Electromagnetic navigation bronchoscopy under intravenous sedation—tips and tricks

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Abstract: Electromagnetic navigation bronchoscopy (ENB) is gaining acceptance and popularity amongst bronchoscopists as one of the tools to diagnose pulmonary nodules (PNs). Although the majority of ENBs in earlier studies were performed under general anaesthesia (GA), later reports suggest that the diagnostic yield of ENB under intravenous sedation (IVS) was comparable, and was time saving. ENB under IVS may potentially improve access of the techniques to practitioners and patients. However, it is technically challenging when compared to its performance under GA. This article reviews the techniques required for ENB under IVS to maximize its diagnostic yield and safety.

Keywords: Electromagnetic navigation bronchoscopy (ENB); pulmonary nodule (PN); sedation; anaesthesia

Introduction

Pulmonary nodules (PNs) is an increasing diagnostic challenge, because of its increasing detection by widespread availability of computed tomography (CT) scanning, and the concern that it may be malignant in nature.

When a biopsy is necessary to obtain a diagnosis for PNs, CT-guided transthoracic needle aspiration (CT-TTBA) has traditionally been recommended because of its high diagnostic yield (~90%); however, CT-TTBA carries a relatively high risk of iatrogenic pneumothorax (up to 25%) (1,2). Several guided bronchoscopy methods are developed to diagnose PN, including electromagnetic navigation bronchoscopy (ENB), radial endobronchial ultrasound (R-EBUS) and virtual bronchoscopy (VB). Collectively they have better diagnostic yield (pool diagnostic yield 70%) over traditional flexible bronchoscopy (FB)/transbronchial biopsy (TBBx) and lower complication rate over CT-TTBA (3).

ENB is gaining acceptance and popularity amongst bronchoscopists as one of the tools to diagnose PNs. It can be used on its own, or be combined with R-EBUS to enhance the diagnostic yield (4,5). ENB can be carried out under general anaesthesia (GA) or intravenous sedation (IVS), although GA appears to be favoured by the majority of practitioners (6,7). It has been suggested that GA may reduce patient's movement and cough, allows better alignment of the patient's anatomy during bronchoscopy and the planning CT thorax, and thereby improves diagnostic yield. In a meta-analysis, GA was associated with better diagnostic yield (69.2% *vs.* 57.5% in studies with IVS, P=0.02) (6). However, in a retrospective review of 107 patients (120 target lesions), no difference in diagnostic yield was found between GA *vs.* IVS (8). Duration of ENB was the only significant difference between the GA (mean 58 min) *vs.* IVS (mean 43 min) groups (P=0.0005). The authors suggested that the time saved with ENB under IVS may allow more procedures to be performed, with greater flexibility in scheduling.

The prevalence of PNs appears to be much higher in Asia versus Europe and North America (9). On the other hand, the evaluation of PNs in Asia is complicated by the high prevalence of tuberculosis (TB) and the fact that non-smoking history does not have any weight in discounting malignancy risk (10). Therefore, an Asian consensus guideline suggests less reliance on PET scanning, surgical diagnosis or surveillance, and it is in favour of more non-surgical
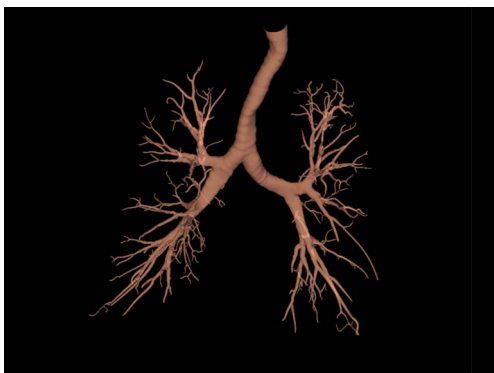
Figure 1 Example of a 3-dimensional reconstructed depiction of bronchial tree using an ENB software. ENB, electromagnetic navigation bronchoscopy.

biopsies (e.g., CT-TTBA or guided bronchoscopy) (11). In this context, it is anticipated that the need for ENB will continue to expand in Asia. To be able to perform ENB under IVS will be of great advantage in view of the high volume of cases expected in Asia, and ENB under IVS allows greater access of this technology to patients and practitioners.

This article describes the techniques involved in biopsying small PNs by ENB under IVS in the authors' department. The techniques aim to maximise the yield of ENB and related techniques under IVS.

ENB under IVS

Sedation

Intravenous opioid and benzodiazepine and/or propofol are necessary for ENB performed under IVS. Opioids that have been used by various authors include fentanyl and morphine; midazolam is the preferred benzodiazepine (12). It should be noted that ENB tends to be a more prolonged procedure when compared to conventional FB (mean 8–9.3 additional minutes) (13,14), with a total procedure time variously reported between 25.7 and 70 minutes (6,7). Therefore it is often necessary to give additional boluses of IVS during the procedure if the effect of the previous doses is wearing off, with higher total doses. Well-trained physicians, nurses and/or respiratory therapists proficient in airway management during moderate to deep IVS are highly recommended to manage the patient during ENB (8). The authors' department prefers IV pethidine/diazepam for their longer half-lives than fentanyl/midazolam combination.

