

Natural Orifice Transluminal Endoscopic Surgery (NOTES) Towards Brighter Future

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Abstract

In natural orifice transluminal endoscopic surgery (NOTES) intentional puncture of one of the viscera (e.g., stomach, rectum, vagina, and urinary bladder) is made and an endoscope is used to access the abdominal cavity and perform an intra-abdominal operation. Early studies focused on feasibility, including such accomplishments as pure transgastric splenectomy and gastrojejunostomy. Contemporary studies are investigating the infectious and immunologic implications of NOTES and honing the tools and techniques required for complex abdominal operations.

Today NOTES has entered the clinical arena in quite a few cases: The first clinical series of transgastric peritoneoscopy has recently been published; many groups are accumulating patients in studies of NOTES cholecystectomy, either via the transgastric or transvaginal route; and a series of transgastric appendectomies has been well publicized, yet they remains unpublished. Although clinically NOTES is gaining momentum, the field should remain in check while rigorous studies are performed and clinical trials are undertaken. The zeal for NOTES should not take precedence over the welfare of the patient.

Keywords: Endoscopic surgery, transluminal, peritoneoscopy.

Kaloo's publication of transgastric peritoneoscopy in 2004¹ has led to evolution of field of natural orifice transluminal endoscopic surgery (NOTES). In a short time period, NOTES has been shown to be feasible in numerous laboratory animal studies and NOTES-specific instrumentation have already reached the research and development stages. Furthermore, the infectious and immunologic impact of NOTES has, in many cases, shown the equivalence of NOTES to laparoscopy and conventional abdominal surgery. As of now careful clinical trials of NOTES peritoneoscopy and cholecystectomy are being conducted, and as the data accumulate and instrumentation improves, NOTES will play a major role in the future of abdominal surgery.

BASICS

Fundamentally NOTES consist of passage of a flexible endoscope through one of the body's natural orifices, perforation of a viscous, and performance of abdominal surgery using endoscopic visualization. The endoscope may be inserted through the mouth, anus, urethra, or vagina with puncture of the stomach (the esophagus for mediastinal exploration), rectum, urinary bladder, or vagina, respectively. Although details of NOTES procedures vary between centers, most groups usually adhere to the same general principles. For transgastric surgery, a standard gastroscope is passed through the mouth into the stomach, small anterior gastrotomy is made, typically with an endoscopic

needleknife, a wire is passed through the site into the abdominal cavity, and then the tract is enlarged with an endoscopic dilating balloon to accommodate the endoscope. Transvesical and transcolonic operations use similar methods for entering the peritoneal cavity. Once the endoscope is inside the abdominal cavity, a pneumoperitoneum is generated using endoscopic insufflation and then scope is maneuvered to view the organ of interest. Endoscopic instruments, such as biopsy forceps and polypectomy snares can then be passed through the working channels and used for tissue manipulation. Once the operation is completed, the endoscope is returned to the lumen of the viscus and the viscerotomy is closed.

SHORT COMINGS OF CONTEMPORARY TECHNIQUES

As we can see from the description above, many limitations of current NOTES techniques are evident. Foremost is the fact that a hole is intentionally made in one of the viscera, which ridicules the decades of surgical dogma.

The flexibility of the endoscope causes difficulty in achieving a stable operating field. A deep loop into the pelvis is required to view the right upper quadrant in transgastric approach, and the endoscope might resist this positioning. Because of retroflexion, the endoscopic image might be reversed or inverted, further complicating the operation.

The current shortcomings of adequate instrumentation restricts the ability to perform meticulous dissection in

NOTES. In-line endoscopic tools are also a shortcoming as they have a restricted range of motion and limited degrees of freedom thus hindering the diamond baseball concept of the visual field and instruments, a concept found to be critical in laparoscopy.

As a purposeful viscerotomy is made in NOTES, its secure closure is a must to ensure the safety of the operation. Initial research work managed the viscerotomy without closure or by occlusion using a percutaneous endoscopic gastrostomy (PEG-type gastrostomy tube).² Both methods were not successful with high rates of intra-abdominal contamination in the porcine model. Thus, more reliable methods that achieve full-thickness closure of the viscerotomy are currently being evaluated.

ADVANTAGES OF NOTES

Some critics are apprehensive with NOTES, because of its differences with conventional surgical teaching. As of now, advances are being made in limiting some of the current shortcomings of NOTES. However, there may be some benefits of natural orifice surgery that make its pursuit rewarding.

