



# Robotic flexible ureteroscopy: A new challenge in endourology

## THE ERA OF ROBOTIC SURGERY IN UROLOGY

Flexible ureteroscopy is an established, essential surgical modality in urology in the 21st century. The flexible ureteroscope is used in retrograde intrarenal surgery (RIRS) and diagnostic ureteroscopy for upper urinary tract urothelial carcinoma, both of which are common procedures. The introduction and popularization of digital and disposable flexible ureteroscopes led to broadening of the role of RIRS for stone removal or tumor control. The robotic surgical system has revolutionized endourology by allowing for diverse motions in operative fields and better ergonomics for surgeons than manual laparoscopy. Robotics has been applied to most oncological urological surgeries, such as prostatectomy, partial nephrectomy, and cystectomy. However, until recently, using a robotic system for RIRS has remained a challenge.

## INITIAL MODELS OF ROBOTIC RIRS

A robotic flexible ureteroscope that used the Sensei-Magellan system (Hansen Medical, Mountain View, CA, USA), which was designed for cardiology and angiography by Fred Moll, the inventor of the da Vinci system, was first used in 18 patients in 2008 [1]. The device consisted of four components: surgeon's console, flexible catheter system, remote catheter manipulation system, and an electronic rack containing computer hardware, power supplies, and video distribution units. The robotic flexible catheter system consisted of an outer catheter sheath (14/12 Fr) and an inner catheter guide (12/10 Fr). A 7.5-Fr fiberoptic flexible ureteroscope was inserted through the inner catheter guide. In the Sensei robotic system, the ureteroscope was manipulated passively only, which proved to be a problem, and the project was discontinued.

Since 2010, ELMED (Ankara, Turkey) has been working on a robot specifically designed for flexible ureteroscopy. The

Avicenna Roboflex surgical robot was developed to provide all the necessary functions for flexible ureteroscopy. The prototype consisted of a small console with an integrated flat screen and two joysticks to move the endoscope, which is held by the handpiece (manipulator) of the robotic arm. All functions of the robotic arm are controlled by the console, which includes an integrated adjustable seat with two armrests and two foot pedals for activation of the fluoroscope and the laser-lithotripter via a pneumatic pedal controller. In 2016, Geavlete et al. [2] presented a phase 3 study that compared robotic vs. conventional RIRS in 132 patients. Treatment time (51 vs. 50 min) and fragmentation time (37 vs. 39 min) were similar; however, the stone-free rate (92.4% vs. 89.4%) was higher with the robotic approach. In their robotic system, the stone basket was manipulated manually by the assistants because the automated system had not been implemented [1].

## RECENT PUBLICATIONS ON ROBOTIC RIRS AND NEW PROTOTYPES

Klein et al. [3] reported 240 consecutive cases of robotic RIRS using the Roboflex System at the SLK-Kliniken, Heilbronn, Germany, from August 2014 to April 2018. In their report, operation time was 91 minutes and stone treatment time was 55 minutes. The detailed analysis of performance factors revealed successful utilization of the robotic systems in endourologic stone surgery and indicated that the robot performs comparably to conventional RIRS as reported previously in the literature.

Zhao et al. [4] introduced their prototype of a robotic flexible ureteroscopic system with a mechanical background. They reported amazing data from phantom and animal experiments which may validate that the robot has significant advantages over manual operations, including ease of use, reduced intraoperative time, and improved surgical ergonomics. However, in the phantom and animal experiments,

they showed the movement of their robotic system only without stone basket manipulation or lasering handling.

In 2022, Shu et al. [5] demonstrated their robotic RIRS system, which is based on force feedback with a neural network-based method. In their prototype system, the operator can accurately feel the obstruction if the interactive axial force or torque exceeds 1.2 N or 15.6 mNm, respectively. Soon, most robotic RIRS systems should have force feedback using haptic sense. Thus, the study by Shu et al. [5] marked the beginning of this latest technology for enhancing the safety of robotic endoluminal surgery.

## ONGOING DEVELOPMENT OF ROBOTIC RIRS SYSTEMS

Auris Monarch (Auris Health Inc., Redwood City, CA, USA) introduced the commercially available robotic bronchoscopy platform containing an inner bronchoscope and an outer sheath, both of which possess four-way steering control [6]. This device received 510(k) clearance from the Food and Drug Administration for use in endourological procedures in the United States. Specific operation types with self-developed flexible ureteroscopes, animal tests, and clinical trial outcomes will be announced later.

The ILY robotic flexible ureteroscope (Sterlab, Sophia Antipolis, France) has been introduced and clinical trials are ongoing at Centre Hospitalier Universitaire de Nîmes in France (Registry: ClinicalTrials.gov; ID: NCT03638336). ILY introduced their robotic system that uses Uscope (Zhuhai Pusen Medical Technology Co., Zhuhai, China) in the exhibition hall of EAU22 in Amsterdam. The ILY robot is a remote manipulator ureteroscope holder with multiple degrees of freedom that is placed near the patient and remotely controlled by the surgeon using a wireless mini-console. However, this system cannot control the laser fiber itself, and the surgeon or assistants must use a stone basket manually. The laser fiber adjustment and movement of the stone basket (open, close, forward, and backward) must be done by the assistant, which is a significant disadvantage in terms of the robotic engineering mechanism. It has been thought that these technologically engineered, automated surgical procedures may be difficult to use in real clinical practice. In the near future when the final clinical trial outcomes are released, we will know the pros and cons of the ILY robotic flexible ureteroscopic system.

## KOREAN ROBOTIC FLEXIBLE URETEROSCOPIC SYSTEM

In Korea, the easyUretero (ROEN Surgical Inc., Daejeon, Korea) robotic RIRS system has been introduced, and Han et al. [7] published their initial use of the system in a porcine renal stone model for laser lithotripsy. The easyUretero system is a master-slave robot system for RIRS, such as the da Vinci or Roboflex robotic system. In the current version, the slave robot can mount commercial flexible ureteroscopes, such as LithoVue (Boston Scientific, Marlborough, MA, USA) and Flex-Xc (KARL STORZ Endoscopy, Tuttlingen, Germany). The master console includes a handle that controls a flexible ureteroscope, a stone basket, and a laser fiber for use by a single operator in a seated position. Uniquely, this robotic system has automation capability such that the motion of the ureteroscope can be recorded and replayed, which can be effectively used for repetitive tasks like retrieval of multiple stones. In addition, the robot system has a safety function that detects the grasping and retrieval of an oversized stone to avoid ureteral injury. Han et al. [7] concluded that the easyUretero robotic RIRS system is feasible and safe for single-surgeon use in animals undergoing laser lithotripsy, even for less-experienced surgeons.

## THE ROAD TO THE FUTURE

Urolithiasis is one of the most common urological diseases with a high incidence and prevalence, which have been increasing worldwide [8]. Therefore, stone surgery is becoming increasingly important, and it is necessary to optimize the surgery to increase efficiency and patient convenience. In the EAU Guidelines on Urolithiasis 2022, radiation exposure and protection during endourology were emphasized. Radiation exposure is as important as the treatment of stones and relates to the working conditions of surgeons and hospital workers. Therefore, we must continuously search for ways to reduce radiation exposure, which would also improve the treatment environment of the patient. Robotic stone surgery is one way to reduce radiation exposure for surgeons and assistants. Robotic stone surgery is appropriate for modern circumstances, and scientific and technological advances will soon usher in the era of robotic stone surgery, probably much sooner than expected.

## CONFLICTS OF INTEREST

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