration. Previously published maps of mediastinal-hilar lymph nodes were primarily drawn based on experts' experience. We generated a virtual map of the most frequently sampled intrathoracic lymph nodes from an intrabronchial perspective using a virtual bronchoscopic navigation system, to assist with training in conventional transbronchial needle aspiration.

Introduction

Transbronchial needle aspiration (TBNA) is now a well-established bronchoscopic technique for sampling mediastinal-hilar adenopathy and masses. This technique was first performed by Dr. Ko-Pen Wang in 1978 via the flexible bronchoscope, and revolutionized diagnosis of mediastinal and hilar adenopathy.[1] However, conventional TBNA (cTBNA) is a relatively blind technique, and thus remains underutilized because of concerns over safety and unpredictable sensitivity. Emerging endobronchial ultrasound-TBNA (EBUS-TBNA) has proven superior to cTBNA in terms of the diagnostic yield and safety because of direct visualization of the needle while crossing the tracheobronchial wall and sampling the lesions.[2–5] However, the requirement of high-cost equipment and general anesthesia limits the widespread application of EBUS-TBNA in less developed regions.[6,7] In contrast, cTBNA, with the use of regular equipment, lower cost, and ease of performance and training has the potential for wide application. An in-depth knowledge of lymph node (LN) positions from an intrabronchial view is a vital factor contributing to eventual diagnostic yield.

Table 1 Correlation between Wang's map and the IASLC map

Wang's map	IASLC map
Station 1, 3, 5	4R
Station 4, 6	4L
Station 2,8,10	7
Station 7, 9	11R
Station 11	11L

IASLC, International Association for the Study of Lung Cancer.

In 1994, Wang published a TBNA map of mediastinal-hilar LNs from an intrabronchial perspective based on his experience with conventional TBNA.[8] However, Wang's nodal map failed to present the precise intrabronchial areas that exactly display intrathoracic LNs. More concise and intuitive characterization of hilar-mediastinal LNs from an intrabronchial view would assist the cTBNA training process and promote its use.