Topical anaesthesia

Lidocaine gel (2%) can be used for nasal topical anaesthesia. Lidocaine spray (10%, 10 mg per actuation, 2–5 actuations) provides oro-pharyngeal topical anaesthesia. Lidocaine (1%, 10 mg/mL) should be used to provide topical anaesthesia of the vocal cords and trachea-bronchial tree during ENB, using a spray-as-you-go technique as in standard FB (15). Similar to IVS, it is often necessary to give additional aliquots of lidocaine during ENB to maintain topical anaesthesia of the vocal cords and trachea-bronchial tree.

Current evidence suggests that lidocaine doses up to 15.4 mg/kg may be used without serious adverse events, but subjective symptoms of lidocaine toxicity (e.g., dizziness, euphoria) were reported in studies using ≥9.6 mg/kg lidocaine (15). It is the authors' practice to limit total lidocaine dose (nasal, oropharyngeal, vocal cords and trachea-bronchial tree) to <9.6 mg/kg especially in patients with cardiac, hepatic or renal dysfunction, and in older patients.

Anti-cholinergics (e.g., atropine, glycopyrrolate) are not routinely recommended during FB (15). In an occasional patient in whom excessive secretions interfere with the alignment process (between CT images and patient's anatomy) for ENB, or obscure the visualization of small peripheral bronchi, anti-cholinergics may become necessary.

Monitoring

All patients undergoing ENB should have heart rate (continuous electrocardiogram), respiratory rate, blood pressure and oxygen saturation monitored regularly before, during and after the procedure as for standard FB (15).

ENB

Excellent review is available that describes the techniques of ENB performance in details (12). Briefly, during the planning phase, data from CT images is loaded onto an ENB software. The target lesion is identified, and pathways to the lesion (via the bronchial tree) are planned semi-automatically with the planning software. Once planning is complete, a 3-dimensional reconstructed view of the bronchial tree (*Figure 1*) with planned route(s) to the lesion is generated by the ENB software (*Figure 2A,B,C,D*). Animated VB that replicates the exact view that will be seen during ENB is also available with the software (*Figure 3A,B*).

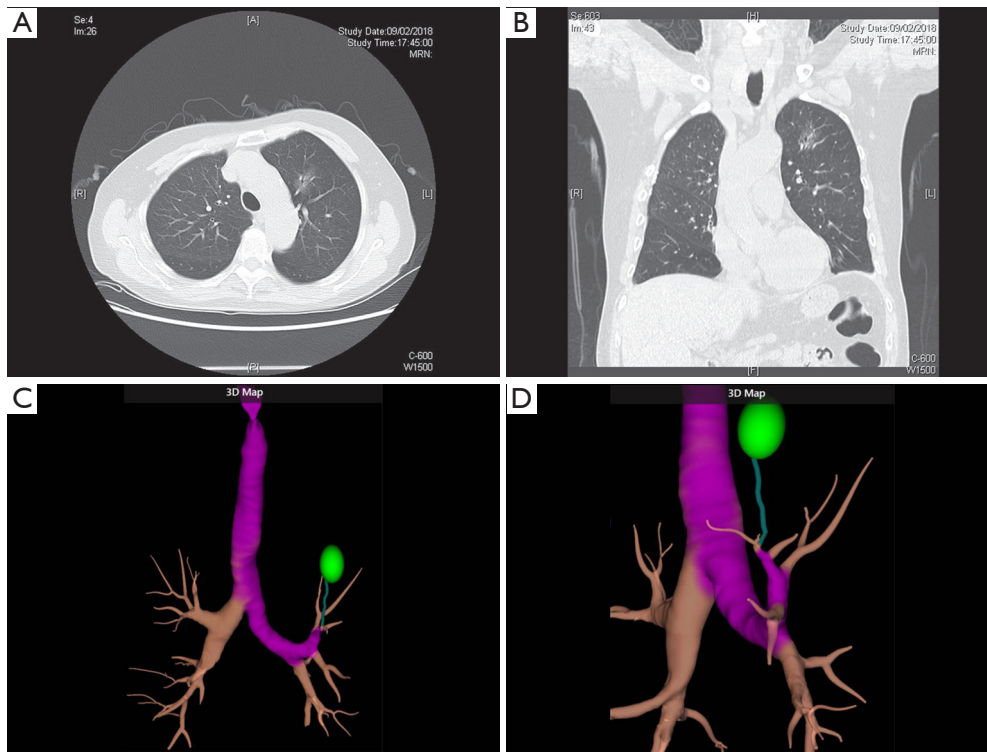During the procedure phase, a surveillance bronchoscopy

