Navigated Liver Biopsy Using a Novel Soft Tissue Navigation System versus CT-Guided Liver Biopsy in a Porcine Model:

A Prospective Randomized Trial

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Rationale and Objectives: The aim of this prospective, randomized animal study was to compare a new computer guided needle–based navigation system for liver biopsy with conventional computed tomography (CT)-guided liver biopsy. Computer-navigated interventions provide continuous needle tracking during motion and deformation from patient respiration and movement.

Materials and Methods: Twenty artificial tumors of about 5 mm in diameter were injected into the livers of five pigs, each at a different site. Each tumor was targeted by conventional CT-guided and computer navigated intervention. Intervention was considered complete after successful tumor biopsy. Data on procedure time, number of CT scans performed, accuracy, and success rate were recorded.

Results: All tumors (100%) were biopsied successfully. Mean procedural time was comparable between the two techniques (20 ± 9 minutes conventional versus 20 ± 8 minutes navigation). Mean number of CT scans were 1.2 ± 0.4 with navigation and 6.1 ± 3.8 with the conventional technique ($P < .01$). The dose-length product in the conventional group was significantly higher (212 ± 116 mGy $\times$ cm) than in the navigated group (78 ± 22 mGy $\times$ cm; $P < .001$). Mean number of capsule penetrations was 4 ± 1 with navigation versus 2 ± 1 with the conventional technique ($P < .001$).

Conclusion: Computer-navigated liver biopsy may provide a promising and innovative device for easy, rapid, and successful liver biopsies with low morbidity. Further technical improvements and clinical studies in humans are required.

Key Words: Liver simulator; liver biopsy; image-guided therapy; navigated biopsy; CT-guidance.

Convergent developments in radiology, teletransmission, computer science, and surgical innovations have allowed for the development of image-guided surgery and navigation. These techniques are well-established in the daily routine in orthopedic, neuro-, and head and neck surgery for improving precision and minimizing radiation exposure (1–3). However, the use of computer navigation systems for interventions in soft organs with motion and deformation, such as the liver (4) is not yet established and constitutes an area of current research (5–11).

In cooperation with the German Cancer Research Center (Heidelberg, Germany), an image-guided navigation system was developed using optical tracking including fiducial needles in combination with preprocedural computer tomography (CT) imaging. After promising results with in vitro studies (7,12–14), we examined common clinical procedures in the liver to select a clinical relevant standardized procedure to evaluate technical aspects of computer navigation and allow comparison to current clinical practice (15). Based on this examination, we chose to evaluate CT-guided liver biopsy with and without the use of our novel soft-tissue navigation system.

Percutaneous liver biopsies allow physicians to obtain tissue for diagnostic and therapeutic purposes with significantly less

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morbidity and mortality than invasive procedures such as surgery (16). Since Paul Ehrlich's first liver biopsy in 1883, technical aspects have been continuously refined. Image-guided biopsies further decrease procedural risks and allow physicians to access lesions that are deep or are surrounded by complex anatomic structures. Currently, almost all tissues are accessible using the percutaneous biopsy approach. Depending on the size and location of the lesion to be sampled, CT, ultrasound (US), fluoroscopy, or magnetic resonance imaging (MRI) are used for biopsy needle guidance. For difficult lesions, CT-guided liver biopsies are the most common technique (17). However, biopsies of small liver lesions (<1 cm) are still challenging and multiple passes are often required, increasing the risk of complications. With both US- and CT-guided procedures, an overall accuracy rate of 90%–98% can be achieved (18,19). Nevertheless, a lack of real-time data during CT-guided biopsy, as provided by navigation systems, limits the utility of CT guidance. Additionally, repeated CT scans to confirm the position of the needle tip increase radiation exposure and operation time. Implementation of optical tracking in the procedural algorithm of CT guided biopsy based on only one preinterventional CT scan would allow the radiologists to perform real time procedures with reduced radiation risk.

