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Chapter 5

Natural Orifice Translumenal Endoscopic Surgery of the GastroIntestinal Tract

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Additional information is available at the end of the chapter

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Abstract

Research Focus - NOTES is a new technique that faces numerous challenges. Current technology, training and research activities are conducted to make it a safe and effective minimal access technique.

Research Methods Used - This chapter is based on the current evidence of published NOTES studies. Medline search is conducted through November to December 2014, including English literatures only. The search words are NOTES, natural orifice translumenal endoscopic surgery, hybrid NOTES and hybrid natural orifice translumenal endoscopic surgery; additional search words are specific for the titles like NOTES gastric, NOTES oesophageal, NOTES biliary, NOTES cholecystectomy, NOTES pancreatic, NOTES small bowel, NOTES colorectal and NOTES appendicectomy. Animal and human studies are selected after 2008. Small studies are excluded unless they report a novel approach or a new procedure.

Results/Findings of the Research - There is development in the technology by installing new platforms, instruments and closure devices to add more safety and security. There is also development in training and research activities across the continents; a number of NOTES procedures are performed safely on human beings including cholecystectomy, appendicectomy, peritoneoscopy, POEM and other procedures. Feasibility studies are conducted on animal and human cadaver models including numbers of complex procedures.

Main Conclusions and Recommendations - NOTES is evolving and gaining popularity. The growth rate however is slowed by challenges of the need for an ideal working platform and closure devices that are easy to use, cheap and time effective, in addition to the dedicated effective training.

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Keywords: Upper GI NOTES, Lower GI NOTES, Oesophageal NOTES, Gastric NOTES, Duodenal NOTES, Liver NOTES, Pancreatic NOTES, Splenic NOTES

1. Introduction

Modern endoscopy began in 1805, when Phillip Bozzini first used a system to visualise the inside of the rectum and bladder through a mirror, a candle and a double-lumen ureteral catheter. The first source of inner light was invented by Bruck [1]. In 1878, Maximilian Carl-Friedrich Nitze introduced the first working cystoscope that contained a prismatic lens system and a channel through which you could insert a ureteral catheter, conducted in collaboration with Joseph Leiter [2]. Diagnostic methods of gastrointestinal tract have been evolving using flexible endoscopy. Dimitrij Oscarovic Ott (1855–1929) can undoubtedly be called the true pioneer of laparoscopy, especially of natural orifice translumenal endoscopic surgery (NOTES). In 1901 already he performed abdominal examinations via a transvaginal (Tv) access calling this procedure 'ventroscopy' [3]. In 1954 Hopkins made a crucial development by the idea of incorporating the light into scopes using the concept of multiple lenses separated by a room of air. Hopkins could never make the fibrescope, and it was a South African, Basil Hirschowitz, who made the first flexible fibreoptic gastroscope using Hopkins's idea [4]. Endoscopic retrograde cholangiopancreatography (ERCP) which was developed in 1968 and endoscopic ultrasound (EUS) in the 1980s are important milestones. With the development of sophisticated flexible scopes, it became feasible to conduct certain diagnostic and therapeutic GI procedures. Anthony Kalloo in 2000 reported the first peritoneoscopy on pigs [5]. Gastrointestinal (GI) NOTES is a further development in the minimal access surgery (MAS). It has been received by surgical community with scepticism similar to what happened with the first laparoscopic cholecystectomy (LC) when Muhe introduced it for the first time to the German Surgical Society in 1985. In 2004 Rao and Reddy performed the first transgastric (Tg) appendicectomy [6]. In 2012, authors considered that rigid standard laparoscopy provided better organ visualisation, better lesion detection and better biopsy capability than the transgastric (Tg) and transrectal (Tr) NOTES approaches [7], and that is expected as NOTES still undergo refining and development which should push for more efforts to overcome these challenges. In spite of uncertainty, GI NOTES proved itself for a number of procedures that are applied in elective and emergency settings with significant contribution to improve the care and attained a high level of patient satisfaction and most importantly a great scale of safety and efficacy. The GI NOTES is gaining popularity but at slower rate compared to LC. It has been limited to the university institutions and big teaching tertiary centres across Europe, America and Asia. Nevertheless, large series are reported on human beings. Many centres are conducting feasibility studies on animals as well as cadavers and patients. Several obstacles are preventing the wide applications of NOTES. Of these is the need for advanced endoscopic and laparoscopic skills, infrastructure setting, funding and local health authority approval and health systems bureaucracy. Germany reports the highest number of human NOTES procedures in the Europe, while the USA is the leading state in the American continent.

