



Robotic hip arthroscopy: a cadaveric feasibility study

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Objective: The aim of this study was to test if robotic surgery can be used while performing hip arthroscopy.

Methods: Hip arthroscopy was performed on two hip joints of a fresh-frozen male human cadaver. The arthroscopic control of the femoral head and neck and acetabular labrum were evaluated using the da Vinci Surgical System.

Results: Docking of the robotic system and manipulation of the instruments were successful. Although most regions reached in standard arthroscopy were also reached with this robotic setting, the 5-mm instrument was limited in movement due to its long articulation section. The 8-mm instrument had shorter articulation section and exhibited a full range of motion inside the joints. The posterior part of the femoral head and the posteroinferior portion of the acetabular labrum could not be observed because of the rigidity of the equipment.

Conclusion: Robotic hip arthroscopy appears feasible in a cadaveric model but has some significant limitations. With the development of special instrumentations, arthroscopy of the large or small joints may be possible with robotic surgery. Robotic surgery may also enable surgeons to perform more complex and precise tasks in restricted spaces.

Key words: da Vinci Surgical System; hip arthroscopy; robotic surgery.

The management of hip injuries has evolved significantly in the past few years with the advancement of arthroscopic techniques. Recent advancements in hip arthroscopy have elucidated several sources of intra-articular abnormalities that result in chronic and disabling hip symptoms, resulting in the diagnosis and treatment of many previously unrecognized conditions.^[1]

Burman^[2] made first arthroscopic visualization of the hip on 20 cadaveric hips in 1931. He also described the anterolateral portal, still used today as a common arthroscopic portal of the hip.

The first clinical application of hip arthroscopy was reported in 1939 by Takagi who treated two Charcot joints; one case of tuberculous arthritis and one case of

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septic arthritis.^[3] The most common indications today include the presence of symptomatic acetabular labral tears, loose bodies, hip capsule laxity and instability, chondral lesions, arthritis, ligamentum teres injuries, iliopsoas bursitis, adhesive capsulitis, tears of the hip abductors, and diagnosis of unresolved intra-articular hip pain.^[1,4,5]

Robotic technology offers technical advantages over standard laparoscopic approaches.^[6,7] It may also enable the surgeon to perform more complex and precise tasks in restricted spaces. The da Vinci Surgical System offers remote control of articulated instruments with full range of motion at the tip. These advantages of robotic technology was first noticed by Kather et al. who suggested the use of this surgical system for hip arthroscopy owing to skillful instrumentation of the robot making it possible to reach the parts of the hip joint that are inaccessible with rigid instrumentation.^[8]

Recently, we investigated the use of this surgical system for the arthroscopy of the smaller shoulder joint. We concluded that robotic shoulder arthroscopy seems feasible in a cadaveric model but has some significant limitations at this time.^[9]

In this study, we aimed to test whether the da Vinci Surgical System can be used while performing hip arthroscopy as an alternative to conventional hip arthroscopy and to discuss the advantages and disadvantages of robotic hip arthroscopy. We also aimed to provide technical tips related with the present problems, limitations and possible solutions of robotic hip arthroscopy.

Materials and methods

Robotic hip arthroscopy was tested on the two hip joints of a male fresh-frozen human cadaver (age 88). While no specific data regarding the cadaver was available, it was observed that the cadaver had no obvious sign of hip trauma or recent surgery. A four-armed da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA, USA) was used for all experiments.

The cadaver was operated on the right and left sides in a lateral position (Fig. 1). The surgeon sat comfortably at the control panel to manipulate the robotic arms. A 8.5-mm Endoscope Cannula (Intuitive Surgical Inc., Sunnyvale, CA, USA) was introduced from the anterolateral portal into the joint and the da Vinci 8.5-mm Endoscope 30° (Intuitive Surgical Inc., Sunnyvale, CA, USA) was then introduced into the cannula. Under arthroscopic control, a 5-mm da Vinci trocar (Intuitive Surgical Inc., Sunnyvale, CA, USA) was inserted into the hip joint with anterior portal (Fig. 2). The robot was then docked, using the camera and the right robotic arm