An alternative approach to generate an intrabronchial view of hilar-mediastinal LNs is the use of a virtual bronchoscopic navigation (VBN) system. Virtual bronchoscopy is a method for displaying a three-dimensional (3D) view of the airway lumens by reconstructing the continuous volume data of helical computed tomography (CT), resembling the real-life bronchoscopic view.[9] It was originally intended to guide peripheral lung lesion sampling,[10,11] airway stenosis evaluation,[12] postoperative bronchial complications, and tracheal/bronchial injury.[13,14] We herein generate a virtual intrabronchial map of hilar-mediastinal LNs using a VBN
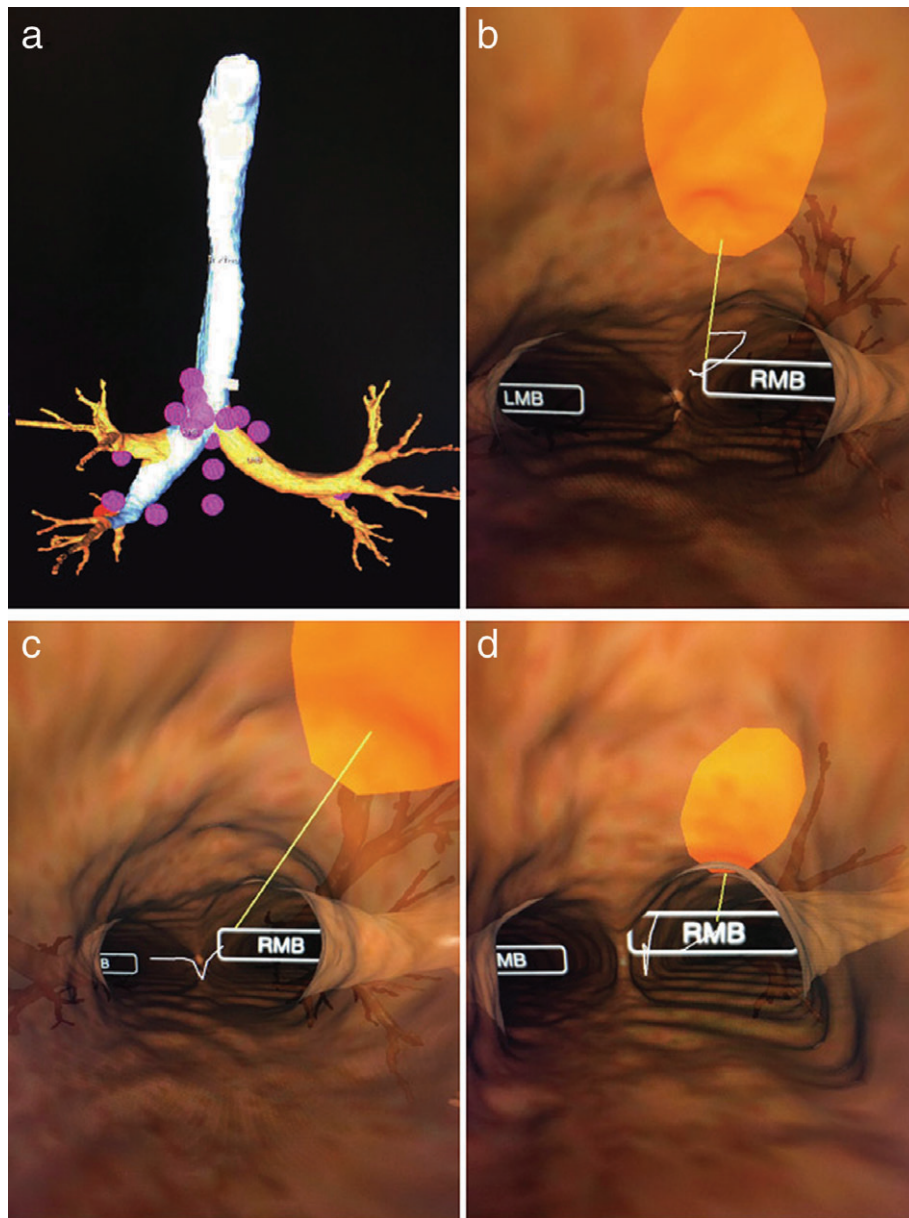

Figure 1 Virtual intrabronchial view of region 4R in the International Association for the Study of Lung Cancer map. (**a**) The three-dimensional view of intrathoracic lymph nodes. (**b–d**) Stations 1, 3, and 5 in Wang's lymph node map, respectively. LMB, left main bronchus; RMB, right main bronchus.

system to present an intuitive impression of the localization of biopsy sites for bronchoscopists.
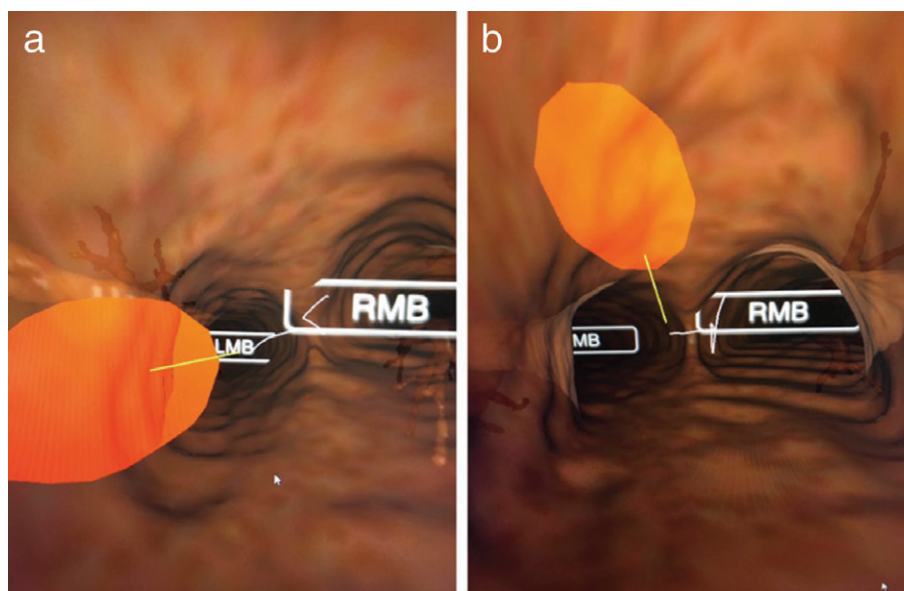
Methods