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1.1. Challenges to NOTES

1.1.1. Experience

The NOTES main tool is a flexible scope and unstable working platform. Preliminary endoscopic, and to less degree laparoscopic, experience is a pre-request for conducting NOTES procedures. An excellent endoscopic experience is crucial in conducting NOTES procedures [8]. A study from Germany showed endoscopic experience was the strongest influencing factor, whereas laparoscopic skills had limited impact on the performance of NOTES surgeons with previous endoscopic experience [9]. This can be explained by the ability of the endoscopist to adapt for movement and to perform procedure using unstable and flexible platform. Reputable institutions are organising training courses for NOTES, and a good example is Strasbourg in France. Training on animal models is providing opportunity of operating on living subjects and increasing the confidence of performing the procedure on patients [10]. An example of the training model is the endoscopic–laparoscopic interdisciplinary training entity (ELITE) used in Germany. One of the important issues in training is the willingness and interest of the junior surgeons to adapt NOTES in their institutions.

1.1.2. Governance, regulations and training

Extensive training is required for surgeons to overcome the vision–motion difficulty before they can perform NOTES safely and effectively [11]. Different bodies are sponsoring NOTES training in the USA, Europe, South America and Asia. NOSCAR and EAES are leading the research, training and development of NOTES. In 2005, the American Society of Gastrointestinal Endoscopy (ASGE) and the Society of American Gastrointestinal Endoscopic Surgeons (SAGES) formed the Natural Orifice Surgery Consortium for Assessment and Research (NOSCAR) and published the NOTES white paper [12, 13]. In Europe, the New European Surgical Academy (NESA) founded the NOS (Natural Orifice Surgery) working group, which is exploring another surgical route, the TransDouglas (Td) one. The NOS/SLO group is an interdisciplinary working group of the NESA. Its goal is to develop surgical procedures using the natural openings of the human body and "scarless" operations [14]. There are similar scientific bodies in South America like Brazilian group and also in Asia like Japanese, Chinese and Indian NOTES groups. The Virtual Translumenal Endoscopic Surgical Trainer (VTEST (TM)) is being developed as a platform to train for NOTES procedures and innovate NOTES tools and techniques [15]. Different tools are used in NOTES training courses. These include operating on animal models with an acceptable grade of satisfaction. One of such tool is the endoscopic–laparoscopic interdisciplinary training entity. A study has shown the constructing validity for the ELITE model which seems to be well suited for the training of NOTES as a new surgical technique [16].

1.1.3. Funding

The rising costs of healthcare are forcing all parties to consider both the medical risks/benefits and the economic efficiency of proposed tools and therapies [17]. Funding is required for research and for setting of the infrastructure to perform NOTES procedures on animals and

patients. NOTES surgery needs extra cost for the instruments. The endoscopic closure devices, the working platforms and scope are very expensive compared to the classical laparoscopic instrumentations. Funding is a problem in the current era, and the leading teaching centres across America and Europe can afford it. The collaboration with businesses and industries has resulted in huge budget of funds to the NOTES research. For example, by 2009 Olympus has donated $1.25 million supporting NOTES activities in the USA [18]. Ethicon offered similar support and funding for NOSCAR research in the USA. The Center for Integration of Medicine and Innovative Technology's (CIMIT) investment in NOTES research will top $3 million overall, making CIMIT the largest financial sponsor of this technology worldwide [19].

1.1.4. Pressure of common acute and elective surgical take

Undertaking NOTES procedures in addition to the common surgical workload is adding a practical challenge. However, this can be resolved by dedicated time for specific NOTES activities. It is expected that NOTES will be a separate and distinguished speciality for the gastrointestinal surgeons.

1.1.5. Bureaucracy of health systems

It is not a surprise that the first reported NOTES procedure of appendicectomy was from the Hyderabad group in India which has less bureaucratic health system compared to Europe and the USA. The bureaucracy because of high grade of concerns about safety of any new technique or intervention. While this is a healthy issue, sometimes it defers innovations and frustrates surgeons who are trying to bring in reality and clinical practice new ideas and approaches. NOTES is not an exception to be rejected as a new method. In order to install NOTES technique, one would need extra efforts to pass through the hurdles that built up across modern health systems. In the UK we are much behind the fellow Europe states like Germany as far as NOTES is concerned. This may also be explained by less popularity of the technique in the UK. South London's Surrey University, Guildford, held the first ever NOTES training course in 2008. In the UK, there is no specific body to support NOTES research like NOSCAR in the USA or the NESA group of Europe.