The aim of this prospective randomized trial was to assess a novel computer-guided navigation system for liver biopsy by comparing it with conventional CT-guided interventions in a porcine model.

MATERIALS AND METHODS

Experimental Setting, Artificial Tumor Placement, and Parameters

Five female German landrace pigs weighing 30–45 kg were given ad libitum access to food and water and fasted for 12 hours before the experiments. Animals were housed at the Animal Resource Service Facilities at the University of Heidelberg according to the procedures outlined in "Guide for the Care and Use of Laboratory Animals" of the National Academy of Sciences. The anesthetic protocol we followed is standardized and has been used for many years in different porcine studies (20,21). Briefly, after initial sedation by intramuscular injection of 5 mg/kg ketamine hydrochloride (Ketanest S, Pfizer, Freiburg, Germany), 0.1 mg/kg midazolam (Dormicum, Roche, Mannheim, Germany), and 0.5 mg/kg azaperone (Stresnil, Jansen-Cilag, Neuss, Germany), general anesthesia was induced with tracheal intubation and a mixture of oxygen, nitrous oxide, and Isoflurane (Abbott, Chicago, IL).

After midline laparotomy and exposure of the liver, liquid contrast–enhanced blue-colored agar (a pinch blue color [Coomassie brilliant blue] and 15:1 mixture of 5% agar and contrast medium [Ultravist, Schering, Berlin, Germany]) was injected into the liver parenchyma at four different sites imitating artificial tumors of about 5 mm in diameter. Blue color was added to the agar mixture to easily distinguish the artificial lesions from liver parenchyma in the extracted specimen. The tumor size of less than 1 cm was chosen because of published data showing increased difficulties in successful biopsies of small tumors. Overall, 20 tumors were placed in five different pigs as deep as possible in the parenchyma of all three major lobes (22). The abdominal wall was then closed and the sedated and intubated pigs were transferred to the experimental radiology unit.

The sequence of the procedures (conventional versus computer navigated) was selected by randomization. All scans were performed using the same commercially available helical CT scanner (Toshiba Aquilion 16 slice multidetector CT scanner, Toshiba, Tokyo, Japan). An experience radiologist (B.R.) performed all conventional CT-guided procedures using a semiautomatic biopsy gun with integrated coaxial needle (BioCut Integral 16 G, 25 cm, Bioservice SpA, Poggio Rusco [MN] Italy). Because of the excellent results in preliminary tests evaluating the navigation system, all computer-navigated interventions were performed by one intern in radiology (S.R.) with an optically trackable biopsy gun (12,23). In both settings, the following parameters were recorded.

1. Mean procedural time (scouting, planning, targeting, and performing successful biopsy) and overall number of CT scans. The entire procedure was repeated four times to access the four tumors in each pig. Time end point was successful tumor biopsy.
2. Success rate in tumor biopsy. A successful tumor biopsy was defined as the presence of a fragment of blue agar in at least 50% of the specimen or with a length of at least 3 mm, according to the recommendations of our pathologists.
3. Number of biopsy passes for successful soft agar extraction.
4. Number of attempts at needle positioning, including number of liver capsule penetrations.
5. Penetration angle of the needle to the body surface.
6. Iatrogenic complications including persistent intraabdominal bleeding after relaparotomy and accidental penetration of other abdominal or thoracic organs.
7. To obtain a dose quantity describing the radiation exposure for a complete examination the dose-length product was used (in units mGy × cm).

The Committee for Animal Care and Research of the Karlsruhe regional council approved this study.

Conventional CT-guided Liver Biopsy

An unenhanced preinterventional CT scan of the liver was used to determine the simplest approach to biopsy the tumor. A set of needles placed on the pigs' body, visible on the second CT scan, served as a navigation aid to plan the trajectory (11,14). Thereafter, the insertion point was identified and the biopsy needle was aligned with the trajectory. Then, the biopsy needle was gradually advanced or redirected under apnea while its position was reassessed by repeat CT scans.