NOTES
Technical Aspects - Hype or Hope?

HUBERTUS FEUSSNER, M.D.1,3
PHYSICIAN

DIRK WILHELM, M.D.1,1
PHYSICIAN

ALEXANDER MEINING, M.D.2
PHYSICIAN

ARMIN SCHNEIDER, M.Sc.1
ENGINEER

ADAM FIOHLA, M.Sc.3
ENGINEER

SALMAN CAN, M.Sc.3
ENGINEER

HELMUT FRIESS, M.D.1
PROFESSOR OF SURGERY

1DEPARTMENT OF SURGERY, KLINIKUM RECHTS DER ISAR DER TUM
2DEPARTMENT OF GASTROENTEROLOGY, KLINIKUM RECHTS DER ISAR DER TUM
3WORKING GROUP, "MINIMALLY INVASIVE INTERDISCIPLINARY THERAPEUTIC INTERVENTION" (MITI)
MÜNCHEN, GERMANY

ABSTRACT

Natural orifice transluminal endoscopic surgery (NOTES) is currently an intensely discussed topic. The debate is extremely controversial, ranging from euphoric visions to complete refusal, and the future clinical role of natural orifice surgery is difficult to describe. This chapter analyzes the current technological status, and addresses the question of whether to enrich the surgical procedures will become an option. A literature research was undertaken using Medline and Pubmed. Personal experiences and communications were also included in this state-of-the-art report. The individual barriers currently impeding the clinical use, as defined by the NOSCAR group, are addressed in detail. With the exception of the vaginal access, no natural orifice-entering technique is already clinically mature. The selective use-potentially in combination-in a more refined technique than currently, is likely to provide a breakthrough. Most of the remaining obstacles are just a matter of further progress in advanced medical engineering. However, it should not be forgotten that the problems to be solved are less than trivial, and close cooperation between engineers and surgeons is essential. NOTES is still in the early stages of development. Currently available tools and techniques remain in the pioneer stage. However, worldwide activities in research and development will lead to promising solutions, which certainly will help to overcome the existing barriers. Whether "pure NOTES" or hybrid procedures only, surgery will take another step forward toward a less-invasive discipline.
INTRODUCTION

Less than 20 years ago, laparoscopic surgery emerged to minimize the operative trauma and improve the surgical outcome. After about 15 years of minimally invasive surgery, the next, even less-invasive surgical concept of natural orifice transluminal endoscopic surgery (NOTES) was developed to avoid even the tiny scars that result from laparoscopic interventions.

NOTES began in the animal laboratory with a landmark study published by Kallnoo and colleagues. They described a simple transgastric peritoneoscopy with liver biopsy in a canine survival model. In a short period of time, many additional papers were published that demonstrated the feasibility of even more complex procedures, such as cholecystectomy, appendectomy, lymphadenectomy, and others (Table I) (Fig 1).

It did not take long that the first human “NOTES cases” were performed as well (Table II). However, only a few were “true” NOTES interventions according to the definition of NOTES by Baron and coworkers: “NOTES implies surgery performed endoscopically by initially passing the endoscope transorally or tranannally, then transmurally into areas that would not otherwise be accessible endoscopically.”

In the majority of cases, current clinical reports deal with “pseudo NOTES” procedures. It has to be emphasized that the use of a transvaginal approach had already been established, such as for removal of gallbladders with large stones and of the specimen after laparoscopic splenectomy.

Obviously, the hurdles to perform “real NOTES” are still too high to introduce this new surgical concept into clinical routine. The relevant barriers for NOTES have already been identified and named rather early in the short history of NOTES by a working group known as NOSCAR (Natural Orifice Surgery Consortium for Assessment and Research) (Table III). They comprehend both medical and technological challenges, but the latter clearly prevail.

The aim of this Chapter is to describe the current status of NOTES and delineate the prospects to overcome the currently valid barriers.

DISCUSSION

Access to Abdominal Cavity

To date, the four different entry sites for natural orifice surgery have been used: transgastric, transcolic, transvesical, and— in female patients—the vaginal approach. So far, none of them is considered as ideal (Fig 2).