1.1.6. Public opinion

As expected a study of 1006 patients demonstrated public's interest in these new techniques and thus gave further support to continued research and development in this area [20]. The Swanstrom group from the USA reported that majority of the patients surveyed (56%) would choose NOTES for their cholecystectomy [21]. It is not surprising that patients would choose an approach that provides excellent cosmetic and clinical outcomes with high safety profile [22]. Surgical societies are committed to work towards perfection, and NOTES is the ultimate approach for the management of a number of surgical conditions and provides extra benefits of minimal access techniques.

1.1.7. Septic complications

NOTES is not different from classical surgery of possible risk of infection. Intravenous antibiotics in addition to topical Betadine or chlorhexidine have effectively reduced microbial

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burden in both gastric and colonic mucosa in porcine model [23]. The common Tg and Tv routes are compared in animal models, and authors concluded that without gastric or vaginal lavage and antibiotic peritoneal irrigation, the Tg procedure has a higher infection rate than the Tv access. After antiseptic preparation, the bacterial load significantly decreased in the Tg group, which seems as safe as the sterile Tv approach [24]. However, in a study of 40 patients who underwent Roux-En-Y gastric bypass (RYGBP), contamination of the peritoneal cavity does occur with Tg endoscopic peritoneoscopy (TEP), but this does not lead to an increased risk of infectious complications [25]. Another study of 130 patients who underwent Tg NOTES showed that the risk of bacterial contamination secondary to peroral and Tg access is clinically insignificant [26]. Pure Tg endoscopic surgery results in less perioperative inflammatory response than laparoscopy in the early postoperative phase [27]. In a review of literature by the Darzi group, UK showed that recommendation requiring no preoperative preparation can be made for the Tg approach. Antiseptic irrigation is recommended for Tv (grade C) NOTES access, as is current practice [28].

1.1.8. Intraoperative NOTES complications

The management of intraoperative NOTES complications could be challenging. Adequate experience is therefore necessary to recognise and treat them to avoid morbidity and mortality and to minimise conversion to hybrid NOTES or open technique. Effective management of NOTES complications however is reported, for example, bleeding complications and splenic laceration [29]. For intestinal perforation, the case may be different. Authors found that small intestinal injuries are difficult to localise with currently available flexible endoscopes and accessories. Endoscopic clips, however, may be adequate for closure of small bowel lacerations if the site of injury is known [30]. A study has shown that urinary bladder injury occurring during NOTES can be successfully managed via a NOTES approach using currently available endoscopic accessories [31].

1.2. Principles of NOTES

1.2.1. Indications

NOTES approach is indicated in a variety of conditions across surgical specialities, not only gastrointestinal tract but also urology, gynaecology and thoracic field. NOTES indications could be an emergency or elective which is the majority. This chapter is concentrating on upper GI NOTES.

1.2.2. Access

1.2.2.1. Major sites for access

1. Transgastric (Tg): The first human NOTES procedure was performed using Tg route. The experimental studies proved ultrasonography-guided access through the stomach to be feasible and safe without iatrogenic complications [32]. There are two challenges in the Tg route: the closure and the abdominal contamination and septic complications. The ideal

Tg access closure is expected to be easy, effective, cheap and less time consuming. Tg NOTES peritoneoscopy and the gastrotomy can be closed by deploying a 2-sided ECM occluder on animal model [33]. The results indicated that closure of gastrotomy by Eagle Claw VIII could withstand higher endoluminal pneumatic bursting pressure than endoclips [34]. Submucosal approach is a new and promising technique for the development of NOTES [35] (see Figure 1).