Using the SPiN Thoracic Navigation System (Veran Medical Technologies, St Louis, MO, USA), 3D spherical markers are placed in the location of intrathoracic LNs on a CT image. Subsequently, 3D images of the airway tree are automatically generated and the target LN is displayed in color by virtual bronchoscopic animation.

Results

We sequentially marked the anatomic location of intrathoracic LNs as the target, and then generated a virtual display from an intrabronchial perspective. To better illustrate intrathoracic LNs, we used both Wang's map and the International Association for the Study of Lung Cancer (IASLC) nodal map. The IASLC nodal map has been applied to describe tumor node metastasis (TNM) staging of lung cancer; the close correlation between Wang's map and the IASLC map has been widely recognized (Table 1).

Figure 1 shows the virtual intrabronchial display of 4R LNs in the IASLC nodal map (Fig 1a presents a 3D view of the intrathoracic LNs). According to Wang's LN map, station 1 anterior carina LNs are shadowed on the areas around the first tracheal cartilage ring and slightly toward the right (Fig 1b), while station 3 right paratracheal LNs are located around the third tracheal inter cartilaginous space above the carina at about the two o'clock position (Fig 1c). Right main bronchus (RMB) station 5 LNs are mapped above the opening of the RMB (Fig 1d).

Region 4L LNs in the IASLC map are illustrated in Figure 2. Station 4 left paratracheal LNs in Wang's map are displayed in the aortic-pulmonary artery window at approximately the nine o'clock position (Fig 2a), while station 6 left main bronchus (LMB) LNs are projected just above the opening of the LMB (Fig 2b).

Region 7 LNs in the IASLC map correlating to the posterior carina, subcarina, and sub-subcarinal LNs as station 2, 8, and 10 in Wang's LN map, respectively, are interpreted in Figure 3. The projection of station 2 is at the medial posterior wall of the opening of the RMB, station 8 is displayed on the carina and the medial wall of the RMB, and station 10 is shadowed at the medial posterior wall of the bronchus intermedius below the right upper bronchus.

Right upper hilar LNs in Wang's station 7, as well as right lower hilar LN in Wang's station 9 correlating with region 11R in the IASLC map are located at the anterior aspect of the right upper lobe spur and at the anterior lateral aspect of the bronchus intermedius (Fig 4a,b). Wang's station 11, known as left hilar LNs and identical to region 11L in the IASLC map, is displayed at the middle aspect of the left upper lobe spur (Fig 4c).

Discussion

In this report, we generated an endobronchial map of intrathoracic LNs using a VBN system. This virtual map concisely illustrates the endobronchial locations of the most frequently sampled LN stations, including 4R/L, 7R/L, 10R/L, and 11R/L in the IASLC nodal map.

