Title: Robotic CT-guided out-of-plane needle insertion: Comparison of angle accuracy with manual insertion in phantom and measurement of distance accuracy in animals

Abstract

Objectives: To evaluate the accuracy of robotic CT-guided out-of-plane needle insertion in phantom and animal experiments.

Methods: A robotic system (Zerobot), developed at our institution, was used for needle insertion. In the phantom experiment, 12 robotic needle insertions into a phantom at various angles in the XY and YZ planes were performed, the same insertions were manually performed freehand, as well as guided by a smartphone application (SmartPuncture). Angle errors were compared between the robotic and smartphone-guided manual insertions using the Student's *t* test. In the animal experiment, 6 robotic out-of-plane needle insertions toward targets of 1.0 mm in diameter placed in the kidneys and hip muscles of swine were performed, each with and without adjustment of needle orientation based on reconstructed CT images during insertion. Distance accuracy was calculated as the distance between the needle tip and the target center.

Results: In the phantom experiment, the mean angle errors of the robotic, freehand manual, and smartphone-guided manual insertions were 0.4°, 7.0° and 3.7° in the XY plane and 0.6°, 6.3° and 0.6° in the YZ plane, respectively. Robotic insertions in the XY plane were significantly ($p < 0.001$) more accurate than smartphone-guided insertions. In the animal experiment, the overall mean distance accuracy of robotic insertions with and without adjustment of needle orientation was 2.5 mm and 5.0 mm, respectively.

Conclusion: Robotic CT-guided out-of-plane needle insertions were more accurate than smartphone-guided manual insertions in the phantom and were also accurate in the *in vivo* procedure, particularly with adjustment during insertion.