Figure 2 Example of a small pulmonary nodule and the planned pathway to access it. (A) CT thorax image of a ground glass nodule (1.5×2.6×2.7 cm, W × AP × CC) located in the left upper lobe anterior segment (LB3), transverse plane; (B) CT thorax image of a ground glass nodule (1.5×2.6×2.7 cm, W × AP × CC) located in the left upper lobe anterior segment (LB3), coronal plane; (C) 3-dimensional reconstructed view of the pathway leading to the left upper lobe lesion (frontal view); (D) 3-dimensional reconstructed view of the pathway leading to the left upper lobe lesion (magnified and rotated view).
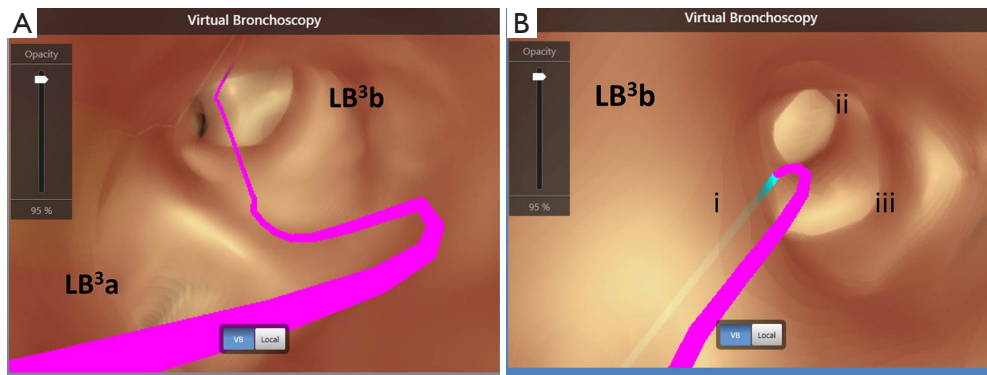

Figure 3 Animated virtual bronchoscopic view of the pathway leading to the small pulmonary nodule in *Figure 2*. (A) Virtual bronchoscopic image of the left upper lobe anterior segment, with highlighted pathway leading to the lesion (purple line) in *Figure 2*; (B) virtual bronchoscopic image of the anterior subsegment (LB3b) of the left upper lobe, with highlighted pathway leading to the lesion (purple line) in the apical division (LB3bi).

is first performed to clear secretions, instill topical anaesthetic and exclude endobronchial lesion. A location board that emits electromagnetic waves is placed on the patient's body.

A sensing device is then inserted into the working channel of the bronchoscope, and the bronchoscope is advanced into various part of the bronchial tree to allow automatic
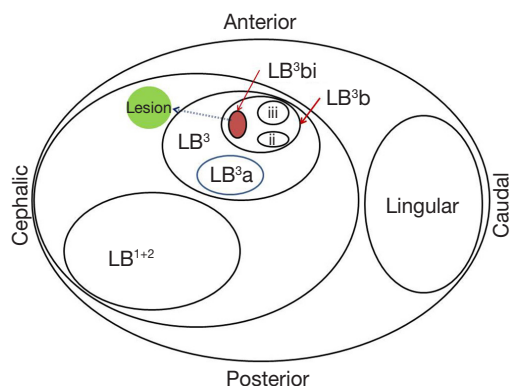
Figure 4 Manual map of the bronchial branch leading to the lesion in *Figure 1*. It is designated as LB3bi.

matching of the CT images with the real life anatomy of the patient (registration). Once registration is satisfactory, navigation can proceed. The bronchoscope is guided by the sensing device to reach the lesion (analogous to driving with Global Position System guidance), using pre-planned pathway(s) within VB images that are displayed side-by-side with the actual bronchoscopic images. When the tip of the sensing device is aligned with and in close proximity to the target lesion, it is recommended to confirm navigation success with R-EBUS before sampling, which will increase diagnostic yield (4).

Sampling methods

It is important to recognize that navigation success does not necessarily equate sampling success. Various anatomical and technical factors may negatively impact sampling success in ENB. One example is the small calibre of bronchus leading to the small PN, which may restrict the opening of the biopsy forceps. Another example is a lesion that does not have a "bronchus sign" on CT. This feature is shown to be associated with a lower yield in meta-analysis (6). Rapid on site evaluation (ROSE) may help to assess the quality of the sampled materials to make a diagnosis, and may help to decide whether additional samples are necessary (6,7).