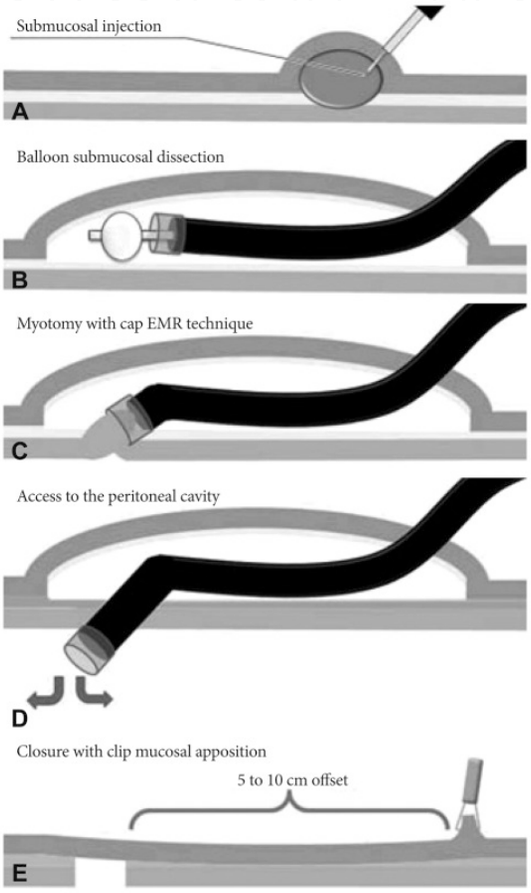


Figure 1. Submucosal tunnel technique is used (Lee SHI et al. 2012)

The Tg access closure is provided by different techniques including clips (over-the-scope clip), sutures, etc. [36, 37]. There are different closure methods in literature, but safety is shown in one of animal studies at least comparable to the classical laparoscopy procedure [38]. A novel gastric closure device, the loop-anchor purse-string (LAPS) closure system, had been described [39]. If hybrid technique is used, then laparoscopic stapler can be applied to the gastric access [40]. A multilayer extracellular matrix (ECM) occluder is assessed on animals, and it was safe and effective [41]. A loop and clip [KING closure], (see figure 2), [42] and QUEEN closure are other methods [43]. Self-approximating translumenal access technique (STAT) and implantation of a cellular matrix in the STAT tunnel are the two methods that have shown safety and efficacy on animal model [44]. There has been a method of testing support closure with T-tags and Padlock-G-clips over OVESCO OTS-clips and standard endoscopic clips [45].

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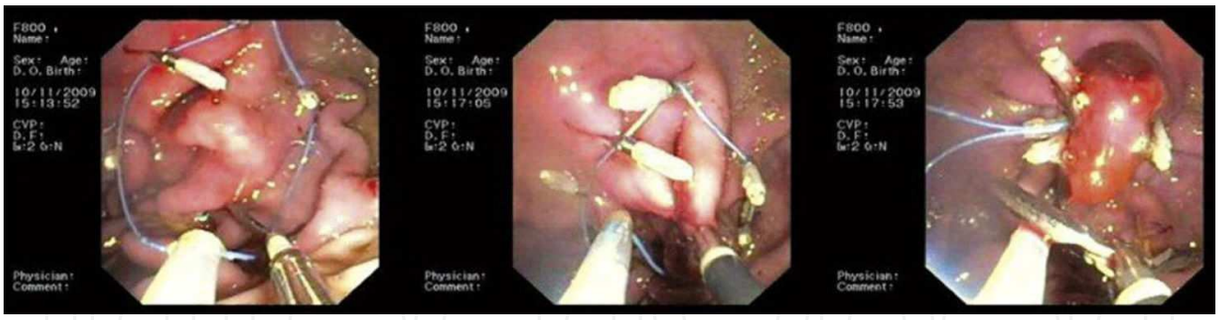


Figure 2. KING closure, loop and clip by Ryska O et al. 2012

2. Transvaginal (Tv): A recent meta-analysis confirmed high safety profile with this technique [46]. Infectious complications and the closure are the two important areas in this approach. A recent study of 102 Tv NOTES procedure reported only one case of infection following appendicectomy [47], which is comparable to the laparoscopic approach for similar pathology. Closure of the Tv access can be easier than Tg one [48]. Simple suturing under direct vision is the norm.

3. Transrectal (Tr): Animal studies have shown safety and efficacy [49]. The flexible endoscopic stapler is an effective device for the safe closure of a colon access, which in this feasibility study was equivalent to other well-established techniques [50]. Closure of Tr viscerotomy using end-to-end (EEA) circular stapler technique is feasible, easy to perform and histologically comparable to suture closure through a TEO platform. It may offer an attractive alternative for NOTES segmental colectomies and endoscopic resections [51]. The colostomy was closed by occlusion loop-and-clip (KING closure) technique [52]. To access the retroperitoneal space, significant challenges locating identifiable landmarks were faced mostly transrectally and improved in transgastric prone position [53].

