An Augmented-Reality Based Navigation System for Pelvic Tumor Resection

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BACKGROUND: Even with improvement in treatment modalities, patients with malignant neoplasm of the pelvic girdle are still at a higher risk of having treatment failure than are patients with a tumor in the extremity. The reason is related to the inadequacy of the surgical margin obtained. Recent introduction of navigation-assisted tumor removal may improve oncological and functional outcomes of pelvic cancer treatment. However, somewhat cumbersome process and high cost may hinder the use of navigation in bone tumor surgery. To address this issue, we developed an Augmented-Reality (AR) based navigation system for bone tumor resection. AR is defined as a real-time direct or indirect view of a physical real-world environment that has been augmented by adding computer-generated information to it. We developed an AR-based navigation system which simply requires tablet PC instead of huge and complex navigation system.

PURPOSE: In this study, we evaluated the accuracy of AR-based navigation assistance in resection of the bone tumor model of pig pelves.

MATERIALS AND METHODS:

Development of AR-based Navigation System - we developed an AR program for pelvic cancer resection, which can display resection margin from all directions and run on a tablet PC (Fig.1).

Simulation of Bone Tumor in Pig Pelves - We designed an experimental bone tumor model in pig pelves for the simulation of tumor resection. A cortical window was made on the acetabulum and bone cement was inserted. Thirty six bone tumor models were created in Zone II and assigned through 1:1 allocation to the AR-assisted resection group (AR group) and conventional resection group (conventional group).

Tumor Resection and Evaluation of Accuracy - The tumor resection was simulated in two manners. One was AR assisted resection performed by a junior orthopedic resident and the other was conventional resection by an expert orthopedic oncologist. For both groups, the bone tumor resection was planned with 10-millimeter safety margin from the edge of bone cement. In the conventional group, the resection was performed based on CT images. In AR group, the resection was performed under AR-guidance. The distance from the edge of

cement to the resection margin was evaluated by an independent orthopedic surgeon. Seventy-two surgical margins of 36 pelves were evaluated. The difference (error) between the obtained surgical margin and planned surgical margin (10 mm) was graded into 4 groups based on the resection errors: Grade A with error ≤ 3 mm, Grade B 3 < error ≤ 6 mm, Grade C 6 < error ≤ 9 mm, and Grade D error > 9 mm or violation of tumor. Student's t-test was used for statistical comparison.

RESULTS: The mean resection error of 36 resections in 18 pelves in the AR group was 1.59 ± 1.35mm (range, 0–6 mm). The mean error of 36 resections in 18 pelves in the conventional group was 4.55 ± 3.17 mm (range, 0–11 mm). A statistically significant difference was observed between AR-assisted and conventional resections ($p < 0.00$). In the AR group, 34 resections were classified as grade A and 2 were classified as grade B. No resections were classified as grade C or D in the AR group. In the conventional group, however, 15 resections were classified as grade A, 13 as grade B, 3 as grade C, and 5 as grade D. Although all resections were performed by an expert orthopedic oncologist in the conventional resection group, five resections had tumor violations or errors larger than 10 mm. The probabilities of a surgeon obtaining a 10-millimeter safety margin with a 6-mm tolerance were 100% in AR group, 80% in conventional group (Fig.2).

CONCLUSION: A simple and intuitive AR-based surgical navigation system was developed to guide a pelvic tumor resection. This system, which can run on a tablet PC, is convenient to apply. We suggest that AR based navigation system is useful for surgery of pelvic bone cancer.