The immunologic impacts of NOTES are favorable for the patient. A recent study from Case Western Reserve University showed lower levels of tumor necrosis factor- α (TNF- α) after NOTES peritoneoscopy compared to laparotomy and laparoscopic abdominal exploration.³

NOTES may lead to a lesser degree of impairment of the peritoneal immune system and possibly even improved oncologic and infectious outcomes.

Natural orifice surgery may decrease postoperative abdominal adhesion formation, like laparoscopy, the minimal access nature of NOTES might decrease the stimuli for adhesions formation and, subsequently, reduce the incidence of postoperative adhesive bowel obstruction.

NOTES can be performed without the need for general anesthesia under conscious sedation as no skin incision is made, therefore NOTES could be performed in the intensive care unit or endoscopy suite, rather than an operating room.

The NOTES team and its equipment are more portable as single endoscopy tower houses all of the necessary equipment.

Furthermore, in NOTES, procedures are performed without sterile instruments, only with scopes subjected to high-level disinfection. This makes NOTES more applicable to compromised environments, such as battlefields and especially in developing countries, where sterilization equipment is not readily available.

Finally, last but not the least the esthetic benefits of NOTES the concept of “no-scar” abdominal operations. This has captivated the public at large and is feasible with pure NOTES cases, although esthetics should not be the only driving force behind NOTES.

NOSCAR (NATURAL ORIFICE SURGERY CONSORTIUM FOR ASSESSMENT AND RESEARCH)

In a collaborative effort, members of the American Society for Gastrointestinal Endoscopy and the Society of American Gastrointestinal Endoscopic Surgeons joined to form NOSCAR. The purpose of this organization is to regulate the progress of NOTES and ensure the safety of clinical applications.

A NOSCAR publication which delineates the guidelines for laboratory and clinical natural orifice surgery has been deemed the “White Paper”.⁴ In the White Paper, the authors outlined the current shortcomings of NOTES techniques and some of the potential solutions. A call for rigorous scientific research was made before clinical employment of NOTES. Cooperation between the fields of gastroenterology and surgery was mandated, ensuring the communication of research findings and the multidisciplinary make-up of NOTES teams.

Recently, NOSCAR has launched a comprehensive NOTES database. All patients throughout the world who are enrolled in NOTES trials will be entered into the database.

ACHIEVEMENTS TO DATE

The publication by Kalloo led to the organization of the Apollo group. Shortly after the publication of transgastric peritoneoscopy, the Apollo group published reports on transgastric tubal ligation,⁵ gastrojejunostomy,⁶ and splenectomy⁷ in a porcine model.

Recently, members of the Apollo group collaborated in the performance of per oral transgastric ventral hernia repairs in a porcine model. These publications were significant as it proved that complex operations were feasible using NOTES techniques and the animals survived without undue complications.

Many studies followed and performed animal feasibility studies. Transgastric appendectomy,⁸ cholecystectomy,⁹ and oophorectomy¹⁰ were performed. The transcolonic⁹ approach was used to perform cholecystectomy, and the transvaginal approach has been used in laboratory animals to perform nephrectomy.¹¹ Combined transrectal and

transgastric approaches allowed performance of complex small bowel resections with intracorporeal formation of anastomoses.¹² Much of the initial studies focused on the feasibility of NOTES. It is now believed that although complex and plagued with restrictions, practically any abdominal operation could be performed using the available natural orifice techniques.

Reliable closure of the viscerotomy is the corner stone in avoiding intra-abdominal sepsis. As mentioned above, leaving the viscerotomy open and PEG tube occlusion of the gastrotomy were shown to be inadequate in the porcine model. Endoclips for closure have also been used with some success,¹³ however clips only provide mucosal approximation. Numerous devices have been used to attempt full thickness closure. One such instrument is the NDO Plicator which was initially developed for the endoscopic management of gastroesophageal reflux disease. It is a 15 mm instrument whose jaws place a full-thickness permanent suture with polytetrafluoroethylene bolsters. Closure of full-thickness gastrotomies has been shown to be reliable with the NDO Plicator.^{14,15} Bursting pressures of the porcine stomach after closure exceed 90 mm Hg and a water-tight closure is achieved, as evidenced by fluoroscopic contrast studies. Survival studies in porcine models have shown minimal rates of intra-abdominal infections after transgastric peritoneoscopy and closure with the NDO Plicator.

