

# Natural orifice transluminal endoscopic surgery in urology: Review of the world literature

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**Abstract** Natural orifice transluminal endoscopic surgery (NOTES) has gained momentum in the recent urologic literature as a new surgical approach for intra-abdominal organs with scarless and painless postoperative recoveries. We sought to review the published literature concerning the safety and reproducibility of NOTES in urology. PubMed literature review of articles published in the English language was performed over a 10-year period, i.e., between 2001 and 2011; all articles were critically reviewed and analyzed. Despite its novelty, pure or hybrid surgical approaches have been adapted in performing NOTES. NOTES essentially utilizes transluminal flexible endoscopic instruments along with laparoscopic instruments to gain access to abdominal, pelvic, and/or retroperitoneal cavities. The preliminary results of NOTES in surgery and to a limited extent in urology appear promising, yet further research in animal survival and human cadaveric models is requisite prior to human applications, especially for complex surgeries. Future innovative research, particularly biomedical engineering, should be directed to improving the technicality and mechanistic application of NOTES; hence, better safety and efficacy of NOTES.

**Key Words:** Natural orifice transluminal endoscopic surgery, urology, world literature

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## INTRODUCTION

Since introduction of laparoscopic radical nephrectomy by Clayman *et al.*,<sup>[1]</sup> the procedure revolutionized the practice of urology and ushered in a new era of expanded utilization of minimally invasive surgery (MIS) for major urological surgery, including laparoscopic partial and/or radical nephrectomy, laparoscopic radical prostatectomy, and laparoscopic radical cystectomy.<sup>[2-4]</sup> The advantages of laparoscopy over traditional open surgery include decreased morbidity, more rapid return to normal activity, and improved cosmesis.<sup>[5-7]</sup>

More recently, natural orifice transluminal endoscopic surgery (NOTES) has gained momentum as feasible techniques of MIS for a wide range of urological procedures, including oncological surgery, thus opening the door to a new surgical era, considered as “third generation surgery.”<sup>[8]</sup> The utilization of the natural orifice as a transluminal access to the peritoneal cavity has been shown to be effective and reproducible.<sup>[9]</sup>

In this systematic literature review, we sought to assess the actual role of NOTES, reviewing its history, analyzing the potential benefits and drawbacks, browsing and comparing the different transluminal routes, and describing the equipment and platforms currently available in the urological field.

## METHODS

A detailed, comprehensive literature review was performed to identify all published peer-reviewed articles which describe NOTES in the urological literature over a 10-year period, i.e.,

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between 2001 and 2011. The search was conducted through MEDLINE® database, the Cochrane Library® Central Search, and the Web of Science. Initial search terms were NOTES and urology. Search results were screened for appropriate studies with particular emphasis placed on clinical and experimental studies as well as review articles. Article referenced were screened to maximize review and inclusion of pertinent data. While English language text was not a specific search parameter, only English language publications were considered. All relevant studies collected were carefully examined to extract relevant data pertained to NOTES.

### Evidence synthesis

#### *Natural orifice transluminal endoscopic surgery progression*

NOTES was first described by Kalloo et al. in 2004;<sup>[10]</sup> following Kalloo's first experience, the American Society for Gastrointestinal Endoscopy (ASGE) and the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) working group on NOTES produced a consensus paper to further define its nomenclature, surgical description, and potential role in the advancement of surgery.<sup>[11]</sup> The ASGE/SAGES paper also highlights the need for a multidisciplinary approach to NOTES. Surgeons must have up-to-date knowledge of the NOTES procedure and should be aware of the current treatments offered by NOTES.<sup>[11]</sup>

Since then, NOTES has gained much attention by surgeons as the next step in MIS. NOTES involves the intentional puncture of one of the viscera (e.g. stomach, rectum, vagina, ureter and urinary bladder) with an endoscope to access the abdominal cavity and perform intra-abdominal operations [Figure I]. Hypothetically, NOTES offers the advantages of MIS, eliminates visible scars and trauma to the abdominal wall from incisions with potential for reduction in postoperative pain, analgesic requirements, and time to recovery.<sup>[12-18]</sup> The major advancement of NOTES when compared with traditional laparoscopy is the utilization of endoscopic flexible instruments at which laparoscopic surgeons can be trained and of which urologist are quite familiar with from routine urologic practice.<sup>[19-22]</sup>