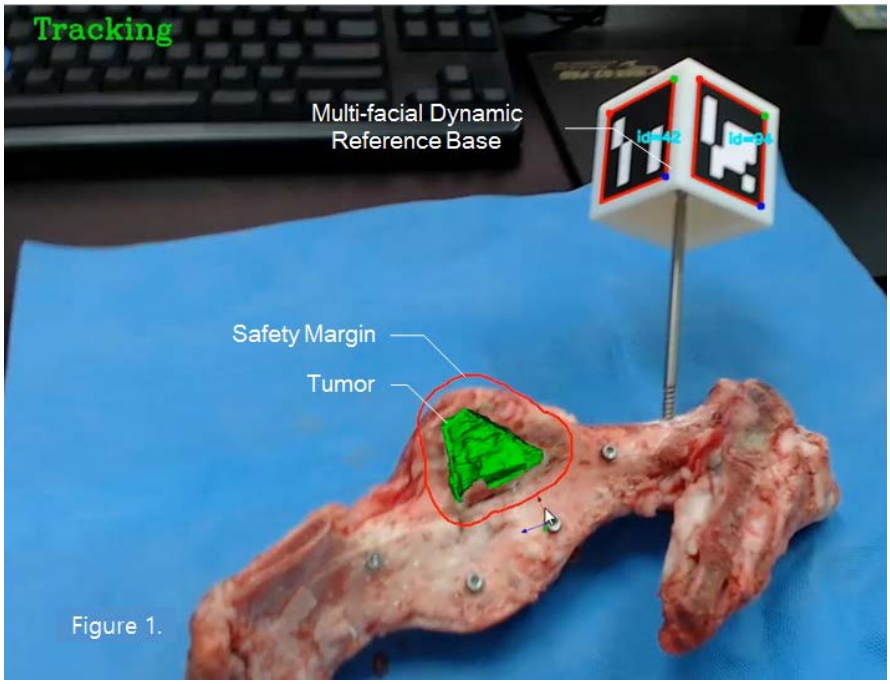

Fig. 1. AR-based navigation in tumor medel using the pig pelvis. Red line around tumor contour (green) indicates 10-millimeter-safety margin.

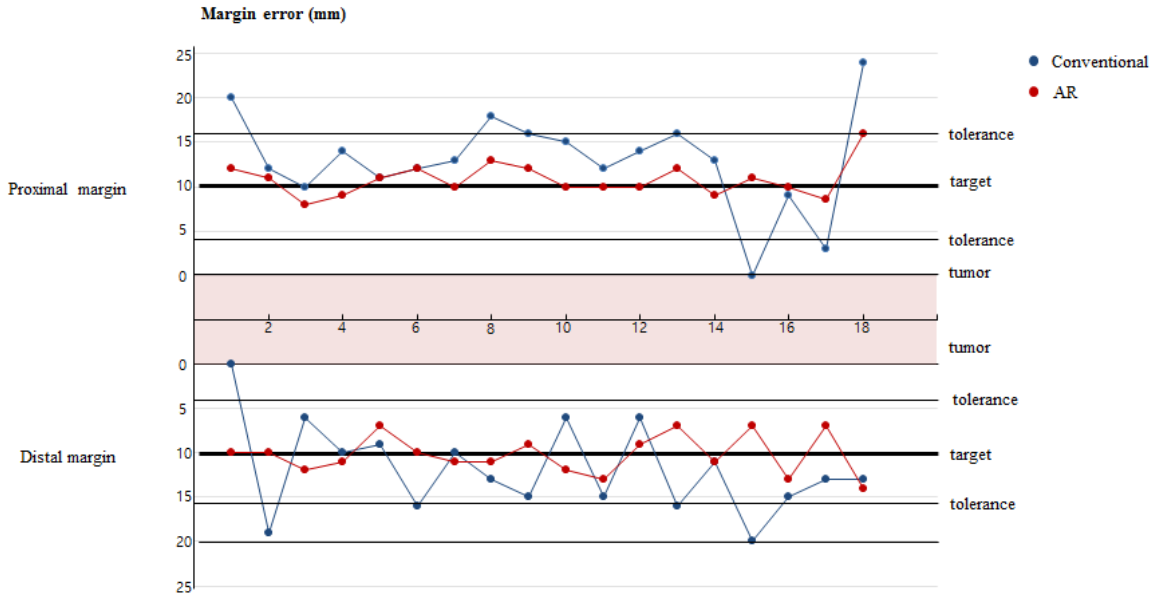

Fig. 2. The results of tumor resection from the conventional method and AR intervention. Some trials of conventional method were exceed the tolerance of safety margin (±6 mm), but the all results of the AR guidance were within the tolerance.