**Introduction**

Transthoracic needle biopsy (TNB) is often performed in the clinical routine to further evaluate pulmonary lesions. Indications for TNB are a new or enlarging pulmonary, mediastinal, pleural or hilar nodule or mass [1, 2]. Relative contraindications are an uncooperative patient (cough, altered consciousness), bleeding diathesis, contralateral pneumectomy, hypervascular lesion or severe chronic obstructive pulmonary disease [1–7]. In 20 to 30% of patients, a...
pneumothorax occurs during or after the intervention. 2.4% require thorax drainage [8–11]. Minor hemoptysis occurs in 3.8% of procedures [8–10]. Adequate samples are obtained in 98% of the biopsies [8]. The complication rate is reduced with a smaller needle diameter [11]. With 18-gauge coaxial needles available for several years now, some authors found no significant difference with respect to the rate of pneumothorax of Tru-cut biopsies in comparison with fine needle aspiration (FNA) [12–14]. However, some authors state a loss of accuracy when using smaller diameters [15]. Advantages of using a coaxial needle are the possibility of collecting multiple histological samples once the needle is in position while FNA only delivers cytological samples. Saline injection through the needle has been proposed for further reduction of the pneumothorax rate [16, 17]. Although ultrasound-guided biopsies are possible if the lesion is in close proximity of the thorax wall [18, 19] and MR-guided biopsies are safely feasible [20], CT-guided biopsies deliver adequate samples in most cases and are performed most frequently due to system availability [1–4, 8]. However transbronchial biopsy lesions or resectional biopsy may be alternative methods to obtain histological samples [21, 22]. Punctures using CT fluoroscopy in order to control the needle position may be advantageous in small lesions or patients who cannot hold their breath [23–25]. The application of a breath-hold control system with CT fluoroscopy is reported to decrease radiation exposure time and needle puncture attempts [25]. A disadvantage of this technique is the higher radiation exposure for the examiner [24, 25]. Very often an intermittent control of the needle trajectory is performed by means of the acquisition of a few CT sections.

In order to properly superimpose the geometry of the target lesion during imaging and needle (re-)positioning steps, it is crucial to maintain the same geometry and this includes the respiratory position of the patient, since breathing may shift the location of a pulmonary lesion by several centimeters [26–28]. Especially in small target lesions with diameters of approx. 1 cm, the target may be missed due to different respiratory positions. However, patients do not always succeed in reaching the same respiratory state.

In this prospective study we evaluated the effects of a biofeedback device that shows the breathing position to the patient. Our hypothesis was that using the biofeedback device would decrease the standard deviation of the table position from the target lesion during intervention. If this proved to be true, we also wanted to test whether the procedure time and number of imaging steps would be reduced. Finally, we wanted to study the influence of the device on the success of transthoracic CT-guided lung biopsies.

**Materials and Methods**

A Tru-cut biopsy was performed on 36 patients (4 female, 32 male, mean age 65 years; range 33–88) with a peripheral intrapulmonary nodule of unknown etiology with a diameter of greater than 1 cm. We excluded patients with impaired coagulation (Platelet count <100000/mm³, INR >3.0), respirational insufficiency (PO₂<60 mmHg), contralateral pneumectomy or pulmonary hypertension since elevated complication rates are associated with these conditions [21]. The intervention was executed using a strict sterile technique and local anesthesia, after a pre-interventional interview and written consent according to the declaration of Helsinki. In half of the patients (2 female, 16 male, mean age 67 years), an interactive breath-hold control system (IBC, Mayo Clinic Medical Devices, USA) was applied and the patients were instructed how to resume the same respiratory position (IBC group). This device detects the respiratory position using a strain detector on a belt (Fig. 1). This belt was positioned around the thorax or abdomen at a position that showed the maximal excursion during breathing. After the definition of the expiration position, the device showed the current relative respiratory position on an LED array. No additional device was used in the other half of the patients (control group). The biopsy was executed using a 64-row dual-source CT scanner (Somatom Definition, Siemens, Forchheim, Germany) using the i-sequence protocol. Prior to the intervention the target lesion was delineated using a helical scan (64x0.6 mm, 120 kV, 110 mAsEeff, pitch 0.9). In order to define the puncture location and the in-plane trajectory, a grid was positioned on the surface of the patient. Intersection of an interlobar fissure with the needle was avoided. After the in-plane trajectory of needle was planned, the puncture site was marked on the skin. Cutaneous sterilization and application of drapes were then performed. Local anesthesia (Mepivacain, 0.5%) was administered at the puncture site. An 18-gauge Tru-cut needle (Cardinal Health, Dublin, UK) was inserted. Using intermittent CT guidance to check the needle trajectory, the needle was advanced into the lesion (Fig. 2). During these steps patients were asked either to hold their breath in end-expiration (control group) or to resume the respiratory position as the IBC indicated (IBC group). The i-sequence protocol was used in this phase (12x1.2 mm, 120 kV, 80 mAsEeff). This scanning protocol imaged 12 contiguous CT sections with a thickness of 1.2 mm and was centered at the needle position. Depending on the size of the nodule, two to six core biopsies were obtained and the needle was removed. The intervention was completed with a post-interven-

