C-Arm Based Tomosynthesis for real-time Augmented Fluoroscopy imaging during Robotic Bronchoscopy

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Introduction:

The widespread availability and use of computed tomography (CT) have led to increased nodule detection rate that prompted a need for improved technology to aid in diagnostic procedures. In the modern era of diagnostic bronchoscopy, there has been an advent of innovative platforms, including electromagnetic navigation bronchoscopy (ENB) and robotic-assisted bronchoscopy (RAB). However, bronchoscopists continue to have substantial challenges and have not achieved the diagnostic yield seen with a transthoracic approach [1]. One of the main reasons for this shortcoming is the presence of CT-Body Divergence (CTBD). Combining artificial intelligence (AI) guided real-time imaging such as C-arm Based tomosynthesis (CABT) with navigation platforms can potentially help improve diagnostic yield and accuracy.

Indications:

ENB and RAB have proprietary software that uses a pre-procedure CT scan of the chest with a thin-slice protocol (1mm thickness) that is obtained at full inspiration (Total lung capacity - TLC) to build a virtual-navigation pathway for intra-procedural guidance. CTBD results from a physiological difference in lung volume that shifts airway anatomy and location of the lesion that may affect the intra-procedural accuracy. During the procedure, patients are under positive pressure and not at TLC, whereas during the CT they were at TLC, with a breath hold, and not under positive pressure. Furthermore, anatomical positional differences with respect to the positioning of the arms (upright), chest wall, which is expanded and lateralized at the time of imaging are different from the time of the procedure; the development of intra-procedural atelectasis secondary to lower lung volumes, higher FiO2 during anesthesia, procedural time and bronchoscopic tool manipulation of the airway, may also contribute to the deviation of the actual real-time pathway from the prior virtual pathway created. This variation has been studied with a pre-procedure CT performed at full inspiration and expiration in 46 patients (85 lesions) that detected an average motion of 17 mm in all lesions [2]. Similarly, another study that looked at planning CT and intra-procedure CBCT reported an average divergence of 14 mm [3]. This has been documented and noted across several peripheral navigation platforms (ENB and RAB) [4].

The role of real-time imaging (CABT) to confirm lesion location serves an essential role in diagnostic procedures. For parenchymal lesions, depending on the location of the lesion, CTBD can significantly affect the relationship in the positioning of the tool and lesion. CTBD is noted to be highest in the lower lobes and although there are strategies that can be used to minimize CTBD and atelectasis (eg. adjusting ventilator settings), knowing a real-time relationship between tool and the target lesion adds significant value intra-procedurally and may increase the diagnostic yield when used in conjunction with navigation platforms [3,4].

Planning:

For our procedures, we use the Monarch® system as the navigation platform (Auris Health, CA) and Lung Vision (Body Vision Medical Ltd, Israel) device for augmented fluoroscopic imaging, which connects to our standard OEC Elite c-arm (GE).

Body Vision's proprietary technology, Lung Vision, utilizes CABT which allows for updated confirmation of a lung nodule in real time based on tomosynthesis registration of the lesion. The system uses any standard C-arm to reconstruct a 3-dimensional intraprocedural image of the target, thus overcoming CTBD. Additionally, the Body Vision platform provides fluoroscopic visualization of pre-planned pathways and visualization of tool to lesion relationship, both of which can help fine-tune the bronchoscope's position regardless of the navigation platform used. A pre-procedure CT scan is uploaded to the tablet, and the lesion pathway is marked. A CT scan is also uploaded to the Monarch planning software which performs the airway segmentation and a virtual pathway is created to the lesion.

There are several ways to minimize CTBD. In our practice, we employ a ventilation protocol of PEEP of 10, a tidal volume of 6-8 ml /Kg pre-

dicted body weight, and a FiO2 of 0.4 or less as allowed by oxygen saturation and hemodynamic stability. Once under general anesthesia, a 2-step registration is performed to integrate the pre-operative CT scan with the C-arm spin tomosynthesis. The first step is registration of the main carina which is performed with a C-arm spin typically from -35 degrees to +35 degrees (LAO to RAO) after which the C-arm is iso-centered on the lesion and registration of the lesion is performed with breath-hold with APL of 20cm. This process takes about 2-3 minutes. After registering the lesion, the C-arm is pulled back, and an inspection bronchoscopy is performed for airway surveillance to rule out central airway lesions and to clear secretions. After the survey, the robotic bronchoscope is introduced to navigate to the lesion. The bronchoscope is advanced till about 2cm from the lesion (Figure 1A). The C-arm is then iso-centered back on the lesion and final navigation and positioning is performed before sampling.

Sampling:

After the final navigation is performed to the updated target location, a radial EBUS is advanced to identify and confirm the lesion location, proximity to the scope and to understand better the relationship with respect to the working channel to the best of the ability (Figure 1B). If no radial EBUS imaging is obtained (Figure 1C), as is the case in a semisolid and ground glass nodule, sampling is performed based on the target location obtained by tomosynthesis (Figure 1D). A biopsy tool, either needle or forceps, is used for sampling. Once the bronchoscope and tool are advanced to the lesion, another spin can be performed before the biopsy to visualize the tool-lesion relationship to obtain real-time feedback and confirm "tool in lesion". All biopsy specimens are then reviewed with the onsite pathologist to ensure adequate qualitative and quantitative sampling (Figure 1E). We terminate the procedure by slowly withdrawing the bronchoscope while ensuring that there is no bleeding with 5-10 ml saline irrigation.

