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REVIEW

Robotic stone surgery – Current state and future prospects: A systematic review

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KEYWORDS

Robotic stone surgery;
Urolithiasis;
Nephrolithiasis;
Stone disease;
Endourology

ABBREVIATIONS

EAU, European Association of Urology;
ESUT, European section of Uro-Technology;
EULIS, EAU Section of Urolithiasis;
PCNL, percutaneous nephrolithotomy;

Abstract ***Objective:*** To provide a comprehensive review of robot-assisted surgery in urolithiasis and to consider the future prospects of robotic approaches in stone surgery.

Materials and methods: We performed a systematic PubMed© literature search using predefined Medical Subject Headings search terms to identify PubMed-listed clinical research studies on robotic stone surgery. All authors screened the results for eligibility and two independent reviewers performed the data extraction.

Results: The most common approach in robotic stone surgery is a robot-assisted pyelolithotomy using the da Vinci™ system (Intuitive Surgical Inc., Sunnyvale, CA, USA). Several studies show this technique to be comparable to classic laparoscopic and open surgical interventions. One study that focused on ureteric stones showed a similar result. In recent years, promising data on robotic intrarenal surgery have been reported (Roboflex Avicenna™; Elmed Medical Systems, Ankara, Turkey). Initial studies have shown its feasibility and high stone-free rates and prove that this novel endoscopic approach is safe for the patient and comfortable for the surgeon.

Conclusions: The benefits of robotic devices in stone surgery in existing endourological, laparoscopic, and open treatment strategies still need elucidation. Although recent data are promising, more prospective randomised controlled studies are nec-

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RIRS, retrograde intrarenal surgery; SFR, stone-free rate; SWL, shockwave lithotripsy; (f)URS, (flexible) ureterorenoscopy

essary to clarify the impact of this technique on patient safety and stone-free rates.

Introduction

Urolithiasis is a common disease affecting men and women of all ages. Over the last decade, the prevalence and incidence of urinary tract stones has increased [1]. However, the incidence of urolithiasis depends on geographical, racial, and socioeconomic factors. The probability of stone formation is reported to be highest in Saudi Arabia (20.1%) and the USA (13%) but seems lower in Europe (5–9%) and Asia (1–5%) [2]. Stone disease is more frequent in Caucasians than in Blacks; however, a significant increase in the prevalence of urolithiasis in the Black race can be seen once they adopt Caucasian eating habits [3,4]. Generally, dietary habits seem to play an important role in the formation of calculi in the urinary tract. In particular, the intake of animal protein might increase the risk of stone formation and affect the chemical composition of stones [5]. With increasing patient numbers worldwide, urolithiasis is a present social and economic problem [6].

Currently, there are a variety of therapeutic options for urolithiasis. With minimally invasive techniques gradually replacing open surgery, treatment has changed considerably since the 1970s. The development of technologies, such as ureterorenoscopy (URS), percutaneous nephrolithotomy (PCNL), shockwave lithotripsy (SWL), laparoscopy, and robot-assisted interventions, has shifted treatment away from open surgery. Over the last two decades, interventional therapy for urinary calculi has increased significantly [7]. Whilst SWL rates have increased by 26%, URS approaches increased by 86% in the UK [8]. The significant increase in URS is clearly connected with the introduction of flexible endoscopes and, thus, retrograde intrarenal surgery (RIRS), improvements in laser technology, and better availability of devices [9]. PCNL rates increased with respect to the total number of treatments but were relatively stable compared to other treatment options. The total number of open surgery procedures decreased, whilst the total number of all modalities showed inconsistent trends in different countries [7].

However, in the last two decades, the use of robotic surgery has increased in the treatment of urolithiasis. The first use of robotic surgery was in 1999, when Intuitive Surgical Inc. (Sunnyvale, CA, USA) introduced the da Vinci™ Surgical System [10]. Initially designed for telesurgery in battlefields, the da Vinci system is currently the most common surgical robot. Like most robotic systems, the da Vinci robot is a master–slave system for laparoscopic surgery with various adaptions for utilisation in different disciplines and for an increasing number of indications [11,12]. In the field of urology, robotic surgery is mostly used for laparoscopic and, recently, for RIRS. In 2013 the Roboflex Avicenna™ (Elmed Medical Systems, Ankara, Turkey) master–slave robotic system was first clinically tested for RIRS [13].

Robot-assisted surgery for urolithiasis, one of the most common diseases in urology, is rare. One reason for this is that most patients with kidney or ureteric stones are treated with modern endourological interventions or extracorporeal SWL and, therefore, only a few indications for open or laparoscopic surgical interventions in urolithiasis remain [14–17]. Only in the few cases, where minimally invasive treatment options are not applicable or particular circumstances hamper their use, do urologists have the option to perform open surgery, laparoscopic surgery, or robot-assisted stone treatment.

The present article aimed to summarise the current knowledge on the application of robotic surgery for urolithiasis treatment.

Materials and methods

We conducted a PubMed© literature search using predefined Medical Subject Headings (MeSH) terms to identify robotic stone surgery-related studies listed on Medline and published up to the present (last search performed on 06/27/2017) (Fig. 1). We also screened abstracts from the 2016 and 2017 AUA Congresses, European Association of Urology (EAU) Congresses, European section of Uro-Technology (ESUT) Meetings and EAU Section of Urolithiasis (EULIS) Meetings. Publications relevant to the subject and their cited references were retrieved and appraised independently by two authors (D.S.S. and A.M.). In the case of a disagreement, a third reviewer was consulted to reach a unanimous decision. Systematic reviews and clinical studies (randomised controlled trials, cohort studies, case-control studies, and case series) were included. Animal studies, non-systematic reviews, and publications with 'Epub ahead of print' status were also included. Non-English-language articles, case reports, publications based on expert opinion, physiology/bench research or 'first principles', epidemiological studies, cross-sectional studies, and cadaveric studies were