The first advantage of this virtual map is the 3D reconstruction of the helical chest CT, reflecting actual anatomical structure and avoiding the potential bias of subjective factors compared to previous maps. Secondly, virtual bronchoscopy
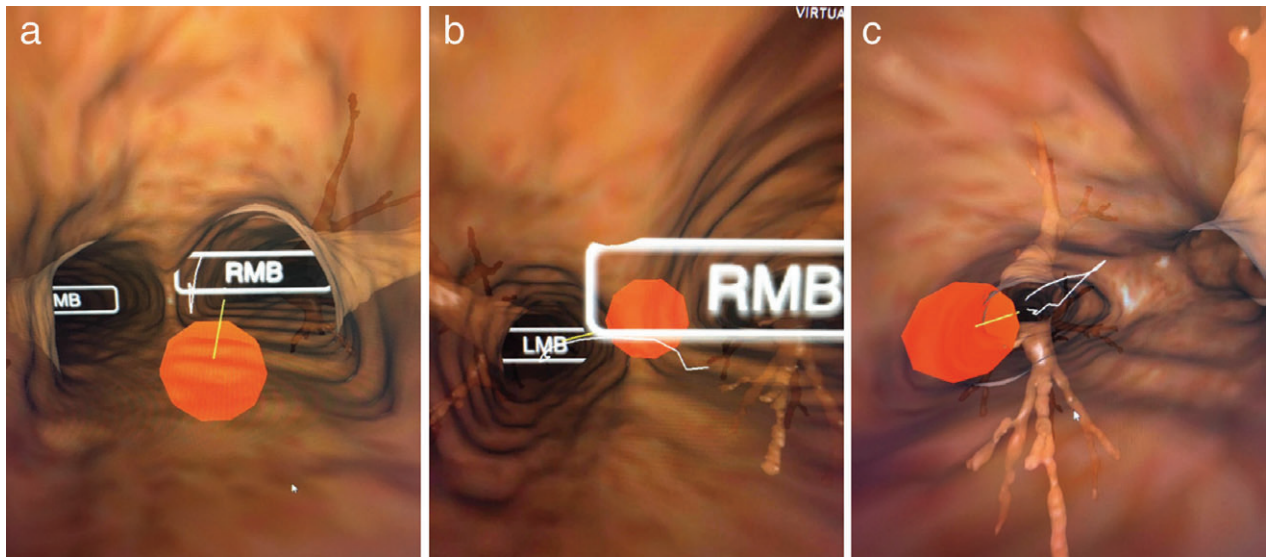
Figure 2 Virtual intrabronchial view of region 4L in the International Association for the Study of Lung Cancer map. (**a,b**) Stations 4 and 6 in Wang's lymph node map, respectively. LMB, left main bronchus; RMB, right main bronchus.

Figure 3 Virtual intrabronchial view of region 7 in the International Association for the Study of Lung Cancer map. (**a–c**) Stations 2, 8, and 10 in Wang's lymph node map, respectively. LMB, left main bronchus; RMB, right main bronchus.

can be utilized as guidance for cTBNA procedures, especially to train beginners, as virtual bronchoscopy images resemble the live bronchoscopic view so well that they could facilitate the determination of the exact puncture sites for target LNs. Thirdly, VBN may show an advantage for some LN stations that have unclear intraluminal landmarks in contrast to LN stations with clear landmarks. For instance, before performing cTBNA of nodal station 2 in Wang's map, we have to undergo a thorough review of chest CT images to locate the level of opposite bronchial cartilaginous ring. However, VBN guidance would skip this step and directly navigate the operator to the puncture site. Fourthly, using a next-generation VBN system, virtual image information of the large vessels outside the bronchus could also be superimposed on the live bronchoscopic images during cTBNA, hence averting the incidence of severe bleeding from large vessel injuries. Finally, for LNs or lesions adjacent to the secondary or tertiary bronchi that cannot be reached by EBUS-TBNA, virtual bronchoscopy-assisted cTBNA would be applicable to achieve cytopathological evaluation.