4. Transvesical (Tve): Many animal studies have reported feasibility of NOTES procedures through the urinary bladder [54, 55]. Still there are no significant clinical applications on patients because of the challenging access closure and also because of the specimen delivery. J Bhullar et al. from Providence and medical centre, USA, used Vicryl loop for bladder access closure on a porcine model [56], (figure 3).



Figure 3. Vicryl loop closure of transvesical access (J Bhullar et al. 2012)

1.2.3. Instrumentation

Developing interfaces that are both intuitive and simple to use is crucial for NOTES dissemination [57]. The minimally invasive cardiac surgery (MICS) robot [58] is another step towards optimisation of the NOTES technique and to address the problems of optics, flexibility and the comfortable and adequate exposure. Abdominal navigation and accessing the pancreas was investigated on animals, and based on its success, pancreas resection was performed. A prototype multitasking platform "EndoSAMURAI" with the use of a biosimulation model and ex vivo porcine stomach was reported [59], (figure 5). There are new ancillary instruments like forceps, and training on using them is continuing [60]. The SPIDER platform is a sterile and disposable device that contains 4 working channels (2 flexible instrument delivery tubes positioned laterally and 2 rigid channels superiorly and inferiorly to accommodate an endoscope or any of the shelf rigid surgical instruments) [61]. This device has addressed some of the technical problems, and it is relatively expensive which limits its wide use. Authors concluded that the new manual handling system (MHS) is fully capable of achieving payload transport during a NOTES operation. The system is intuitive and easy to use. It dramatically decreases collateral trauma in the natural access point and can advantageously reduce the overall duration of a procedure [62]. The 3D display system is a great step in optics development. At least 34 systems are developed, for example, Aesculap's EinsteinVision (see Figure 4). This is in current use for laparoscopy and has the potential to improve the vision and anatomy at challenging NOTES procedures [63]. The Direct Drive Endoscopic System (DDES; Boston Scientific, Natick, MA) is a flexible laparoscopic multitasking platform that consists of a 55-cm steerable guide sheath that houses 3 lumens extending from a rail-based platform with interchangeable 4-mm instruments [64], (figure 6). Incisionless Operating Platform (IOP) is another flexible scope used for NOTES procedures including cholecystectomy [65].



Figure 4. Aesculap's EinsteinVision® system

1.2.4. Anaesthesia

There are three main issues when using transoral access to perform upper GI NOTES procedures: The first one is to intubate via transnasal route to spare the oral space for NOTES flexible scope, the second issue is to position the patient according to the type of procedure, and the

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Figure 5. EndoSAMURAI platform, Yasuda K et al. 2014



Figure 6. Direct Drive Endoscopic System (DDES), S Shaik et al. 2010

third point is to monitor ETCO2 [66], (figure 7). For other NOTES accesses, transnasal intubation is not necessary. Anaesthetic technique can be different from laparoscopic surgery. The effect of pneumoperitoneum may be not different; both techniques will have pneumoperitoneum if it is abdominal NOTES procedure. POEM procedure, for example, does not need pneumoperitoneum [67, 68]. Any patient that cannot tolerate pneumoperitoneum because of cardiopulmonary disease is not a candidate for NOTES procedure. Cardiorespiratory physiology is affected by laparoscopic procedure mainly because of pneumoperitoneum. However, the non-inferiority of NOTES compared to the laparoscopy is demonstrated from reported studies, although the evidence is limited by a number of researches [69]. When administering anaesthetic care to a patient undergoing NOTES, anaesthesiologists should closely monitor the patient's position as well as ETCO2 to minimise the incidence of mediastinal emphysema and pneumomediastinum and to ensure early detection of pneumoperitoneum-related respiratory and hemodynamic changes [70].