1. The transgastric route is currently the most popular way to enter the peritoneal cavity. Maneuvering the endoscope within the stomach is comparatively easy, and the degree of contamination is considerably lower than in the colon. Several technical refinements have been published to facilitate the initial gastroscopy, such as the balloon dilatation and PEG technique or the submucosal tunneling. However, some abdominal regions, such as the hiatus, are difficult to reach by way of the transgastric access.

2. In female patients, the vagina is a suitable natural orifice for the majority of NOTES procedures. Decontamination is easily achieved and it is little wonder that most human series on NOTES were per-

Figure 1. NOTES cholecystectomy in the animal model. The cystic artery and duct are already closed by hemoclip and dissected. After injection of a blue-dyed solution the gallbladder is separated from the liver and dissected by electrocautery.

Figure 2. Access to the peritoneal cavity is gained via different routes. The transgastric approach is currently applied the most often, but provides a limited view to upper gastrointestinal organs. Alternatively the abdomen can be entered via a transcolic, transvesical or transvaginal access of a blue-dyed solution the gallbladder is separated from the liver and dissected by electrocautery.
formed trans vaginally. However, it is only applicable in 50% of the patients, and there remains the concern regarding late complications (eg, dyspareunia).  

3. The transvesical access has been used for peritoneoscopy and thoracoscopy. It is the only orifice more or less sterile, and closure of the urinary bladder is safe and easy. The almost exclusive disadvantage is the restricted diameter. Only small-bore instruments (<5 mm) may have to be used to avoid damage to the urethra and sphincters.

4. The colonic approach is considered as the most problematic one by many authors despite the good viability. The main concerns are bacterial contamination and secondary leakage.

In three series, serious complications occurred in up to 20% of the patients. The authors developed the so-called innovative, safe, and sterile sigmoid access (ISSA). After establishment of a fluid peritoneum using a Veress needle, the gas-contaminating bowel is separated from the pelvic floor and rectosigmoid. Using transanal ultrasound, an entry point is identified at the anterior rectosigmoid junction in a safe distance from the bowel and major vessels. Closure is achieved using a purse string suture and a linear stapler (Figs. 3a & 3b). There will probably be no universal approach for the entire range of NOTES procedures. Imaginable is that the transgastric approach will be preferred for interventions in the lower abdomen, whereas the transvaginal or transanal access is superior for surgeries in the upper abdomen. Most interestingly, own first experience has confirmed that a dual access may be additionally helpful.

Prevention of Infection

Prevention of infection is the Achilles heel of NOTES, since the sealed, sterile, peritoneal cavity is entered not through the abdominal wall, which is decontaminated and disinfected easily, but by way of the more or less contaminated intestinal lumen.

As compared to the significance of this issue, current knowledge remains scarce. The stomach is usually not contaminated, but as soon as the intragastric pH is raised, bacterial and fungal overgrowth is common. Furthermore, the mouth and pharynx carry a heavy bacterial load and contact with the endoscope is inevitable.

As learned from an early study, NOTES interventions without any gastric preparation or decontamination are followed by a high rate of abdominal micro abscesses. Currently, most authors recommend gastric lavage with or without antibiotics. One study

