News Release

Title

Experimental pilot study for augmented reality-enhanced elbow arthroscopy

Key Points

- **Elbow arthroscopy requires significant training for surgeons, and even skilled surgeons have reported complications during surgery. We hypothesized that AR-enhanced arthroscopy would reduce the risk of serious complications associated with elbow arthroscopy.**
- **The technological integration of AR with arthroscopy was successful. We attained satisfactory accuracy and demonstrated the working of such a system.**
- **Upon resolution of some limitations, AR-enhanced arthroscopy system has the potential to become the next-generation arthroscopy.**

Summary

Michiro Yamamoto, a lecturer in the Department of Hand Surgery, Graduate School of Medicine, Nagoya University, Professor Hitoshi Hirata, and Shintaro Oyama, an assistant lecturer in the Medical IT Center of Nagoya University Hospital, conducted joint research with Hideo Yokota, a team leader, Image Information Processing Research Team, Center for Advanced Photonics, RIKEN have collaborated to develop a next-generation elbow arthroscopic surgery that incorporates AR (augmented reality) technology.

Arthroscopic surgery developed in Japan has spread throughout the world and is now the standard treatment for orthopedic surgery. However, complications such as serious nerve injury have occurred especially in elbow arthroscopy. The development of the next generation arthroscopy considering the safety was necessary in order to offer the effective treatment in the low invasion.

We obtained bone and nerve segmentation data by CT and MRI, respectively, of the elbow of a healthy human volunteer and cadaveric Japanese monkey. A life size 3-dimensional (3D) model of human organs and frame was constructed using a stereo-lithographic 3D printer. Elbow arthroscopy was performed using the elbow of a cadaveric Japanese monkey. The augmented reality (AR) range of error during rotation of arthroscopy was examined at 20 mm scope–object distances. We successfully performed AR arthroscopy using the life-size 3D elbow model and the elbow of the cadaveric Japanese monkey. The target registration error was 1.63 ± 0.49 mm (range, 1–2.7 mm) with respect to the rotation angle of the lens cylinder from 40° to -40°. We attained reasonable accuracy and demonstrated the operation of the designed system. Given the multiple applications of AR-enhanced arthroscopic visualization, it has the potential to be a next-generation technology for arthroscopy. This technique will contribute to the reduction of serious complications associated with elbow arthroscopy.

Research Background

The history of arthroscopy began in Japan. In 1918, Kenji Takagi, a professor of orthopedic surgery at Tokyo University, and his colleagues observed the knee joint using a cystoscope. In 1959, under the guidance of Kenji Takagi, Masaki Watanabe and others developed the No. 21 scope which became the world's first practical arthroscope, and arthroscopic surgery spread throughout the world.

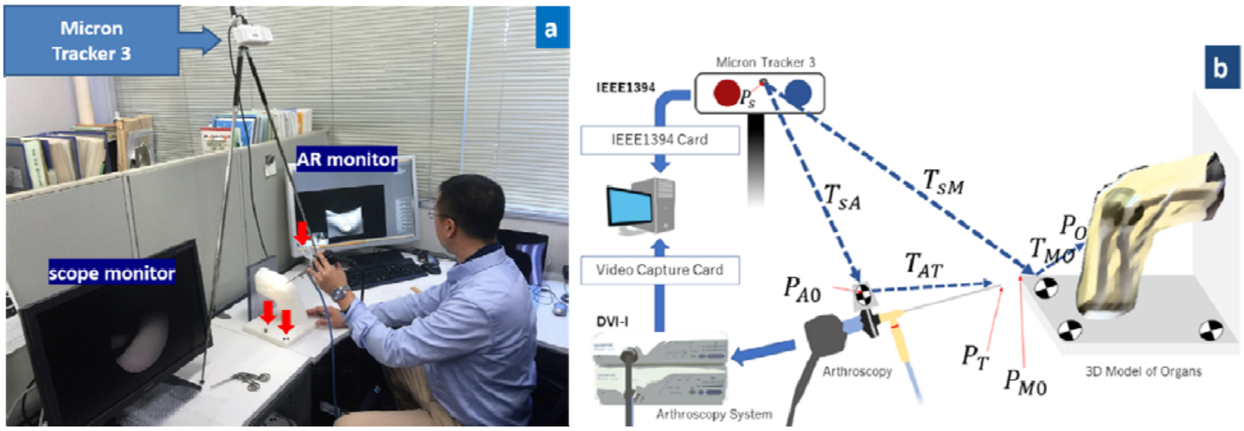
Available evidence supports the use of elbow arthroscopy to manage multiple conditions including rheumatoid arthritis, osteoarthritis, tennis elbow, and osteochondritis dissents. A major drawback of elbow arthroscopy is the risk of intraoperative complications, including serious neurovascular injuries. The small working space and near adjacency of neurovascular and arthroscopic portals make elbow arthroscopy a technically demanding procedure. Successful elbow arthroscopy requires extensive knowledge of the spatial correlations among the neurovasculature, entry portals, and joint structures.