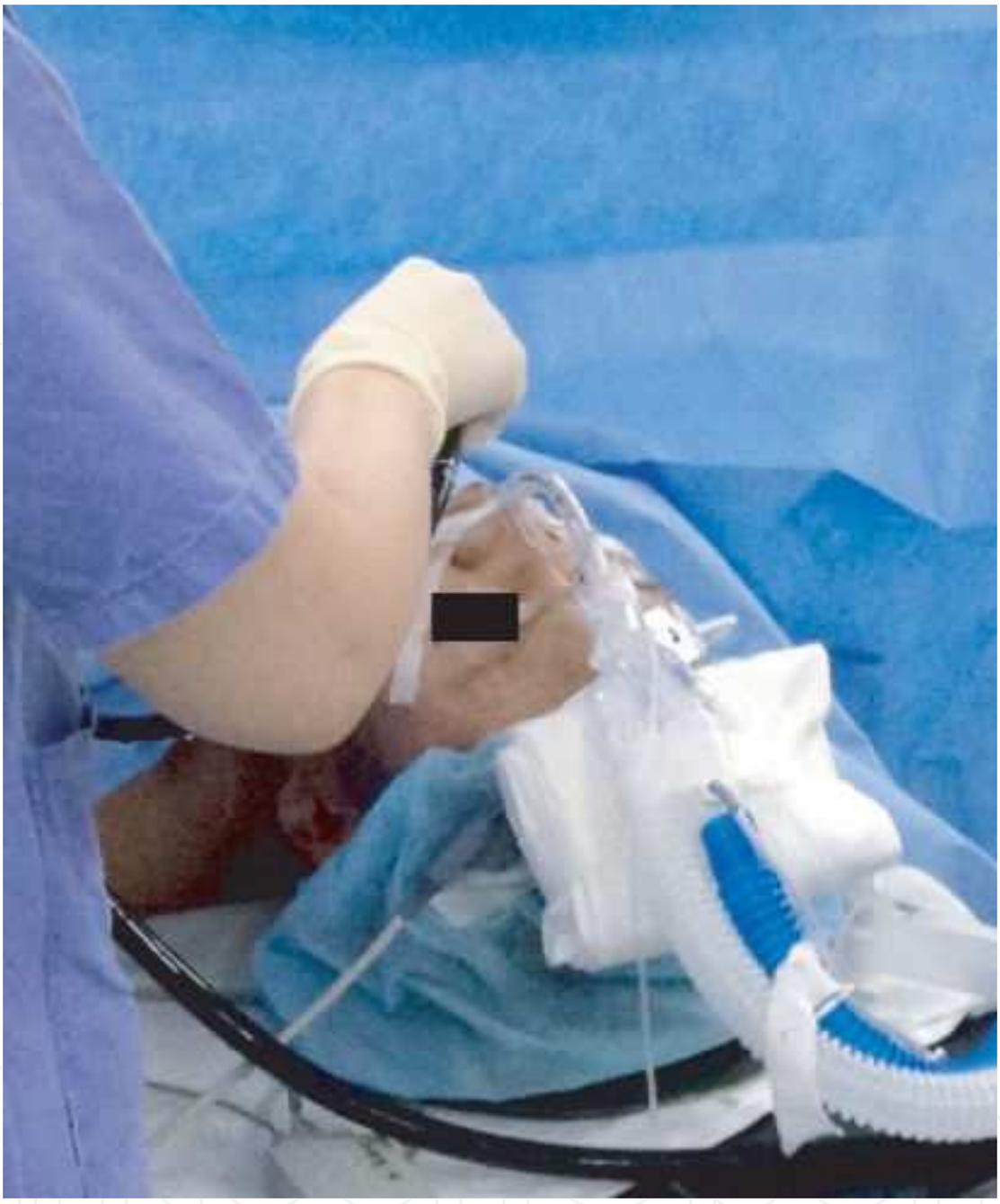


Figure 7. Transnasal intubation in upper GI NOTES. The patient was placed in the supine position and intubated via a nasal RAE™ tracheal tube. The endoscopic operator stood near the head of the patient and inserted the endoscope via the mouth (Ji Hyeon Lee et al. 2014)

1.2.5. Setting

NOTES units are part of surgical departments whether upper or lower GI, gynaecology and urology units. These units are usually located in well-established teaching hospitals. Theatre facilities are available for minimal access approach. Staffs are trained in NOTES, and they are familiar with the preparation and assistance.

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1.2.6. Expertise

NOTES experience is crucial for the quality and safety of this intervention. The current guidelines advise to run through milestones of animal studies, cadaveric and live subject experimental and pilot projects. Once the learning curve is achieved after a number of procedures, NOTES can be performed under strict governance system. This has been achieved in a number of US and European states.

1.2.7. Complications

All minimal access surgery serious complications are those of organ injury due to suboptimal exposure that results from bad technique. It is anatomical and visual hallucination. This is to be avoided to provide the high grade of safety. Industries, related professionals and surgeons are striving to address all the issues that preclude safety.