Interestingly, this virtual map has high consistency with Wang's map.[15] The efficiency of cTBNA in sampling
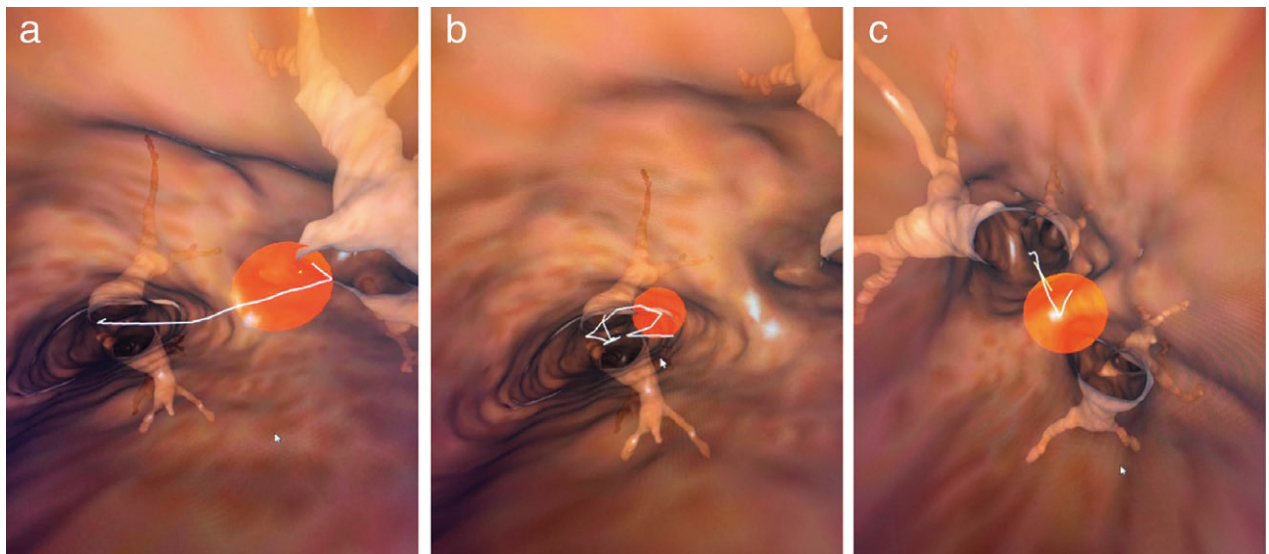

Figure 4 Virtual intrabronchial view of regions 10R and 10L in the International Association for the Study of Lung Cancer map. (**a–c**) Stations 7, 9, and 11 in Wang's lymph node map, respectively.

intrathoracic LNs guided by Wang's map demonstrates the accuracy of puncture positions. The sensitivity of cTBNA for detecting and staging lung cancer is reported to be between 60% and 90%,[16,17] the accuracy of diagnosis of tuberculous lymphadenitis is 50–85%[18] and 20–60% in sarcoidosis.[19,20] Our map further validated the accuracy of Wang's map for the depiction of puncture sites for cTBNA.

Another map of optimal TBNA areas for intrathoracic LNs has been proposed based on pictures drawn by four experienced physicians from three centers.[21] It is notable that this LN position map has good consistency with our virtual map and Wang's map, especially of stations 4L, 11R, and 11L. However, the authors described LNs using the IASLC map, which has shown limitations in guiding TBNA compared to Wang's map.[22] Hence, the LMB, RMB, posterior carina, and sub-subcarinal LNs are not mentioned in this map, which further explains the lack of agreement on station 4R.

Our virtual map of intrathoracic LNs from an intrabronchial view might be helpful to train physicians for cTBNA because of its visual impression. The virtual navigation system has the advantage of real-time guidance for cTBNA procedures, which could be further investigated in the future.

Disclosure

No authors report any conflict of interest.

References

1 Wang KP, Terry P, Marsh B. Bronchoscopic needle aspiration biopsy of paratracheal tumors. *Am Rev Respir Dis* 1978; **118**: 17–21.

2 Bonifazi M, Tramacere I, Zuccatosta L *et al*. Conventional versus ultrasound-guided transbronchial needle aspiration for the diagnosis of hilar/mediastinal lymph adenopathies: A randomized controlled trial. *Respiration* 2017; **94**: 216–23.

3 Herth F, Becker HD, Ernst A. Conventional vs endobronchial ultrasound-guided transbronchial needle aspiration: A randomized trial. *Chest* 2004; **125**: 322–5.

4 Herth FJ, Eberhardt R, Vilmann P, Krasnik M, Ernst A. Real-time endobronchial ultrasound guided transbronchial needle aspiration for sampling mediastinal lymph nodes. *Thorax* 2006; **61**: 795–8.