![Fig. 1](image1.png) The interactive breath-hold control system (IBC, Mayo Clinic Medical Devices, USA) consists of a strain detector belt and a display as shown on this image. After initialization during expiration, the device indicated the current relative strain on the belt respective to the respiratory position on an LED array.

**Abb. 1** Wie auf diesem Bild gezeigt, besteht das interaktive Atemkontrollsystem (IBC, Mayo Clinic Medical Devices, USA) aus einem dehnungs- sensitiven Gurt und einer Anzeige. Nach der Initialisierung in Expiration zeigt das Gerät die Abweichung der Dehnung, somit die relative Atemlage, auf der LED-Anzeige an.
tional control scan, which imaged the biopsy site using a helical scan in order to assess possible complications such as bleeding or early pneumothorax (64×0.6 mm, 120 kV, 110 mAeff, pitch 0.9). Follow-up chest X-rays were taken two and four hours after the intervention to further detect a developing pneumothorax.

The time required for the instruction of the patient and application of the IBC device, the duration of the intervention procedure from the definition of the needle position until the removal of the biopsy needle, the technical success of the biopsy and the size and depth of the target lesion were recorded. Furthermore, the table position of the target lesion in each imaging step during the puncture procedure and the number of imaging steps were analyzed after the intervention. The pathology report was also evaluated with respect to the adequacy of the biopsy material for diagnosis.

We used an independent two-sample t-test to inspect the influence of the IBC device after calculating the standard deviation of the position of the target lesion during the intermittent imaging steps for every patient. We furthermore applied an independent two-sample t-test to decide whether the intervention time and number of imaging steps were smaller in the group using the IBC.

**Results**

The biopsy needle hit the target lesion in all patients. With a diameter of 30±19 mm in the IBC group and 28±15 mm in the control group, the size of the target lesion was comparable in both groups. The distance between the body surface and center of the lesion was almost identical in both groups; 81.2±24 mm in the IBC group and 80±22 mm in the control group. The two groups also showed no significant difference with respect to patient age: 67±13 years in the IBC group and 63±12 years in the control group.

As shown in **Fig. 3**, the number of imaging steps per intervention was significantly (p<0.05) smaller in the IBC group (8.8±5.1) compared to the control group (12.9±5.4).

The effect of the IBC on the standard deviation of the lesion location is shown in **Fig. 4**. The table position of the target lesion showed a significantly (p<0.05) smaller deviation in the IBC group (2.3±2.0 mm) compared to the control group (3.9±2.2). The histogram in **Fig. 4** shows that one patient did not get along with the IBC device. However, none of the patients were removed from the statistical analysis.