Sampling methods of ENB is similar to conventional FB, which includes transbronchial needle aspiration (TBNA), TBBx, brush cytology, targeted bronchoalveolar lavage (BAL). Catheter suction (aspirating material by continued suction by a 10-mL syringe and moving the catheter back and forth) was reported to increase the diagnostic yield over TBBx (16). Biopsy forceps and cytology brush generally

follows that path of the airway, whereas transbronchial needle and needle brush can penetrate outside the bronchial wall ("off-road" tools). The authors generally use TBNA and needle brush if the lesion does not have a bronchus sign, or is not directly aligned with the supplying bronchus, in addition to TBBx and regular brush cytology.

Complications of ENB

Severe complications are seldom encountered. A pneumothorax rate of 3.1% (95% CI: 2.1–4.3%) was reported, in which 1.6% (95% CI: 1.0–2.6%) required chest tube drainage. Minor or moderate bleeding was reported in 0.9% (95% CI: 0.4–1.6%), none of them required specific treatment (6). It is believed that the bronchoscopic instrument (e.g., extended working channel) that is wedged in the sub-segment harbouring the PN provides tamponade of the bleeding source.

Manual mapping

Because of the relatively long procedure time of ENB when compared to conventional FB, it is desirable to contain or reduce the procedure time of the former, so that patients are not given IVS and topical anaesthesia excessively. The authors find it rewarding to spend more time at the planning phase, and to mentally rehearse the pathways to the lesion before the actual navigation. This will allow the navigation to be more focused at the likely bronchial branch(es) leading to the lesion at each successive generation, instead of a trial-and-error approach to test each potential division.

To assist the mental rehearsal, it is useful to manually draw map of successive bronchial branches leading to the lesion. Manual mapping method has previously been described using thin-cut CT thorax with detailed analysis of the bronchial branches (17). The ENB software provides a 3-dimensional reconstructed view of the bronchial tree and animated VB with the planned route to the target lesion. Such features facilitate manually drawing of bronchial map to the lesion (*Figure 4*). Understanding the map of the bronchial branch(es) leading to the lesion allows rapid navigation to the target.

For the purpose of accurate documentation, it is useful to name successive bronchial branches systematically. The authors modify from a previously described nomenclature system (18) as follows:

(I)   The segmental bronchus is designated according to the Nomina Anatomica (e.g., RB[1], RB[2], etc.);

(II) The more peripheral bronchi are designated sequentially, using (a/b/c, i/ii/iii, α/β/γ, x/y/z) for third-, fourth-, fifth- and sixth-order bronchi;

(III) The axial plane is considered first, with the more apical bronchus receiving the smaller letter/number;

(IV) The antero-posterior axis is considered the second, with the more posterior bronchus receiving the smaller letter/number;

(V) Then the lateral bronchus receives the smaller letter/number.

An example is given in *Figure 4*.

Alternatives to ENB

There will be a minority of patients who cannot be adequately sedated with the above approach, making ENB (registration and/or navigation, see below) difficult. In such circumstance, conversion to examination by an ultra-thin bronchoscope (UTB) with multi-modality guidance (*vide infra*) usually allows the procedure to be continued with better tolerance because of a smaller bronchoscope size. If ENB is not possible and UTB is non-diagnostic, patient may need to have ENB under GA or have surgical biopsy of the PN.

Ultra-thin bronchoscopy guided by multi-modal devices

Apart from ENB, TBBx using R-EBUS and VB have been reported to have good diagnostic yield for small PNs (19,20). Since the ENB software provides 3-dimensional images of the bronchial tree and animated VB, it can be easily adapted to guide an UTB to the target. Using the manual mapping method with VB images described above, UTB assisted by R-RBUS and fluoroscopy (21) can be used to target PNs without the need for electromagnetic guidance, with potential for substantial cost savings.

There is no randomized controlled trial directly comparing the diagnostic yields of ENB with UTB/R-RBUS/VB. In the interim, the authors favour the use ENB in patients with:

(I) unclear distal bronchial branches (due to imperfect CT quality), or

(II) ground glass lesions (less distinct on R-RBUS when compared to solid lesion), or

(III) lesion adjacent to a bronchial branch, rather than surrounding a bronchial branch, in which the diagnostic yield was reported to be less with R-EBUS (22).

On the other hand, patient's tolerance to UTB maybe better in view of the smaller size (3.0 mm). The authors routinely prepare an UTB to back up ENB in case the patient does not tolerate ENB.

Conclusions

ENB is gaining acceptance and popularity amongst bronchoscopists as one of the tools to diagnose PNs. To be able to perform it under IVS may improve access of the technology to practitioners and patients, which is an advantage in Asia in view of the high PN burden. VB software and manual mapping can facilitate navigation, and potentially shorten procedure time. They also facilitate the use of UTB (in combination with R-RBUS and fluoroscopy) as an alternative to ENB in specific patient subgroups.

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None.

Footnote

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

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