Another method of gastrotomy closure is using a commercially available over tube and suturing device.¹⁶ The over tube is steerable, torque-stable, fixable, and accommodates a slim endoscope and a suturing device. The suturing device consists of a grasper that locks at 45 degrees angle to the instrument shaft. A needle and suture passes through the device and can be bolstered with polyester tissue anchors. In the porcine stomach, robust, full-thickness sutures and fine tissue manipulation was achievable using this platform.

The self-approximating transluminal access technique (STAT)^{17,18} has been developed by the Penn State group that might obviate the need for full thickness closure. An incision is first made in the gastric mucosa, and then a submucosal tunnel is developed of at least 5 cm length using a dissecting balloon. After tunneling away from the mucosal defect, the muscularis and serosa are punctured, and the abdomen is entered. After the operation, the scope is withdrawn and only the mucosa is closed. In a porcine model, this technique has yielded favorable results.

Sumiyama have published transgastric cholecystectomies in laboratory animals using an offset gastrostomy, similar to STAT. A submucosal tunnel was created using high

pressure carbon dioxide followed by puncture of the remaining gastric wall. The endoscope was advanced through the tunnel into the peritoneal cavity and a cholecystectomy was performed. The submucosal tunnel was crafted cephalad to position the endoscope for operating in the right upper quadrant. At the end of the operation, the mucosal entry point was closed with clips or tissue anchors.

The Ohio State group has closed gastrotomies in animal studies with a bio absorbable plug, as in inguinal hernia repair.^{19,20} This eliminated the need for complex tissue manipulation and provided watertight closure with minimal chances of infectious complications. This technique might simplify the process of viscerotomy closure.

The pneumoperitoneum in NOTES is commonly created using endoscopic insufflators and as in laparoscopy, the intra-abdominal pressure requires continuous monitoring otherwise unchecked insufflation might lead to abdominal compartment syndrome. A recent study have shown that pressure transducers fitted to the end of a gastroscope or passed through a working channel can detect intra-abdominal pressure with a high accuracy.²¹ Such devices could be easily incorporated into NOTES operating endoscopes. Alternative means to monitor intra-abdominal pressure include passage of a transabdominal Verees needle for the same.

Adequate retraction is a must to safely perform complex abdominal operations, such as cholecystectomy but with endoscopic instruments, appropriate retraction has been difficult to achieve. Keeping this in mind a group from the University of Texas-Southwestern has developed an ingenious method using intra-abdominal magnets to provide retraction during operations.^{22,23} In their technique, an external magnet is paired to its intra-abdominal counterpart. The organ of interest is attached with a metal device, such as a clip, and paired to the magnet. Tissue manipulation is performed by moving the external magnet to achieve the desired retraction. To provide a stable surgical field for natural orifice surgery, new endoscopes are under development. Swanstrom²⁴ and others¹⁶ are using endoscopes that allow the surgeon to operate with both hands, without the need of one hand being used for stabilizing the endoscope. Others²⁵ are using commercially available multi bending endoscopes with dual instrumentation channels to provide better stability and maneuverability at the same time.

The NOTES endoscope of the future will have the ability to maintain a fixed position and its multi working channels would be angled in such a way as to make a diamond baseball concept with the operating field.

Some groups have overcome these obstacles of diamond baseball concept and retraction by inserting more than one

endoscopes into the abdomen. A group from the University of California-San Diego has performed complex small bowel resections by inserting endoscopes and staplers through both stomach and rectum.^{12,26} Although these procedures were done under laparoscopic supervision, but the same dual scope technique might be applied to pure NOTES cases.

Recently, NOTES sigmoid colectomy has been performed in human cadavers without a flexible endoscope. Swanstrom used transanal endoscopic microsurgery techniques to perform a radical sigmoid colectomy,²⁷ with high ligation of the vessels and generous lymphadenectomy.

There are only few reports in the literature of human transluminal cholecystectomy, all of them using the transvaginal route.

CLINICAL NOTES

Although one can suggest that natural orifice surgery has been practiced for years as transluminal drainage of pancreatic pseudocysts²⁸ and transgastric pancreatic debridement²⁹ are considered standard procedures for many advanced endoscopists. Culdoscopy, a procedure in which a laparoscope is inserted into the abdomen through the vagina, is commonly used in the management of infertility and tubal ligation. Some even might even suggest that percutaneous endoscopic gastrostomy, first described in 1979,³⁰ was the first endoscopic procedure that purposely breached the gastric lumen and supplanted a standard operation, thus qualifying as NOTES.