Fig. 1. The robotic setup of the cadaver positioned in lateral position. A view from the right side. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

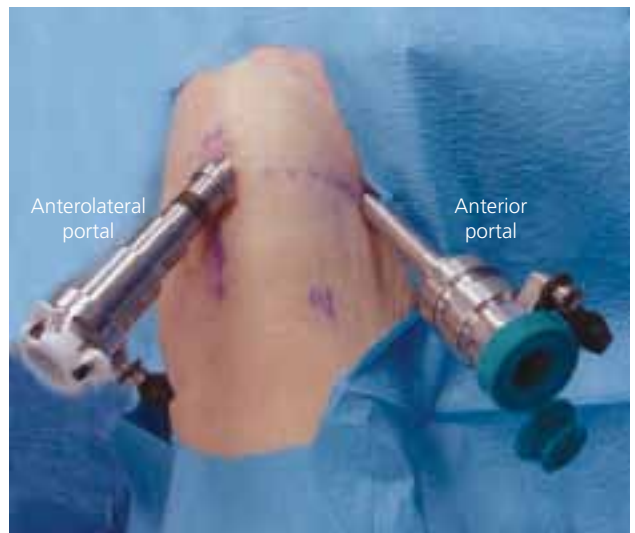


Fig. 2. 8.5-mm Endoscope Cannula was introduced from the anterolateral and 5-mm da Vinci trocar was inserted through anterior portal. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

and a 5-mm robotic needle holder was mounted onto the robotic arm. Range of motion and accessibility of the hip joint were tested and the labrum manipulated under pure robotic control. Arthroscopic control of the acetabular labrum, femoral head and neck were evaluated.

Both sides of the cadaver were dissected after robotic arthroscopic surgery to investigate the success of the robotic instruments in the hip joint. The portal anatomy and landmarks were also exposed with standard anatomical dissection through the anterolateral approach.

Results

Insertion of the da Vinci 8.5-mm endoscope into the hip joint was possible and all important structures, such as the femoral head and acetabulum were identified in

the lateral position. It was feasible to use the trocars that were originally designed for laparoscopic surgery in these positions. There were no unidentifiable regions or structures within the joint capsule orthopedic setting. Da Vinci trocars, both 8- and 5-mm, could also be inserted into the hip joint without any complications.

Docking of the robotic system was possible using the camera and one or two working arms. Furthermore, the robotic instruments were able to pass inside the joint for manipulation. A good range of motion of articulation was noted. The arthroscopic control of the acetabular labrum, femoral head and neck were partly possible in each attempt. As the camera was rigid and it was not possible to position the hip adequately due to the presence of the robotic arms, the posterior part of the femoral head and the posteroinferior portion of the acetabular labrum could not be observed (Fig. 3).

Although the majority of regions reached by standard arthroscopy were also reached with this robotic setting, the 5-mm instruments were limited in movement due to its long articulation section. The 8-mm instrument had a shorter articulation section and exhibited a full range of motion inside the joints. It was possible to lift, manipulate and resect the acetabular labrum with the harmonic instruments. No pathological changes were observed in

the patient and there was no need to dock another accessory portal in this setting.

After the surgical procedure, the hip joints of the cadaver were dissected. It was confirmed that all instruments were correctly located intra-articularly without any neurovascular injury.

Discussion

Robotic technology provides substantial advantages to traditional laparoscopy.^[10] The first adaptation of robotic surgery to arthroscopy was performed on the hip joint. Despite some limitations, the procedure was feasible on a cadaver.^[8] Additionally, a recent cadaveric model of robotic shoulder arthroscopy demonstrated the feasibility of this approach as an alternative shoulder joint surgery.^[9] For proper robotic hip arthroscopy, the surgical staff should include a surgeon who operates the robot, an assistant who is capable of managing the devices of the robot and robotic arms, an anesthesiologist and a physical assistant who is technically familiar with robotic surgery and is capable of adjusting the robot and instruments as needed. During the present study, the hip joint was easy to access in all attempts with 8- and 5-mm trocars and a 8.5-mm endoscope originally designed for laparoscopic and robotic surgery. The 12-mm trocar hosting the 12-mm da Vinci Endoscope was not used because of its large size in comparison to the size of the hip joint. The ideal instrumentation appears to be the 5-mm endoscope, the most commonly used endoscope size in conventional arthroscopy. While a 5-mm endoscope providing 3D vision was not available in our clinical setting, the presence of any significant advantage of 3D vision is questionable for the hip joint.