The regression analysis shows (**Fig. 5**) that the intervention time in the 36 patients was dependent on the number of imaging steps per intervention.
It required 4 ± 2 min to install IBC device and explain it to the patient. The intervention time was 17 ± 10 min in the IBC group and 26 ± 12 min in the control group (Fig. 6). Using a single-sided two-sample t-test, the reduced intervention time in the IBC group was statistically significant (p < 0.05). If the installation and instruction time is added to the duration of the intervention in the IBC group, no statistically significant difference remains between the two groups in our sample (IBC: 21 ± 10 min, control 26 ± 12, p = 0.061).

Following the intervention, 10 patients developed a pneumothorax (28%). Thorax drainage was applied in 2 patients (6%). One Patient had a short episode of hemoptysis (3%). 4 Patients from the IBC group and 7 patients from the control group developed complications.

A malignant histology was found in 29 patients (81%). This included adenocarcinoma (10 patients), squamous cell carcinoma (6 patients), metastasis (5 patients), small cell lung cancer (1 patient), sarcoma (1 patient) and dedifferentiated carcinoma (6 patients). Silicotic or hyaline nodules were diagnosed in 7 patients (19%).

Discussion

The intention of the use of the IBC device is to help the patient to resume a constant exhalation position during the imaging and intervention steps of the procedure. It is easy to imagine that pain and disconcertment hamper a consistent exhalation position in the patient. In our study we were able to show that the IBC is able to significantly (p < 0.05) reduce the variance of the lesion position during the imaging steps of the intervention. With less movement in the IBC group, fewer readjustments of the trajectory of the needle are necessary. Since each readjustment means further application of X-rays, the employment of an IBC system also reduces patient radiation exposure. The time for each imaging and intervention step was comparable in both groups. The resulting intervention time was significantly (p < 0.05) shorter in the IBC group than in the control group. One could speculate that an increase in the interventionist’s confidence regarding lesion location during the interventional steps after using the IBC for a while might further accelerate interventions since greater confidence in the geometry could mean more expeditious advancement of the needle. Other studies demonstrated that lung biopsies are feasible in one breath-hold using CT fluoroscopy [24, 25]. The efficiency of a comparable system in CT fluoroscopy-guided punctures with regard to intervention time and a reduction in the pneumothorax rate has been reported [25]. The advantage of intermittent imaging, as used in our study, is that the interventionist can leave the examination room during the imaging steps so that there is virtually no staff radiation exposure. The intervention time does not include the additional time needed to install the IBC system and to instruct the patient, but these tasks did not necessitate the presence of a doctor. If these times are included in the analysis, there is no statistically significant difference between both groups even if one could speculate about a trend towards a shorter intervention time since the p-value is p = 0.061 in our sample. Thus, our data does not provide any evidence that the occupation time of the CT scanner is reduced using the IBC device.

Since all procedures were successfully completed, no evidence was found that the application of the IBC system influences the outcome of the intervention. The sample size was considered too small to examine whether the application of the IBC...
system influenced the complication rate. However, the complication rate was consistent with other publications [8–11]. Other assisting devices for CT-guided biopsies have been proposed and tested [24, 25, 29, 30]. The principle of many systems is to project the trajectory of the needle on the body of the patient. This approach might be prone to errors if the patient changes his position slightly. This occurs inadvertently by changing the depth of breath. The current system helps the patient to repeatedly find the same position for breath-holds, so that errors should be significantly reduced.

The variance of the intervention time challenges schedules of the CT scanner and it is not easy to estimate the duration of the intervention, which depends also on the patient’s ability to cooperate. In our institution we are able to quickly fill up unused times that were reserved for interventions with on-call in-patients. However, the application of the IBC device helped to decrease the time that required the presence of the interventionalist.

**Conclusion**

The patient group in which the IBC device was used showed a significantly smaller standard deviation of the relative lesion position in the imaging steps as compared to the control group. Fewer imaging steps were needed to reach the target lesion in the IBC group. Since each imaging step involves radiation exposure, the application of the IBC device is expected to reduce radiation exposure. With each imaging step taking comparable time in both groups, the IBC device helped to reduce intervention times in CT-guided Tru-cut biopsies of lung nodules. Since it is known that intervention duration is positively correlated with complication rates [10], this might help to further reduce complications.

**References**