2. Upper GI NOTES

2.1. Oesophagus NOTES

A number of oesophageal NOTES procedures are conducted safely on patients. Oesophageal discontinuity, which is a very complex procedure, is performed using a modification of NOTES [71]. The peroral endoscopic myotomy (POEM) for lower oesophageal conditions like achalasia has been performed on animals and patients with great success. NOSCAR has recently produced its white paper about the milestones of the POEM technique and the current opinion about the indications and quality and safety [72]. Distal oesophageal spasm that can progress to achalasia is another indication for POEM [73]. In 2002, Smith et al. found that the endoscopic stapling technique for the treatment of Zenker diverticulum results in a statistically significant shorter operative time, hospital stay and time to resume oral feedings compared with the standard open technique [74]. Transesophageal approach to posterior mediastinum has been reported on animal models [75]. Transoesophageal, anterior spinal NOTES reported lymph node resection, vagotomy, thoracic duct ligation, thymectomy, biopsy of the lung and pleura, epicardial coagulation, saline injection into the myocardium, pericardial fenestration and anterior thoracic spine procedures [76]. Exposure of the GOJ and placement of an anti-reflux prosthesis via a hybrid NOTES procedure were feasible, despite some complications [77]. Translumenal oesophago-oesophageal anastomosis was feasible on animal model [78]. Transoesophageal thoracic NOTES are a growing field. Diagnostic procedures have been well described. Closure of the oesophageal access is managed by different approaches including stenting [79].

2.2. Gastric NOTES

Gastric resection and specimen extraction through the upper GI route are reported by authors [80]. On animal models, a gastrojejunostomy was feasible with a 4-cm length using an anastomosing metal stent. After gastrotomy formation using a needle knife, a jejunotomy was

then performed in the gastric cavity, which was followed by deployment of an anastomosing metal stent under fluoroscopic guidance [81]. Also on porcine model, combined NOTES and single trocar sleeve gastrectomy is feasible in a porcine model [82]. Through Tv NOTES gastrectomy for gastric submucosal tumours, with the assistance of two transabdominal ports, "oncologically acceptable" partial gastrectomy was successfully performed [83].

The hybrid NOTES technique is a combined method, including the advantages of both laparoscopic resection and endoscopic resection for gastric subepithelial tumours (SETs) [84]. After a 40-mm submucosal tunnel was created using an endoscopic submucosal dissection technique, in TGP, balloon dilation of a serosal puncture and intraperitoneal exploration were performed; in EFTR, a full-thickness incision and snaring resection were performed. Closure of the mucosal incision was performed by endoclips [85].

Hybrid sleeve gastrectomy (SG) and delivery of the specimen by transoral remnant extraction (TORE) are feasible and avoid port complications [86]. A study of 136 patients showed that Tv hybrid NOTES SG technique can be performed, but there is still a need for additional trocars through the abdominal wall [87]. Combined use of laparoscopy and NOTES enabled gastric pull-up without cervical and thoracic incisions [88]. NOTES omental repair of gastric perforation appears comparable to that of laparoscopy [89]. Hybrid NOTES resection of gastric gastrointestinal stromal tumour (GIST) was successfully reported on patients [90].

2.3. Duodenal NOTES

Currently, there is scarce of literatures on duodenal NOTES. This is because of rarity of duodenal pathologies that benefits from NOTES. Peritoneoscopy is actively used to assess upper GI tract including the duodenum [91]. This approach is feasible in selected series of patients [92].

2.4. Liver NOTES

Continued development of NOTES techniques may further alter the approaches to the biliary tract, liver and pancreas [93]. On animal models intraoperative NOTES-EUS is feasible to assess liver lesions [94]. Liver biopsy was performed successfully without any bleeding, and adequate samples were obtained in animal cases [95]. Using the Erbe Jet2 water-jet system, transanal and transvaginal wedge hepatic resection was successfully performed [96]. Tr liver resection and delivery of specimen were feasible and safe without problem of the rectal access [97]. Another study reported an animal liver wedge resection using MASTER robot [98]. Human cases of liver resection were reported as well. A combined laparoscopic Tv approach was used. Four 5-mm trocars were used. The liver parenchyma was divided using the harmonic scalpel, whereas the left hepatic vein was transected using the laparoscopic Tv vascular stapler. The specimen was placed in an Endobag and extracted transvaginally [99]. Complex liver surgery like hepatico-jejunostomy, major hepatic resection and transplantation is unlikely to be introduced at this stage due to the current limitations of the technique.

