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Breast biopsy navigation system with an assisted needle holder tool and 2D graphical user interface

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ABSTRACT

Objective: This paper proposes the development of a breast biopsy navigation system with an assisted needle holder tool for a coaxial needle and a graphical user interface, which utilizes an optical tracking device to localize the needle position relative to the ultrasound image with the aim to improve performance especially for a new radiologist or an inexperienced group.
Materials and methods: The system consists of an assisted needle holder tool, which as an attachment for the 2D ultrasound transducer and the graphical user interface (GUI) that shows the needle pathway, needle line and warning signs. An optical tracking system is used to track the needle motion, ultrasound image and transform all information to with respect to the technique. The system is evaluated using a phantom made from gel candle. There were nine experienced and eight inexperienced participants who performed the breast biopsy intervention, using three methods: the freehand method, only the needle holder tool guidance, and the whole navigation guidance (GUI + assisted needle holder).
Results: The results demonstrate a success rate of over 90% using only assisted needle holder and the whole system to perform breast biopsy for the experienced and inexperienced groups, whereas for the inexperienced group a success rate of 57.5% was achieved using the freehand method. The use of only assisted needle holder for breast biopsy reduces the time for a procedure in the inexperienced group by 6 s when compared to the freehand method.
Conclusion: The authors believe that this navigation system can be applied in a clinical setting and give an advantage to inexperienced radiologists who must successfully perform clinical breast biopsy.

1. Introduction

Percutaneous imaging-guided core needle biopsy (CNB) for suspicious breast lesions is a standard diagnostic tool for tissue characterization [1–4]. Ultrasound plays an important role for a real-time breast biopsy [5] and has various other applications, such as carotid artery [6,7]. As the system allows for real-time guidance, no ionizing radiation is required [8], the procedure is inexpensive and it is comfortable for the patient [9–11]. The radiologist uses one hand to hold the ultrasound transducer to scan for suspicious lesions and the other hand is used to perform needle insertion, while the patient lies in a supine or decubitus position [9]: this is referred to as the free-hand technique.

The ultrasound probe is covered with a plastic bag to avoid infections then a coaxial needle is inserted towards the target before using the biopsy needle to avoid scars from multiple needle insertion. However, the advance of technology and knowledge allow no infection and successful treatment with the covered probe and an uncovered probe [10]. The success of a core needle biopsy to examine breast lesion depends on the accuracy of the diagnostic. High accuracy of the diagnostic leads to high proficiency treatment planning and low sampling error [3]. False negative is an important concern for core needle biopsy because it leads to inappropriate treatment causing the patient to suffer from re-biopsy or re-operation. For 14-guage (G) CNB under US, the success rate is about 96% [4,12]. The false negative rate is around 2% (1.6 [4], 2.4 [12]). Even ultrasound guided breast biopsy is a conventional method for breast biopsy, difficulties of needle guidance in 2D image is a major problem.

The radiologist needs to control the needle within the ultrasound plane for visualizing the needle. Moreover, the needle has to parallel to the patient's chest wall to avoid chest wall puncture. This procedure is