The first reported case of actual natural orifice surgery was performed nearly a decade ago by a surgeon in the United States. A hybrid of laparoscopic/endoscopic cholecystectomy was undertaken. Needlescopic instruments were used and laparoscopic cholecystectomy was done using standard techniques, however, for the retrieval of gallbladder anterior gastrotomy was made and the specimen was placed into the stomach and removed by mouth with the endoscope. The gastrotomy was then closed using intracorporeal suturing techniques.

After this first unpublished hybrid case, natural orifice techniques were largely ignored until Kalloo's 2004 publication. After the successes of the Apollo group with laboratory notes, a group in India performed a series of transgastric appendectomies and transgastric tubal ligations. Although unpublished, the videos have been widely circulated. The Columbia group in New York City performed a hybrid cholecystectomy with extraction of the specimen through the vagina.^{31,32} Dissection and retraction were performed with both the laparoscopic and endoscopic

instruments. The patient, reportedly recovered well after this procedure without complications. Many series of hybrid cholecystectomy, using a variety of techniques, have been publicized at international surgery and gastroenterology meetings.

The Ohio State group performed the first institutional review board-approved series of hybrid transgastric peritoneoscopy.³³ NOTES peritoneoscopy was performed in all patients with suspected adenocarcinoma of head of the pancreas. An initial diagnostic laparoscopy was performed followed by the creation of an anterior gastrotomy and transgastric peritoneoscopy under laparoscopic supervision. In most of the cases, NOTES abdominal exploration was found to be equivalent to laparoscopy in detecting peritoneal metastases. There were no complications directly related to the transgastric procedure. Thus the authors concluded that transgastric peritoneoscopy in humans is feasible and safe.

The first case of pure NOTES published from the United States was conducted at case Western Reserve University, Cleveland.³⁴ A PEG tube placed for nutritional support was dislodged three days after its initial placement and as the stomach had not yet adhered to the anterior gastric wall, therefore there was a free communication between the gastric lumen and the abdomen. The abdominal exploration and irrigation was done, and the gastrostomy tube was restored using pure NOTES techniques. To retrieve the PEG without laparotomy or laparoscopy, a gastroscope was advanced into the stomach, the prior gastrotomy site was dilated with a balloon and the endoscope advanced into the abdominal cavity. Some soilage was identified, which was cleansed using the endoscopic irrigation channel. The original abdominal incision was used to pass a wire into the peritoneal cavity, and the PEG was retrieved using the pull technique. After the "PEG Rescue" the patient recovery was uneventful.

The first true transluminal cholecystectomy was reported by Marescaux and colleagues from Strasbourg, France.³⁵ The transvaginal route was used to access the abdomen in a 30-year-old woman with symptomatic cholelithiasis. A 2 mm needle port was used for insufflation and monitoring of intra-abdominal pressure. The cholecystectomy was performed without the aid of a laparoscope using only NOTES techniques. The patient's recovery was uneventful.

NOTES: WHOSE DOMAIN IS IT ANYWAY?

The question arises as to whether surgeons or gastroenterologists will be the primary operators of NOTES.^{36,37}

After all, abdominal operations are typically under the purview of the general surgeon, but gastroenterologists are usually expert in flexible endoscopy. In all likelihood, minimal access surgeons and a small subset of advanced gastrointestinal endoscopists will be the NOTES surgeons of the future.

The NOTES surgeon should be expert in flexible endoscopy, abdominal anatomy, and surgical techniques. He or she should be capable of managing the pre- and postoperative care of the patients and, in particular, should be capable of handling complications from the procedure itself. It is also practical and of paramount importance that NOTES surgeons should be able to perform an operation laparoscopically and conventionally, as conversion to one of these modalities is a possibility in any NOTES procedure. These qualifications cross the boundaries of most gastrointestinal endoscopy teaching programs; hence, a new training model should be adopted. A gastrointestinal surgeon wishing to practice NOTES should pursue fellowship training in advanced endoscopy while gastroenterologist should complete a year of advanced interventional endoscopy and possibly an additional year dedicated to Surgery. Trainees from both the fields of surgery and gastroenterology should dedicate a substantial amount of time to laboratory endeavors, as this is where skills can be safely polished before clinical application. Training for a future in NOTES surgery will be different for surgeons and gastroenterologists. A gastrointestinal surgeon will likely focus on the technical aspects of flexible endoscopy, and a gastroenterologist might need familiarization with gross abdominal anatomy and laparoscopy. Neither surgeons nor gastroenterologists should consider NOTES an infringement on their territory or the demise of traditional surgery or endoscopy.