Conventional hip arthroscopy has become an increasingly popular and more frequently performed procedure as indications are increasing. However, this procedure is technically more difficult in the hip joint than in other joints. The overall process, from patient set-up until the end of the procedure, requires meticulous effort and attention. The anatomy of the hip joint is quite different from other joints and is more difficult to observe certain anatomical structures (such as the femoral head, femoral joint surface, acetabular joint surface, acetabular labrum and surrounding soft tissue). This difficulty necessitates traction of the hip. Experience and skillful hands are necessary for in order to perform successful surgery and portal placement without damaging the joint surface. The da Vinci robotic surgery system is an effective system providing practicable portals without causing injury to joint cartilage or any other anatomic structures. In addition, the need for specially designed instruments and

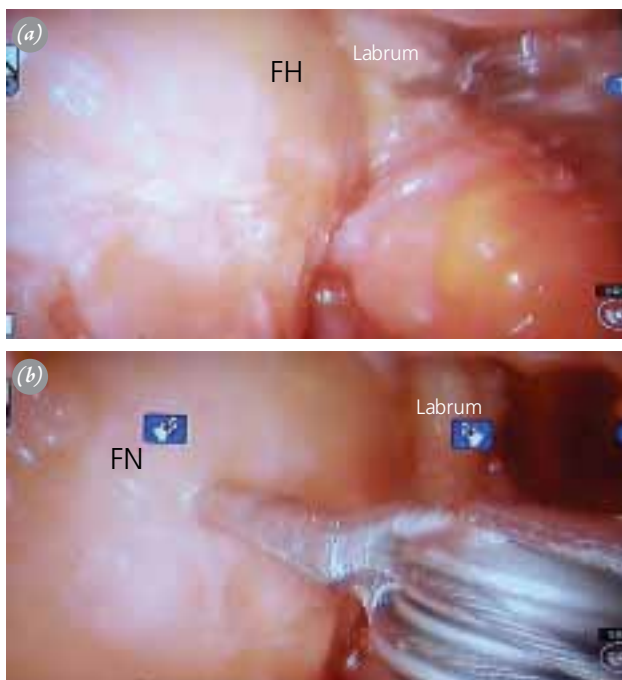


Fig. 3. (a) The endoscopic control and the visual acuity were very good for the acetabular labrum and femoral head (FH). (b) The endoscopic control of the femoral neck (FN). These pictures were captured with a digital camera from the screen. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

approaches for robotic hip arthroscopy is obvious.

The da Vinci system is a telerobotic surgical system. The surgeon's control of the system is based on classical master/slave teleoperation architecture. This architecture consists of two modules: the surgeon console (master) and the robot (slave). Other robotic systems are image-guided systems. Compared to the da Vinci system, these systems allow patient-specific planning and more precise surgery. During surgery, the surgical field is registered and matches with the surgical plan to provide dynamic information. Robotic arm guidance, 3-D visual feedback, and real-time data assist the surgeon.

The distance between the skin and the joint space is longer at the hip joint than the shoulder of the knee joint. This may serve as a disadvantage in robotic hip arthroscopy. The movements of the robotic arms in the body but outside the joint space should also be considered during the procedure due to possible injury caused by tension or traction to the femoral or lateral femoral cutaneous nerves from excessive movement of the robotic arm. Development of robotic arms with limited movement outside the joint may be helpful in reducing such complications.