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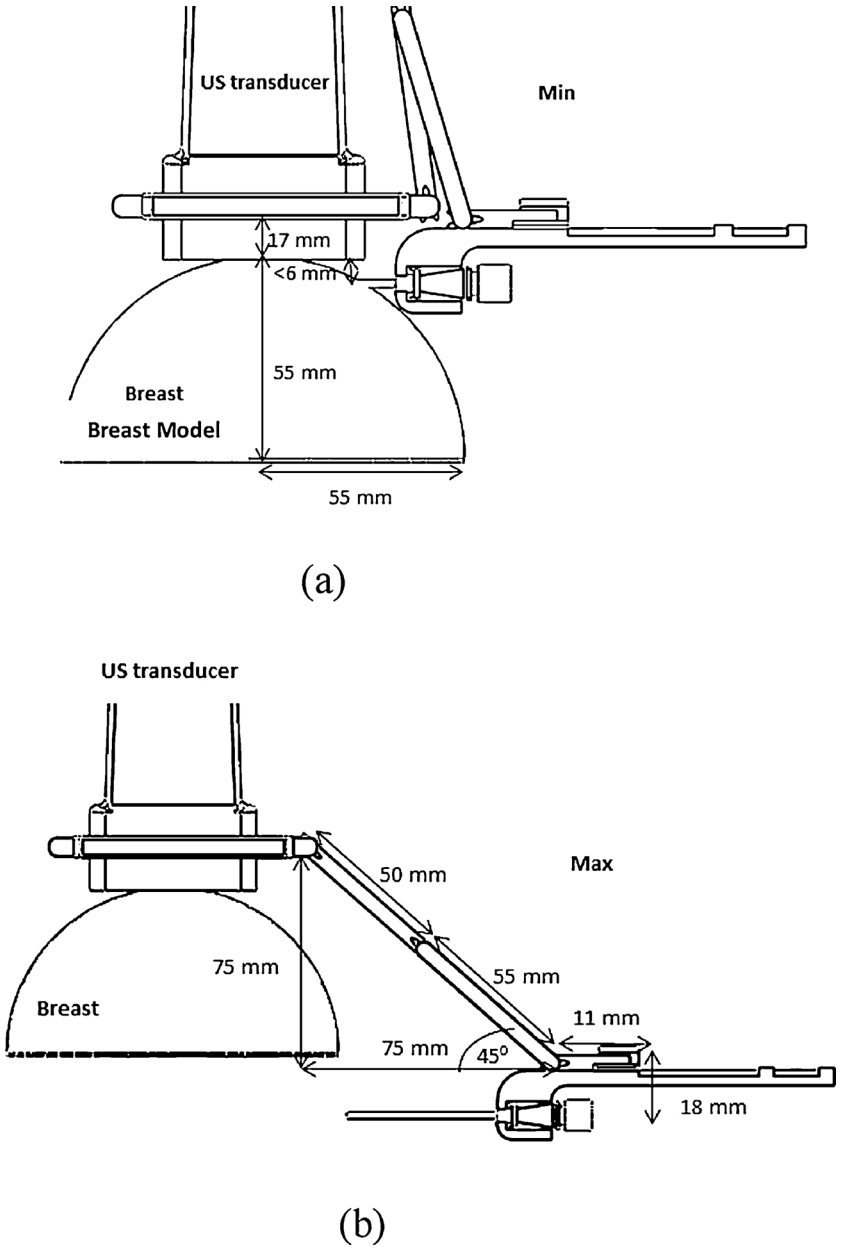

Fig. 1. (a) minimum and (b) maximum of workspace of assisted needle holder design.

difficult and requires a substantial amount of experience from the radiologist. Improper needle localization within the ultrasound plane can affect the procedure times and needle position accuracy [13]. Some research groups [5,14,15] have developed breast biopsy navigation system in the prone position with different type of modalities; however, these approaches consume a lot of time to setup and are uncomfortable for the patient. Augmented reality system [16] has been developed to display the ultrasound plane during needle insertion, which is similar to an optical needle guidance [17] and displays a line along the patient's skin. An optical needle guide [18] and clear guide one also use camera, mounted on an ultrasound probe, to localize a needle alignment relative to the ultrasound plane.

The result of the needle alignment will be displayed on the ultrasound image. However, all of the above mentioned about problems in intervention technique associated with the control needle alignment in the ultrasound plane and with the hand eye coordination between image guidance system and the biopsy tools such as the needle and the ultrasound probe. This problem has been solved by a mechanical guidance device attached to the ultrasound transducer to control needle alignment with respect to the ultrasound image for every movement. A few companies have developed a guidance device for the biopsy procedure by fixing the angle of needle insertion within the ultrasound view. A rotary wheel needle–guide on a bracket which is attached to an ultrasound transducer [19] has been developed to move the needle without fixing the angle, but the position of the needle during movement is still a problem. A two planar linkage with 2D guidance system has been developed with the magnetic rotary sensors to detect the angular displacement [20]. This system is tested and compared between an experienced and inexperienced radiologist group [21], which shows high accuracy and lower procedure time. However, the device cannot be sterilized because of its complex structure.

This article proposes a breast biopsy navigation system with an assisted needle holder tool for a coaxial needle and a graphical user interface, which utilizes an optical tracking device to localize the needle position relative to the ultrasound image. Tool tip calibration [22,23] and ultrasound calibration have been performed before starting the