---

**Table I**

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>N</th>
<th>Orifice</th>
<th>Intervention (N°)</th>
<th>No. of Surviving Animals</th>
<th>Survival Period (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bergstrom 2006</td>
<td>12</td>
<td>O</td>
<td>ANA (12)</td>
<td>Y (6)</td>
<td>7-10</td>
</tr>
<tr>
<td>Fong 2007</td>
<td>6</td>
<td>A</td>
<td>PER (6)</td>
<td>Y (6)</td>
<td>14</td>
</tr>
<tr>
<td>Jagannath 2005</td>
<td>6</td>
<td>O</td>
<td>FAL (6)</td>
<td>Y (6)</td>
<td>14-21</td>
</tr>
<tr>
<td>Kalloo 2004</td>
<td>17</td>
<td>O</td>
<td>BIO (5)</td>
<td>Y (5)</td>
<td>14</td>
</tr>
<tr>
<td>Kantsevoy 2005</td>
<td>2</td>
<td>O</td>
<td>ANA (2)</td>
<td>Y (2)</td>
<td>14</td>
</tr>
<tr>
<td>Lima 2006</td>
<td>8</td>
<td>U</td>
<td>BIO (8)</td>
<td>Y (5)</td>
<td>15</td>
</tr>
<tr>
<td>Merrifield 2006</td>
<td>5</td>
<td>O</td>
<td>OOP, TUB, HYS (5)</td>
<td>Y (5)</td>
<td>14</td>
</tr>
<tr>
<td>Pai 2006</td>
<td>5</td>
<td>A</td>
<td>CHO (5)</td>
<td>Y (5)</td>
<td>14</td>
</tr>
<tr>
<td>Park 2005</td>
<td>16</td>
<td>O</td>
<td>ANA (3); CHO (5)</td>
<td>Y (8)</td>
<td>14-28</td>
</tr>
<tr>
<td>Pham 2006</td>
<td>10</td>
<td>A</td>
<td>CC (10)</td>
<td>Y (8)</td>
<td>7</td>
</tr>
<tr>
<td>Raju 2005</td>
<td>5</td>
<td>A</td>
<td>CC (5)</td>
<td>Y (4)</td>
<td>7</td>
</tr>
<tr>
<td>Sumiyama 2006</td>
<td>5</td>
<td>O</td>
<td>APP (2)</td>
<td>Y (5)</td>
<td>1-2</td>
</tr>
<tr>
<td>Sumiyama 2007</td>
<td>6</td>
<td>O</td>
<td>MGC (6)</td>
<td>Y (5)</td>
<td>7</td>
</tr>
<tr>
<td>Sumiyama 2007</td>
<td>4</td>
<td>O</td>
<td>SEMF (4)</td>
<td>Y (4)</td>
<td>7</td>
</tr>
<tr>
<td>Wagh 2005</td>
<td>8</td>
<td>O</td>
<td>OOP, TUB, HYS (6)</td>
<td>Y (3)</td>
<td>7</td>
</tr>
<tr>
<td>Wagh 2006</td>
<td>6</td>
<td>A</td>
<td>OOP, TUB, HYS (6)</td>
<td>Y (6)</td>
<td>14</td>
</tr>
<tr>
<td>Wilhelm 2007</td>
<td>8</td>
<td>A</td>
<td>PER (8)</td>
<td>Y (8)</td>
<td>10</td>
</tr>
</tbody>
</table>

*Number of subjects receiving this treatment.
†Survival refers to monitoring of animals postprocedure for signs of morbidity, mortality, and recovery.
††Cadaver also used.

A, indicates anal; ANA, anastomosis; APP, appendectomy; BIO, biopsy; CC, colostomy closure; CHO, cholecystectomy; FAL, fallopian tube ligation; HYS, hysterectomy; LYM, lymphadenectomy; MGC, multiple gastrostomy closure; O, oral; OOP, oophorectomy; PER, peritoneoscopy; SEMF, submucosal endoscopy with mucosal flap; TUB, tubectomy; U, urethral.
demonstrated that povidone-iodine prevented the development of micro-
osses observed in control animals, but other data that also exist show gas-
tic rinsing with 5 liters of 0.9% saline is also effective.

The transcolonic approach is prepared even more comprehensively.
After water enema lavage, iodine or antiseptic solutions are usually instilled
and considered to be effective, but what the essentials are is difficult
to describe. It could be shown, however, that povidone-iodine and quater-
nary ammonium antimicrobial solutions lead to a significant reduction of
the amount of colonic flora and prevent postoperative infections/complica-
tions.

In our series, we currently use a mucosal antimicrobial solution (Octenisept, Schülke & Mayr, Norderstedt, Germany) after water enemas. In addition, the fluidoperi-
toneum is established by Taurolidin (Bi Pharma, Ingelheim, Germany). Therefore, the good results obtained encourage us to use the transcolonic
approach more liberally (Fig. 4).