A BRIGHT FUTURE

Although today we are not far from but still we are not on the brink of widespread pure clinical NOTES. There are many potential applications of NOTES that will likely manifest in the near future. Given the portability of NOTES equipment and the requirement for only conscious sedation, NOTES is ideally suited for the intensive care units. There are two potential scenarios that have been described are applicable to ICU NOTES: diaphragm pacing and peritoneoscopic examination for ischemic bowel.

Diaphragm pacing has been shown to be effective modality in promoting ventilator weaning in ICU patients.³⁸ The procedure is commonly performed laparoscopically in the operating room with insertion of pacing wires into both

hemi diaphragms and externalization of the wires. The same procedure of insertion could be performed through a gastrotomy using NOTES which might obviate the need to transport a critically ill patient to the operating room.

Another scenario applicable to NOTES is the question of necrotic small bowel in cases of potential mesenteric ischemia in ICU patients.³⁹ These types of patients are usually critically ill and cannot taken to the computed tomography (CT) scanner without risks. The presence of ischemic small bowel might be confirmed with transgastric peritoneoscopy and should a short segment of ischemic small bowel be visualized, the patient could be wheeled to the operating room. Extensive small bowel necrosis not compatible with life might not be suitable for an operation, and the costs associated with a nontherapeutic laparotomy would be spared.

The minimal requirements of instruments and only the need for disinfection, rather than sterilization, make NOTES appropriate for developing regions of the world. NOTES could be performed without the infrastructure requirements of an operating theater and sterilization unit. The light source, video processor, and monitor could be easily transported from one place to another to best serve populations in need. NOTES might be the means to bring surgical care to underserved people even in the remotest of places.

The transportable nature of NOTES might make it amenable for battlefield abdominal exploration. A frontline facility could be arranged to explore the abdomen after serious abdominal trauma, If required hemostasis might be achieved with topical hemostatics or endoscopically placed packing. Once stabilized, the patient could then be transported to a higher center for definitive management.

Another possible derivative of NOTES is single port laparoscopy. For example a cholecystectomy might be performed through a single 10 mm umbilical port. A flexible laparoscope could be maneuvered into position and locked into place and special triangulating instruments with multiple degrees of freedom could then be used for the dissection. Specimen removal would then occur through the single umbilical port.

CRITIQUES

It is more than tempting to be swept up in the euphoria for NOTES, but hard data supporting the clinical applications of NOTES need to be accumulated before widespread use. NOSCART put forward the questions regarding the safety and utility of NOTES in the White Paper, and some of the answers are manifesting.

The infectious implications of transvisceral surgery may not be as critical as originally presumed. Certainly, bacteria will gain access to the abdominal cavity, but the peritoneum is efficient at clearing the microbes. After all, the bariatric surgeon is not overly worried about the gastrotomy contaminating the peritoneal cavity during construction of the proximal anastomosis. However, a temporary open gastrotomy is not harmful, but peritoneal soilage from a leaking closure may be devastating. Therefore, a substantial amount of effort should be devoted to assuring a reliable method of viscerotomy closure.

Other studies have also shown optimism regarding NOTES, as evidence is accumulating that the immune impact of NOTES is equivalent to laparoscopy. Some groups are developing ingenious methods of intra-abdominal access, retraction and dissection. Novel methods of transgastric access might simplify the issue of reliable closure. In aggregate, these data might be a further evidence that there is a role for NOTES in gastrointestinal surgery.

CONCLUSION

At present, this is generally true that routine NOTES cholecystectomies or appendectomies (i.e. those not under the aegis of an approved clinical trial) should probably not be performed until laboratory and technical advances materialize. Contrarily, there are likely a limited number of applications that are well-suited to the current application of NOTES, e.g. PEG rescue is a simple procedure that relies on available equipment and could have a role in patients with early dislodgement of a PEG tube. NOTES do not signal the demise of traditional gastrointestinal surgery or laparoscopy. It is plainly evident that further advances are required before NOTES can be considered for widespread application.

Current endoscopic instruments are not yet appropriate for total NOTES, but they allow operations using a hybrid approach. Tools that help in retraction, exposure and dissection needs to be developed. An over tube with multiple channels or a multiple channel endoscope with deflecting channels that give good retraction and dissection is likely to be of paramount value.

Above all, regard for patient safety must prevail. Only those with vast laboratory experience with NOTES should contemplate clinical NOTES procedures. Initially, only patients enrolled in clinical trials should undergo NOTES. To conclude NOTES is a precious raw diamond which needs to be further cut and polished.

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