Recent advancements in sophisticated image processing technology have made precise preoperative simulations possible, and they are becoming increasingly common in clinical practice. However, this valuable set of information is ineffectively utilized in elbow arthroscopy at arguably the most decisive point: during the procedure. The ability to access such data that is optimized for use and seamlessly integrated into the surgical navigation system has remained elusive. We propose that the safety of standard elbow arthroscopy can be improved by incorporating augmented reality (AR). AR can allow the delivery of selective complex and highly useful information through computer graphics (CG) superimposed onto real-time video.
The purpose of this study was to develop and evaluate a novel elbow arthroscopy system that uses AR technology to superimpose nerve data on an arthroscopy monitor. We hypothesized that the accuracy of the resulting AR enhancement to standard arthroscopy would be acceptable.

Research Results

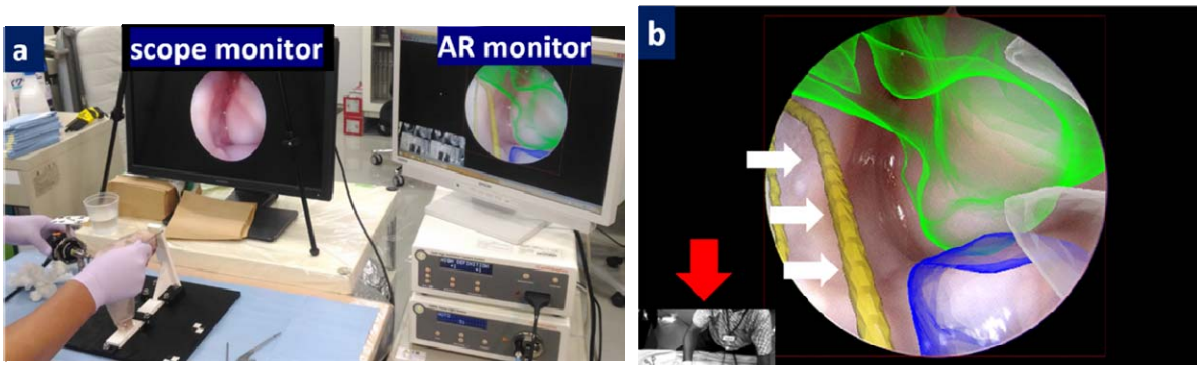
We successfully performed AR arthroscopy for the full-size 3D elbow model (Fig.1). The CG data was superimposed onto the elbow arthroscopy video in real-time. We performed a registration to co-visualize the image of the patient's elbow structures and the CG made by preoperative images. After manual modification of the position, scale, and orientation, the accuracy of the superimposed CG data was deemed acceptable on the AR monitor.

Fig. 1 Experiment with the full-size 3D elbow model
Elbow arthroscopy and tracking device system are shown (a). The Schema of augmented reality (AR) arthroscopy system (b).



AR arthroscopy of the cadaveric Japanese monkey elbow was performed (Fig. 2a). The humeroradial joint and radial nerve were superimposed on the real-time view and displayed on the AR monitor. Although the radial nerve was not seen on the scope monitor as it was located behind the joint capsule, the position of the radial nerve was clearly observed. This was helpful to the surgeon in creating a lateral portal, thereby avoiding radial nerve injury (Fig. 2b).

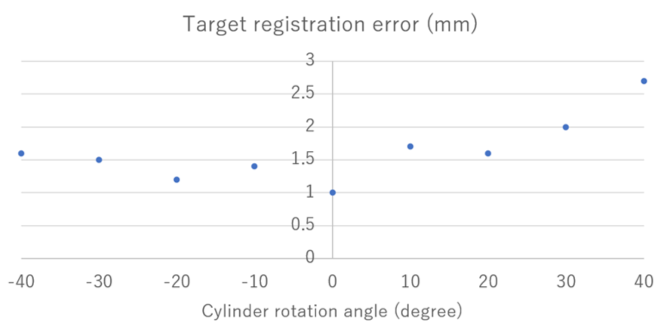
Fig. 2 Augmented reality (AR) arthroscopy on cadaveric Japanese monkey elbow.



Accuracy evaluation of AR position during rotation of arthroscopy

The target registration error was 1.63 ± 0.49 mm (range, 1–2.7 mm) at a 20 mm scope-object distance, with respect to the rotation angle of the lens cylinder from 40 ° to -40 ° (Fig. 3).

Fig. 3 The target registration error.



Research Summary and Future Perspective

We integrated AR technology into elbow arthroscopy. We have demonstrated that the workings of the system and the accuracy of this AR system were deemed satisfactory. Through further iterations and refinements, AR-enhanced arthroscopic visualization has the potential to be a transformative technology. This technique will contribute to reducing the risk of serious complications associated with elbow arthroscopy.

AR-enhanced navigation for arthroscopy may become the next generation arthroscopy system. However, this study has some limitations. First, we used preoperative imaging techniques, such as CT and MRI, but not real-time information of the target tissue. The size and location of the lesion at the time of surgery may differ from the preoperative data. Second, the elbow flexion angle was fixed in our experiments; however, surgeons in a clinical setting typically move the elbow during arthroscopy. Superimposed CG data, therefore, needs to change according to the elbow angle. AR with real-time data of the target tissue is required to solve these problems. Intraoperative CT, MRI, or ultrasonography may be employed to obtain intraoperative data of the target tissue. Actually, nerves around the elbow can be clearly visualized using ultrasonography. Additional algorithm for intraoperative data is required.

Publication

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