Surprisingly, the debate regarding sterility and contamination is complete-
dly dominated by the topic of the approach. From the surgeon's point of
view, the question of being forced to use instruments and tools that cannot
yet be completely sterilized (flexible endoscopes and instruments), is at least
troublesome. It is remarkable how little attention has been given to this issue to date.

Nevertheless, NOTES is accompa-
nied by a significant intraperitoneal bac-

\[
\text{Table II} \\
\text{Human NOTES Cases} \\
\]
<table>
<thead>
<tr>
<th>Author/Year</th>
<th>N</th>
<th>F/M</th>
<th>Age</th>
<th>Orifice</th>
<th>Procedure (N)</th>
<th>Follow-up Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gettman 2007</td>
<td>1</td>
<td>0/1</td>
<td>56</td>
<td>U</td>
<td>PER (1)</td>
<td>2 mo</td>
</tr>
<tr>
<td>Haas 2007</td>
<td>10</td>
<td>NR</td>
<td>67.6 (49-79)</td>
<td>O</td>
<td>PER (10)</td>
<td>NR</td>
</tr>
<tr>
<td>Marks 2007</td>
<td>1</td>
<td>0/1</td>
<td>70</td>
<td>O</td>
<td>PER, PEG (1)</td>
<td>30 d</td>
</tr>
<tr>
<td>Tsai 2007</td>
<td>3</td>
<td>3/0</td>
<td>NR</td>
<td>V</td>
<td>APP (3)</td>
<td>Up to 2 mo</td>
</tr>
<tr>
<td>Burghardt 2008</td>
<td>20</td>
<td>20/0</td>
<td>NR</td>
<td>V</td>
<td>CHO</td>
<td>NR</td>
</tr>
<tr>
<td>Forgione 2008</td>
<td>3</td>
<td>3/0</td>
<td>48</td>
<td>V</td>
<td>CHO</td>
<td>1 mo</td>
</tr>
<tr>
<td>Ramos 2008</td>
<td>32</td>
<td>32/0</td>
<td>33</td>
<td>V</td>
<td>CHO</td>
<td>NR</td>
</tr>
<tr>
<td>Zorrin 2008</td>
<td>20</td>
<td>20/0</td>
<td>NR</td>
<td>V</td>
<td>CHO</td>
<td>NR</td>
</tr>
<tr>
<td>Zorrin 2008</td>
<td>4</td>
<td>4/0</td>
<td>35</td>
<td>V</td>
<td>CHO</td>
<td>NR</td>
</tr>
</tbody>
</table>

1 Number of subjects who received this treatment.
2 Mean (range).
3 Only 3 appendectomies of the case series of 100 patients were considered for this review.

APP, appendectomy; CHO, cholecystectomy; NR, not reported; O, oral; PEG, "PEG rescue"; PER, peritoneoscopy; U, urethral.
Table III
Potential Barriers to Clinical Practice for NOTES

<table>
<thead>
<tr>
<th>Potential barriers to clinical practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to peritoneal cavity</td>
</tr>
<tr>
<td>Gastric (intestinal) closure</td>
</tr>
<tr>
<td>Prevention of infection</td>
</tr>
<tr>
<td>Development of suturing device</td>
</tr>
<tr>
<td>Development of anastomotic (non-suturing) device</td>
</tr>
<tr>
<td>Spatial orientation</td>
</tr>
<tr>
<td>Development of multitasking platform to accomplish procedures</td>
</tr>
<tr>
<td>Control of intraperitoneal hemorrhage</td>
</tr>
<tr>
<td>Management of iatrogenic intraperitoneal complications</td>
</tr>
<tr>
<td>Physiologic untoward events</td>
</tr>
<tr>
<td>Compression syndromes</td>
</tr>
<tr>
<td>Training other providers</td>
</tr>
</tbody>
</table>

Intestinal Closure, Development of Suturing and of Anastomotic (Non-Suturing) Devices

**Problem of Viscerosynthesis**

NOTES is inevitably linked with at least one perforation: either the vaginal wall, urinary bladder, or gastrointestinal (GI) tract. A reliable closure is a condition sine qua non, in particular, of GI tract incisions. Primary or secondary leakage is a catastrophic and has to be avoided by any means.