Of note, we routinely use radial EBUS for our bronchoscopic procedures targeting lung nodules. Published data show increased yield in lesions that give a concentric view (84%) vs. eccentric view (48%) [5]. However, radial EBUS can give pseudo-assurance of positioning as it can be affected by atelectasis or tool-related manipulations that lead to microhemorrhages. At our institution, we performed a retrospective study of 45 patients who had a diagnostic bronchoscopy that combined these technologies with an average lesion size of 16 mm. A radial EBUS confirmation was obtained in 73% of cases, and an immediate diagnosis was obtained in 38 of 45 cases (84%); 32 cases were malignant and six were consistent with specific benign etiology. The other 7 lesions demonstrated inflammation (n=4) or were non-diagnostic/atypical (n=3). Of these 7, two had stable findings at 1-year follow-up and one had a surgical wedge biopsy that was benign, leading to an overall diagnostic accuracy in 41/45 (91%) [6].

Quality control:

Real-time imaging is possible via radial EBUS and/or fluoroscopy (Cone-beam CT and CABT) to provide additional insight at the time of the procedure. While CABT represents a useful tool, the resolution needs to improve further. With the added use of CABT, increased radiation exposure, fluoroscopy time and procedure time is possible and studies evaluating these factors in CABT with RAB need to be performed. Currently, the radiation dose from a Lung Vision procedure is 1/3rd that of Cone Beam CT. The diagnostic accuracy even with use of real time imaging is not a 100% and there is limitation to the “tool in lesion” concept and a bronchoscopist must use appropriate clinical judgement in decision making in non-diagnostic cases.

Conclusion:

Given the current ability of newer platforms to navigate further into the lung parenchyma, the use of augmented fluoroscopy to obtain intra-procedural imaging helps better define the tool-lesion relationship and assist the bronchoscopist in maneuvering while increasing the yield and accuracy in diagnosis of peripheral lung nodules, thus limiting the need for additional procedures.

References:

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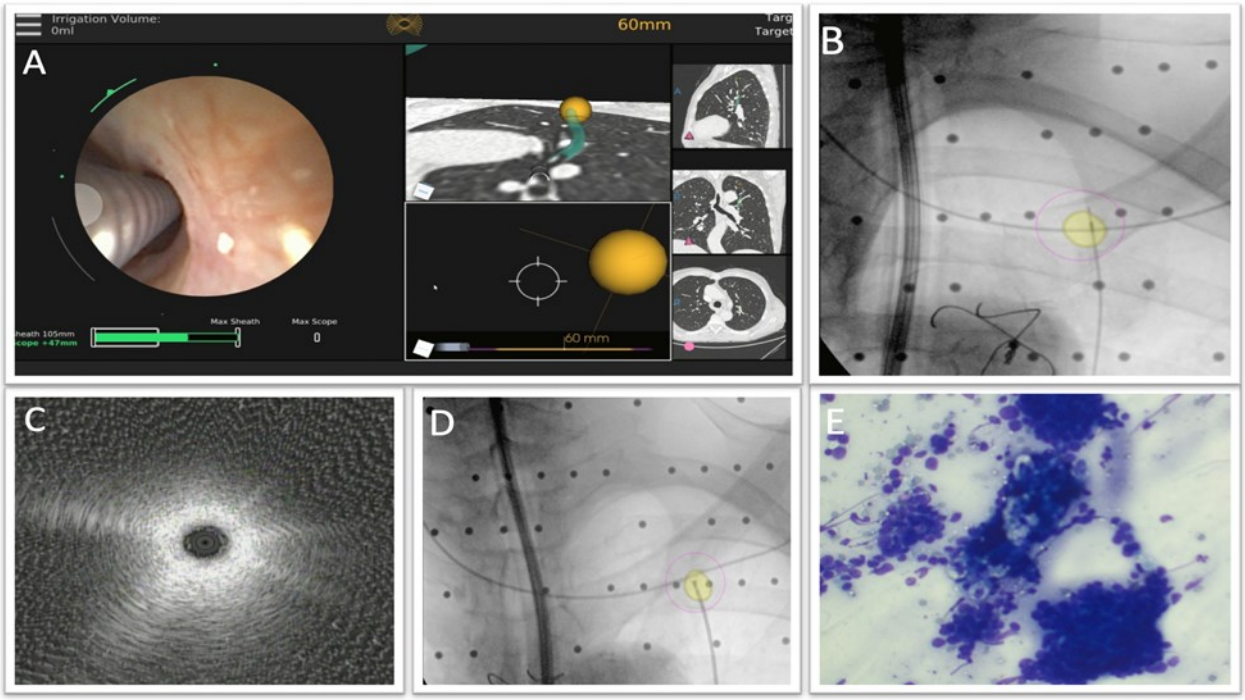

Figure 1: A: Robotic bronchoscopy Navigation, B: Radial EBUS advanced to the location of the nodule as determined on the CABT images post registration (Yellow spot marks the nodule), C: Radial EBUS advanced to the lesion but no ultrasonographic imaging of the nodule obtained, D: Biopsy of the nodule with forceps, E: Rapid onsite evaluation of the nodule biopsy showing non-small cell lung cancer with final path revealing poorly differentiated squamous cell lung cancer.