5 Madan K, Dhungana A, Mohan A *et al*. Conventional transbronchial needle aspiration versus endobronchial ultrasound-guided transbronchial needle aspiration, with or without rapid on-site evaluation, for the diagnosis of sarcoidosis: A randomized controlled trial. *J Bronchology Interv Pulmonol* 2017; **24**: 48–58.

6 Pastis NJ, Simkovich S, Silvestri GA. Understanding the economic impact of introducing a new procedure: Calculating downstream revenue of endobronchial ultrasound with transbronchial needle aspiration as a model. *Chest* 2012; **141**: 506–12.

7 Casal RF, Lazarus DR, Kuhl K *et al*. Randomized trial of endobronchial ultrasound-guided transbronchial needle aspiration under general anesthesia versus moderate sedation. *Am J Respir Crit Care Med* 2015; **191**: 796–803.

8 Wang KP. Staging of bronchogenic carcinoma by bronchoscopy. *Chest* 1994; **106**: 588–93.

9 Kiraly AP, Helferty JP, Hoffman EA, McLennan G, Higgins WE. Three-dimensional path planning for virtual bronchoscopy. *IEEE Trans Med Imaging* 2004; **23**: 1365–79.

10 Ishida T, Asano F, Yamazaki K *et al*. Virtual bronchoscopic navigation combined with endobronchial ultrasound to diagnose small peripheral pulmonary lesions: A randomised trial. *Thorax* 2011; **66**: 1072–7.

11 Asano F, Matsuno Y, Shinagawa N *et al*. A virtual bronchoscopic navigation system for pulmonary peripheral lesions. *Chest* 2006; **130**: 559–66.

12 Hoppe H, Dinkel HP, Walder B, von Allmen G, Gugger M, Vock P. Grading airway stenosis down to the segmental level using virtual bronchoscopy. *Chest* 2004; **125**: 704–11.

13 De Wever W, Vandecaveye V, Lanciotti S, Verschakelen JA. Multidetector CT-generated virtual bronchoscopy: An illustrated review of the potential clinical indications. *Eur Respir J* 2004; **23**: 776–82.

14 Allah MF, Hussein SR, El-Asmar AB *et al*. Role of virtual bronchoscopy in the evaluation of bronchial lesions. *J Comput Assist Tomogr* 2012; **36**: 94–9.

15 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): S279–86.

16 Vitale C, Galderisi A, Maglio A *et al*. Diagnostic yield and safety of C-TBNA in elderly patients with lung cancer. *Open Med (Wars)* 2016; **11**: 477–81.

17 Harrow EM, Abi-Saleh W, Blum J *et al*. The utility of transbronchial needle aspiration in the staging of bronchogenic carcinoma. *Am J Respir Crit Care Med* 2000; **161**: 601–7.

18 Bilaçeroğlu S, Günel O, Eris N, Çağırıcı U, Mehta AC. Transbronchial needle aspiration in diagnosing intrathoracic tuberculous lymphadenitis. *Chest* 2004; **126**: 259–67.

19 von Bartheld MB, Dekkers OM, Szlubowski A *et al*. Endosonography vs conventional bronchoscopy for the diagnosis of sarcoidosis: The GRANULOMA randomized clinical trial. *JAMA* 2013; **309**: 2457–64.

20 Tremblay A, Stather DR, MacEachern P, Khalil M, Field SK. A randomized controlled trial of standard vs endobronchial ultrasonography-guided transbronchial needle aspiration in patients with suspected sarcoidosis. *Chest* 2009; **136**: 340–6.

21 Roth K, Eagan T, Hardie J. Expert opinion of mediastinal lymph node positions from an intrabronchial view. *BMC Pulm Med* 2016; **16**: 15.

22 Xia Y, Ma Y, Arias S, Lee H, Wang KP. Utilization of the International Association for the Study of Lung Cancer and Wang's nodal map for the identification of mediastinum and hilar lymph nodes. *Thorac Cancer* 2015; **6**: 464–8.