One of the major advantages of robotic surgery is the ability to perform more complex and precise tasks such as suturing in restricted spaces. This advantage is also valid for hip arthroscopy, especially with new instruments specialized for arthroscopy. Additionally, the visual acuity of the robotic screen was better compared to conventional technique. However, the excellence of the robotic visual acuity could not be reached during hip arthroscopy. This may be due to the blurring effect of the water-filled joint space when compared to the air-filled abdominal cavity standard for robotic laparoscopy.^[9] Working in a high-pressure fluid-filled space may be an additional disadvantage to the robotic system as current robotic instrumentation are designed to work inside an air-filled space. Another limitation of robotic hip arthroscopy is the difficulty in performing the procedure without the ability to feel the power applied by the robotic arms. The surgeon cannot feel the resistance of contacts between the instrument tips and the tissues of the patient. Absence of tactile feeling is remarkable and a weak aspect of teleoperating type robotic systems. With excessive force, devices can break easily when hitting bone or a hard tissue. Therefore, we suggest the development of a system that transmits force applied by the robot to the surgeon in order to reduce such complications.

Because the camera and the other instruments are not flexible, it was not possible to observe the posterior part of the femoral head and the posteroinferior portion

of the acetabular labrum. In addition, since the robotic arms occupy a large space in the operating area, it was not possible to properly position the hip. Hip arthroscopy necessitates fluoroscopic control from the beginning of the procedure. Placing all equipment (robot, fluoroscopy, surgical and anesthetic instruments, etc.) necessary for the procedure might be impossible in a real setting. We, therefore, suggest the development of a smaller robot with longer arms, using smaller size fluoroscopic equipment or the creation of larger robotic surgery operating rooms to create a solution to these problems. As described by Kather et al., the currently available robotic instruments were not ideal for arthroscopy and did not provide any major practical advantages.^[8] New instruments specialized for joint surgeries are advised. The size of the 5-mm instruments appeared to be ideal despite their limited movement, due to the long passage of articulation. On the other hand, the 8-mm instrument had a shorter articulation section and exhibited a greater range of motion inside the joint, making it easier to operate than the 5-mm. However, as working with a large instrument inside the joint space is not practical or easy, we suggest the design of new flexible instruments with appropriate number of articulations and proper setups for robotic hip arthroscopy.

In the present study, since the cadaver was fresh-frozen and did not have any pathological abnormalities, it was easy to visualize all the regions in the joint space. However, it may be necessary to change the position of the camera or insertion of any other accessory portals in a pathologic case. It would then be necessary to re-set the robotic arms. This serves as a major disadvantage with the present size of the robotic body and robotic arms.

We have performed robotic hip arthroscopy in both the supine and lateral decubitus positions. In the lateral decubitus position, we suggest placing the robot close to the head of the patient, allowing a space distally for the anesthesiologist and for the traction apparatus to enable surgical assistance if necessary. However, in the supine position, placing the robot at the opposite side of the operating hip will obscure the scopic view because of the robotic arms. Placing the robot as suggested by Kather et al. allows no space for the anesthesiologist and prevents display of the hip with fluoroscopy.^[8]

In arthroscopy of the peripheral compartment of the hip, the placement of the surgical instruments and the extent of the resection are determined by fluoroscopy. Therefore, radio-opaque robotic arms may serve as a major obstacle. We suggest the development of radiolucent and thinner robotic arms. Complications may occur during traction in arthroscopy of the central compart-

ment. The duration of traction may be even longer during initial trials of robotic arthroscopy. Advancements in robotic hip arthroscopy may also decrease the time allocated for the traction of the hip joint and, thus, complications related with the traction.

In conclusion, robotic hip arthroscopy seems feasible in a cadaveric model but has some significant limitations that make the procedure impossible in real setting. Currently, it may be performed as diagnostic arthroscopy until more specific instrumentation is developed. After development of special instrumentations and designing an arthroscopy-suitable robot, arthroscopy of the large or small joints may be possible with robotic surgery in the future. The major advantages of the robotic surgery may also enable the surgeon to perform more complex and detailed tasks in restricted spaces.

Conflicts of Interest: No conflicts declared.

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