Likewise, any full-thickness resection of the GI wall or circumferential sleeve resection requires a reliable technique of viscerosynthesis. Independent of whether only a small incision has to be occluded or a circumferential anastomosis has to be performed, the surgical technique should provide:

- adequate blood supply
- lack of tension
- inclusion of the submucosa
- air-tight repair

Many devices currently evaluated for NOTES do not yet meet these requirements.

Before the coming of NOTES, clips were already used occasionally by Endoscopists to occlude defects of the GI wall. If it is possible to control the wound edges to apply the clips properly, they function rather well. It is doubtful, however, that the safety and applicability are really sufficient for systematic use.

**Interesting Innovations**

T-fasteners positioned either before or after full-thickness resection are comparatively well-suited to close the defect. One of the problems is the laceration of adjacent structures. Well-known alternatives are the G-prox (USGI Medical, San Clemente, CA, USA) or the so-called NDO plicator (company no longer in business). The Endorive® (Fig. 5) and Eagle Claw (Olympus Surgical, Hamburg, Germany) need further functional improvement. All of these systems have in common that they are difficult to apply and time consuming, highly technical, and expensive. Recently, the newly developed OTSC® device (Ovesco, Tübingen, Germany) was presented. Further studies are needed to confirm whether it is really more advantageous.

The most reliable and fastest way to achieve viscerosynthesis is the use of staplers. For NOTES’ purposes, they need...
Table IV
Assessment of Current Gastrointestinal Occlusion Techniques\textsuperscript{16}

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Level of Difficulty</th>
<th>Safety</th>
<th>Applicability</th>
<th>Availability</th>
<th>Range of Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Closure</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Urinary bladder only</td>
</tr>
<tr>
<td>Submucosal Tunneling</td>
<td>medium</td>
<td>?</td>
<td>stomach only</td>
<td>exp.</td>
<td>high</td>
</tr>
<tr>
<td>Clips</td>
<td>low</td>
<td>Low</td>
<td>high</td>
<td>exp.</td>
<td>medium</td>
</tr>
<tr>
<td>Endorivet</td>
<td>medium</td>
<td>High</td>
<td>high</td>
<td>com. available</td>
<td>high</td>
</tr>
<tr>
<td>Tie Tag</td>
<td>high</td>
<td>High</td>
<td>high</td>
<td>exp.</td>
<td>high</td>
</tr>
<tr>
<td>Eagle Claw</td>
<td>high</td>
<td>High</td>
<td>?</td>
<td>exp.</td>
<td>medium</td>
</tr>
<tr>
<td>GI Prox</td>
<td>high</td>
<td>High</td>
<td>?</td>
<td>exp.</td>
<td>high</td>
</tr>
<tr>
<td>OTSC</td>
<td>low/medium</td>
<td>High</td>
<td>no lesion</td>
<td>com. Available</td>
<td>high</td>
</tr>
<tr>
<td>Plicator</td>
<td>medium</td>
<td>High</td>
<td>?</td>
<td>com. Available</td>
<td>high</td>
</tr>
<tr>
<td>Linear Stapler</td>
<td>medium</td>
<td>High</td>
<td>medium</td>
<td>com. Available</td>
<td>medium</td>
</tr>
<tr>
<td>Circular Stapler</td>
<td>medium</td>
<td>High</td>
<td>low</td>
<td>com. Available</td>
<td>low</td>
</tr>
</tbody>
</table>

\textit{com} = commercially; \textit{exp} = experimental

Figure 5. The Endorivet\textsuperscript{\textregistered} is a revolutionary modality for endoscopic closure of intestinal incisions or perforations. The rivet is applied via a liberator device and closed by adaptation of implemented plastic cramps. The sharp tip of the rivet is built of magnesium and dissolves autonomously in the acid gastric juice.
to be flexible, and the first examples are already available. The first experimental studies were performed to occlude a gastric lesion. For a broader range of indications, they have to be miniaturized and the head remotely controlled, including an integrated telescope. A universal and safe technique is not currently available (Table IV).

