Coregistered Ultrasound as a Neurosurgical Guide

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Abstract

Introduction: The dynamic nature and three dimensionality of ultrasound data can be utilized to enhance the capabilities of image guidance systems. Methods: Coregistration of ultrasound data was done using an electromagnetic digitizer, and subsequent ultrasound images were correlated with preoperative MRI studies. Thirty-two patients undergoing craniotomy were investigated in this manner. Results: Phantom testing done with a rigid stylus and 3D ultrasound tracker demonstrated an accuracy of 1.36 ± 1.67 mm in determining the location of a point. Thirty-two clinical cases were coregistered without difficulty. Conclusion: Coregistered ultrasound is a useful methodology that can aid in neuronavigation.

Introduction

The static nature of image guidance can be a drawback to its use as intracranial contents shift during surgery. The dynamic nature and three dimensionality of ultrasound data can be utilized to enhance the capabilities of image guidance systems.
Methods

An algorithm has been developed to coregister ultrasound data (Aloka 633 Intraoperative Ultrasound; Corometrics Medical Systems, Wallington, Conn., USA) intraoperatively with imaging studies through the use of an electromagnetic digitizer (Flock of Birds 3D Electromagnetic Tracker; Ascension Technology, Milton, Vt., USA) [1]. The calibration process for the ultrasound transducer was accomplished by acquiring multiple images (50–100) of a single point in a water tank by using the scanhead in as many different positions as possible to exercise all degrees of freedom. Our calibration point consisted of the intersection of two thin nylon wires positioned in a water tank (32 x 64 x 46 cm). To evaluate the patient registration procedure, phantom testing was done in a 32 x 64 x 46 cm water-filled Plexiglas tank containing 60 beads. Images of all the beads were acquired with the ultrasound scanhead and the stylus tip (electromagnetic digitizer). A similar process was then performed in the operating room. Thirty-two patients were coregistered with the transducer-adapted stylus using natural landmark fiducials (tragus, superior pinna, lateral canthi). Fifty ultrasound images per case were acquired with acquisition times of 5 s.

Results

In phantom testing (fig. 1, 2) using a rigidly coupled stylus along with a 3D ultrasound tracker, the location of a point in transmitter space could be determined with an accuracy of 1.36 ± 1.67 mm. When coupling the tracker to an ultrasound scanhead, features on ultrasound images could be located with an error of 2.96 ± 1.85 mm. It was also found that registering a skull phantom to coordinates that were defined by MRI or CT imaging could be done with an error of 0.86 ± 0.61 mm. Over a 12-month period, 32 frameless stereotactic cases were coregistered with ultrasound. Surgery consisted of either resection of tumor or cortical resection for epilepsy in all cases. The coregistered ultrasound process posed no technical difficulty and did not prolong the length of surgery.

Discussion

Intraoperative, coregistered 3D ultrasound is a neuronavigational tool that is still in its infancy. In a series of 7 patients, Koivukangas et al. [2] showed how intraoperative ultrasound could be used to create interactive reconstructions of preoperative CT and MRI data that could then be used to verify the accuracy of the neuronavigation system. Trobaugh et al. [3] addressed the issue of the poor image quality of ultrasound by showing how real-time registration of ultrasound images can be used to continuously update corresponding CT and MRI images. By developing a second view of the underlying brain with the ultrasound image, intraoperative shift can be assessed based on differences between the updated
Fig. 1. a Ultrasound image of phantom. b Reconstructed plane of MRI data corresponding to ultrasound image.
Fig. 2. a Ultrasound image of metastatic tumor in patient. b Reconstructed plane of MRI data corresponding to ultrasound image.
images. Ault and Siegel [4], looking for a more economical and convenient means to accurately locate structures using medical robotic applications, demonstrated how ultrasound can be used to track CT reference features in real time.

Intraoperative ultrasound is a useful adjunct to today’s frameless stereotactic neuronavigation systems. In this paper, we present a reliable methodology.

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References