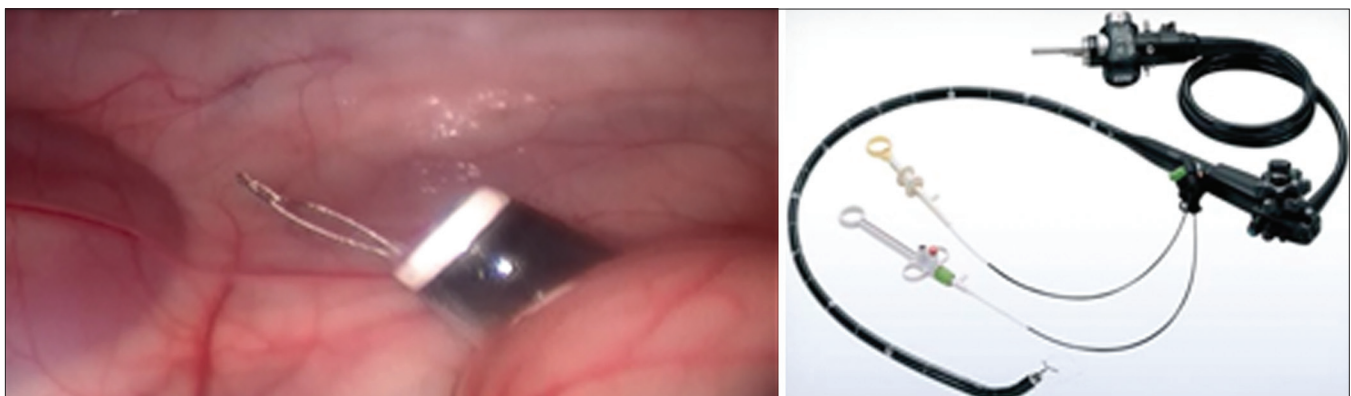
In human beings, Breda et al.<sup>[23]</sup> delivered a non-functioning kidney through the vagina followed by Gill et al.<sup>[24]</sup> reporting of 10 clinical vaginal extractions of kidney after multiport laparoscopic nephrectomy. Aron et al.<sup>[25]</sup> also reported feasibility of pure transvaginal nephrectomy in human cadavers and Sotelo et al.<sup>[5]</sup> and Kaouk et al.<sup>[12]</sup> reported the first successful transvaginal NOTES radical nephrectomy in a human being.

#### *Natural orifice transluminal endoscopic surgery approaches*

NOTES applications in urologic surgery is an exciting and emerging field of investigation, especially with the advancement in endoscopic management of urologic disease.<sup>[26]</sup> A range of surgical procedures were performed using a variety of different entry points in a porcine model. For example, the transvaginal nephrectomy with a periumbilical abdominal trocar for controlled visualization,<sup>[27]</sup> the hybrid transgastric-transvaginal nephrectomy<sup>[17]</sup> and a pure transvaginal route.<sup>[28]</sup> Intra-abdominal and thoracic organs can also be visualized through a transvesical route<sup>[14,18]</sup> or hybrid transgastric-transvesical cholecystectomy.<sup>[29]</sup> An experimental transureteric approach for hybrid NOTES nephrectomy has also been recently described by Baldwin et al. on three female pigs to establish its feasibility and future surgical application.<sup>[30]</sup> At our institution, we recently reported our experience of transrectal Hybrid NOTES where a transumbilical access was utilized for initial visualization of abdominal access and subsequent introduction of instruments for successful completion of procedure [Figures 2-4].<sup>[21]</sup> Pure NOTES abandons the security, provided an additional abdominal trocar; and for this reason, still poses a high risk of injuring organs situated behind the planned visceral perforation.<sup>[31]</sup>

#### *Natural orifice transluminal endoscopic surgery training*

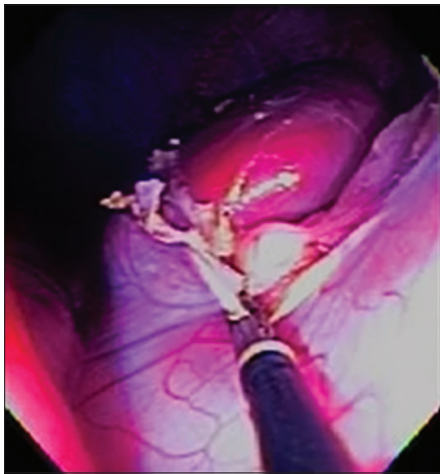
A research-oriented, multi-disciplinary team approach has been previously recommended for the NOTES surgical training.<sup>[20]</sup> This helps consolidate the diverse skill set that is needed to be successful with this approach. This team should include