Spatial Orientation

Endoluminal surgeons and intracavity surgeons live in different worlds, with a completely different perception of the anatomy. Laparoscopists need, and are accustomed to, an “anatomical horizon.” Endoscopists are familiar with the exclusively prograde view to the object and coaxial action of the instruments. The GI lumen, even in the stomach, is comparatively small, which makes illumination and insufflation easy. The field-of-view of modern flexible endoscopes is completely sufficient to perceive the surgical site, and reliable anatomical landmarks are available for spatial orientation. As soon as the GI tract is left and the huge cavity of the abdomen is entered, the working conditions change significantly. It is impossible to achieve an “overview” or panorama view, because of the limited angle of the view, weak illumination, and inadequate position of the endoscope. Spatial orientation has to be gained by a mental synthesis of innumerable single visual segments, which is even more difficult due to the paucity of distinct and stable anatomical landmarks (Fig. 6).

However, it may be expected that computer science will soon be able to make intuitive navigation into the abdominal cavity possible. Augmented reality can be created by using preprocedure computed tomography (CT) or magnetic resonance imaging (MRI), real-time tracking of the endoscope, and reference image registration, which will be helpful in identifying the optimal perforation site or find the route to the intraperitoneal target.

New methods, such as the “time-of-flight”, enable engineers to define exactly the spatial position of each single object within the visual field. Surface rendering is, thus, feasible as well as mosaicing the vast number of images taken from various visual segments of the abdomen and a panorama view is reconstructed. The abdominal cavity is visible in its entirety, far beyond the small segment actually visualized by the endoscope.

Moreover, the precise spatial information is extremely helpful for use of instrumentation platforms by defining “forbidden zones” etc. It may be anticipated that these significant improvements in spatial orientation will make intra-cavity interventional techniques easier to master and use in clinical practice and, thus, more likely to be widely adopted.

Development of Multitasking Platform to Accomplish Procedures

The trend toward single-port surgery and, in particular, NOTES stimulates the development of new flexible manipulation systems. Currently available laparoscopic instruments or flexible endoscopes are inadequate to

Figure 6. The orientation problem inside the abdominal cavity currently is widely ignored; computer software and intelligent imaging processing potentially might provide supporting ambient information and a virtual reconstruction of the scenery.

Figure 7. Multitasking platforms, such as the HVSPS, may transfer the surgeon actions inside the abdominal cavity and therewith facilitate even complex interventions.
perform important maneuvers of manipulating tissues, and to set up traction and counter traction for exposure and division of anatomical structures.

Although a great deal of developmental work remains to be done, building up the hardware is the minor problem. Some systems, such as the Octopus, Direct Drive Endoscopic System (DDES), the miniature robot, or our own highly versatile single-port system (HYPS), are already in experimental evaluation (Fig. 7).

Serious problems, however, arise as soon as the surgeon or surgical team begin working with mechatronic support systems under clinical conditions. The control of multiple devices and functions is excessively demanding. It is inconceivable that humans are able to master this task without intelligent support of something like an autopilot in aircraft industry.

Two critical interfaces have to be considered: the interface between anatomy and the machine, and the interface between the machine and the human operator.

The task of computer science and medical engineering is to provide safety and efficiency of manipulating the tissue with mechanic end effectors by creating automated actions, identifying and avoiding potentially dangerous situations, etc. Computer science should alleviate the use of these types of complex technical systems by supporting decision-making and offering help to the user in performing the required manipulations. Thus, multitasking platforms will become part of an integrated Operating Room environment, which additionally offers a broad range of functionalities such as spatial orientation, as already mentioned, or automatic workflow analysis and support, and provides the optimal working conditions for NOTES.

Control of Intra-peritoneal Hemorrhage

The control of intraoperative bleeding and reduction of blood loss is a cornerstone of modern surgery. Endoscopic hemostatic techniques, however, are mostly confined to weak surface bleeding (Argon beam, epinephrine injections, electrocautery, etc). If a distinct vessel can be identified, clips or endoloupes can be applied. However, in general, NOTES techniques to manage acute and heavy bleedings are still limited and rapid conversion to laparoscopic surgery is recommended. However, it is to be expected that both of the two major advances that stimulated the development of laparoscopic surgery so greatly within the last years will soon be adapted for NOTES as well: impedance-guided electrocautery and ultrasonic dissection. As soon as miniaturized probes are available, NOTES interventions will be significantly enhanced.

Management of Physiologic Untoward Events, Compression Syndromes

The degree of invasiveness of a surgical procedure is not defined by the sum of incision lengths, but rather by the general physiological insult experienced by the patient. Intraabdominal transluminal endoscopy certainly creates new problems that do not appear in conventional diagnostic or interventional endoscopy.

The physiology of pneumoperitoneum has been studied intensively in
laporoscopy, but unknown is whether pneumoperitoneum during NOTES will behave in an identical fashion. In our own study, on-demand insufflation with a standard endoscopic light source/insufflator resulted in a marked increase and wide variation in intra-abdominal pressures throughout transgastric peritoneoscopy. Although only fair hemodynamic changes were observed, major increases in inspiratory pressure suggest a need for stricter control of intra-abdominal hypertension. How far these results may be transferred to humans remains to be further investigated, but dedicated NOTES insufflators will certainly have a pressure control.

Other issues of current and future investigation are the use of CO₂ instead of air, the prevention of gas embolism, and other phenomena like thrombo-cytopenia. Advances in this field will not revolutionize natural orifice surgery, but will improve feasibility.

**Training Other Providers**

It is a peculiarity of NOTES that the cognitive abilities and manual skills of both an Endoscopist and of an experienced Laparoscopic Surgeon are required. Accordingly, the need for education and training is only possible in animals. Inorganic training systems either mechanical or computer-based provide training facilities either for laparoscopy or endoscopy, but not for hybrid surgery or endoscopy. The first training manikins dedicated to education in NOTES is the “endoscopic/laparoscopic interdisciplinary training entity ELITE (CLA, Cæburg, Germany). It offers to simulate standard access techniques (transoral, transanal, transvaginal) and perform current NOTES interventions (e.g. peritoneoscopy, cholecystectomy, appendectomy) using the usual endoscopic instruments (Fig 8).

However, the degree of immersion is physically limited in mechanik models. In the long run, computer-based learning environments for virtual reality have to be provided. As in minor access surgery, or endoscopy, they are indispensable to shorten the way from bench to bedside.

**CONCLUSIONS**

The theoretical concept of NOTES as another step toward completely non-traumatic surgery is certainly exciting. However, this vision remains far away from becoming a reality.

Even though some reports on “scarless surgical procedures” have already been published, it is obvious that NOTES, using flexible endoscopy alone, is extremely difficult and may be applied in only exceptional cases. The use of additional, auxiliary transmural instruments, however, already offers a surgery without visible scars that may be a new alternative to conventional laparoscopic surgery in selected cases.

Further progress in biomedical engineering is predictable and, likewise, dedicated and most helpful new tools for NOTES can be expected. Accordingly, it is not a matter of why but when real NOTES will be available as a standard technique in modern surgery. In theory, even possible is that NOTES could substitute laparoscopy as the primary approach in the surgical treatment of various diseases, but more probably its main role will be that of a super low-invasive alternative to standard laparoscopy in select cases.

**REFERENCES**

23. Kallou AO, Singh VK, Jagannath SB, et al. Flexible transgastric peritoneoscopy: Anovel approach to diagnostic and therapeutic inter-
Surgical Overview

Surgical Technological Innovation XVIII