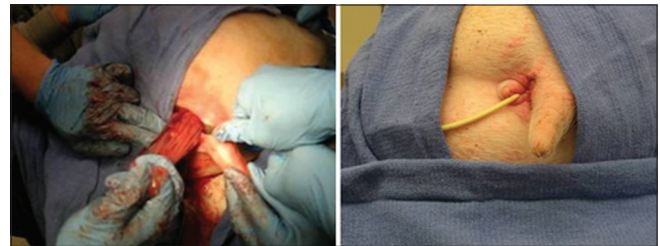
**Figure 1:** Flexible endoscope utilized in NOTES procedure (right image) and laparoscopic view of endoscope with snare (left image)



**Figure 2:** Creating submucosal rectal tunnel (right image) and surgical approach with transrectal trocar (left image)



**Figure 3:** Intraoperative laparoscopic view of dissecting forceps during NOTES procedure



**Figure 4:** Rectal extraction of specimen (right image) and rectotomy closure (left image)

general and gynecological surgery experts, urologists, and possibly even gastroenterologists with endoscopic expertise. A standardized training program is also recommended that focuses on development of a multidisciplinary research team, instrument familiarization, dry labs, simulators, and vivarium tasks before moving on to human trials.<sup>[20,31]</sup>

Future training should be directed to improve the optics and mechanical instrumentations, particularly endoscopes which will eventually help drive the future of NOTES. Computer-based, hands-on training with high fidelity to actual procedures will be important to establish basic familiarization with NOTES. More importantly, new robotic and integrated camera-information systems are being developed to correct camera angle and orientation and thereby improve surgical efficiency. Additionally, needlescopic or capsule-type cameras may improve optics.<sup>[32]</sup> Future NOTES training will also incorporate many of the new robotic and nanotechnology devices being tested as well as small robotic instruments.<sup>[33-36]</sup> These devices provide the surgeon with flexibility and strength of instruments to assist with both retraction and dissection or suturing.

Limitations of surgical training for NOTES remain highly debated in the surgical arenas, which can be partly explained by the lack of the long-term clinical data concerning the safety and efficacy of NOTES. NOTES training is steep learning curve because of the required instruments and expertise of working through a natural orifice which can be technically challenging. Close coordination with other surgical subspecialties, in particular gynecology or general surgery, is requisite to help establish safe access and in establishing a successful training program.

*Future directions of natural orifice transluminal endoscopic surgery in urology*

Both the ASGE/SAGES and the European urology working groups on NOTES (European Association for Endoscopic Surgery and the European Society of Gastrointestinal Endoscopy) have previously highlighted their targeted mission and objectives as (i) to increase awareness of NOTES in urology, (ii) to provide an outlet to share discoveries related to urological NOTES, (iii) to guide scientific evaluation and implementation of urological NOTES, (iv) to facilitate learning opportunities with urological NOTES, and (v) to define nomenclature of urological NOTES. The vision of this working group is to safely and systematically implement NOTES in urology.<sup>[11,15]</sup>

Despite the proposed potential benefits of NOTES in regards to improved cosmesis, shortened recovery period, and better pain control, their safety and efficacy are yet to be proven

in a large randomized trial where patient's oncological and functional outcomes are systematically measured as endpoints. Currently, the transvaginal access of NOTES has been found to be of minimal risk in human being.<sup>[17,24]</sup> However, concerns are related to the potential for dyspareunia, vaginal cuff hematoma, and/or infection following prolonged or complex transvaginal NOTES. Furthermore, the safety of transluminal access and a lack of purpose-built instrumentation are the two significant obstacles that exist in applying NOTES at a larger scale in urology. Hence, future research should focus on improving the safety of NOTES and its mechanistic application at surgery.

Other challenging aspects of NOTES are the suboptimal optical visualization, poor tissue grasping and manipulation, and significant surgeon fatigue. These limitations might further hamper the widespread of NOTES in surgery, including urology. Kaouk et al.<sup>[13]</sup> have previously recommended using extra long, articulating instruments in attempt to facilitate kidney dissection, particularly getting an access to the upper pole of the kidney. In addition, the combination of standard and flexible endoscopes offered a stable high-quality image with improved range of motion partially preventing instrument clashing.<sup>[12,13]</sup>

## SUMMARY

NOTES is a new and novel surgical concept in the urologic surgery. The utility of flexible endoscopic instruments along with laparoscopic instruments in surgery is well recognized in the published literature at the present time. The preliminary results of NOTES in surgery and to a limited extent in urology appear promising, yet further research in animal survival and human cadaveric models is requisite prior to human applications, especially for complex surgeries.

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