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2.5. Pancreas NOTES

It is technically possible by EUS-guided NOTES procedures to achieve a systematic anterior and posterior access for NOTES transgastric peritoneoscopy and direct pancreatic endoscopic procedures [100]. Peripancreatic abscess can be managed by transgastric endoscopy and debridement with successful outcome, which provides great benefits of minimal access approach [101, 102]. NOTES cystogastrostomy for pancreatic pseudocyst management included endoscopic ultrasound (EUS)-guided puncture of the stomach just below the gastroesophageal (GOJ) junction to gain access to the pseudocyst, guidewire placement and then dilatation with a balloon to 18–20 mm. Endoscopic necrosectomy and debridement were performed, followed by transoral surgical anastomosis under endoscopic visualisation with the SurgAssist™ SLC 55 (Power Medical Interventions, Langhorne, PA) using 4.8-mm stapler [103]. A robotic platform to perform complex distal pancreatectomy on animal model was described [104].

2.6. Spleen NOTES

To dissect the upper end of the gastrosplenic ligament and the marginal region between the left diaphragm and upper pole of the spleen, a flexible single-channel endoscope was introduced into the peritoneal cavity simultaneously with the use of a rigid laparoscope. This is also providing the benefits of water-jet lens cleaning, effective suction and better visualisation in dissection of all splenic attachments and ligaments [105]. Hybrid splenectomy is performed on animal models without major complications indicating safety and feasibility [106]. Tv visualisation of the spleen and standard dissection of attachments were feasible, and splenectomy was completed using Tv stapling of the splenic hilum which is safely performed on patient [107].

2.7. Biliary NOTES

A comparison of the surgical errors during electrosurgery gallbladder dissection establishes that the NOTES procedure, while still new, is not inferior to the established laparoscopic cholecystectomy procedure [108]. NOTES cholecystectomy is the commonest upper GI procedure performed on patients. More than 3000 procedures are reported by now. Largest series of more than 2653 cases is from Germany [109]. Only 15% of NOTES cholecystectomy is performed in the USA. Two recent review studies showed increasing number of NOTES cholecystectomy [110, 111]. NOTES peritoneoscopy for accurate diagnosis and staging of intra-abdominal cancers is already in clinical use. Peritoneoscopy can accurately assess hepato-pancreatic-biliary malignancy and lymph node status [112].

2.8. Bariatric Surgery NOTES

Authors reported combined Tv and abdominal variant of SG on humans [113]. On animal models, hybrid NOTES SG is reported [114, 115]. The procedure was performed on humans using hybrid technique [116]. Roux-En-Y GBP was very challenging procedure and needed development of NOTES instruments to make it safe, feasible and time-effective operation.

Trials on human cadavers concluded feasibility, but long operative time mainly because of the lack of proper instrumentation resulting in insufficient tissue traction, countertraction and instrument manipulation complicated several steps during the procedure [117]. There are human series of hybrid NOTES RYGBP for obesity [118]. NOTES gastric band procedure was reported on a patient [119].(see table 1).

Authors	Year	Reference	Operation	Human subjects	Animal subjects
Spaun GO et al.	2010	[134]	Transcervical Heller's myotomy	Yes	Yes
Swanstrom et al.	2010	[135]	Oesophageal mobilisation	Yes	Yes
Welhelm et al.	2010	[77]	Anti-reflux surgery	No	Yes
Swanstrom et al.	2011	[136,137,72]	Endoscopic myotomy	Yes	No
Rieder et al.	2011	[138,74]	Zenker diverticulectomy	No	Yes
Ishimaru et al.	2011	[139]	Gastric pull through for oesophageal atresia	No	Yes
Turner et al.	2011	[140]	Closure of oesophageal access site	No	Yes
Turners et al.	2011	[141,79]	Stent closure of oesophageal access site	No	Yes
Rolanda et al.	2011	[142]	Peroral oesophageal segmentectomy	No	Yes
Cho et al.	2011	[143]	Resection of early gastric cancer	Yes	No
Abe et al.	2009	[144]	Gastric submucosal tumour resection	Yes	No
Nau et al.	2011	[118]	Staging pancreatic mass	Yes	No
			Hybrid gastric bypass	Yes	No
			Pure gastric bypass	Yes	No
Chiu et al.	2010	[145]	Tg gastrojejunostomy	No	Yes
Campos et al.	2010	[146]	Tg drainage of abdominal abscess	Yes	No
Cahill et al.	2009	[147]	Tv gastric lymph node mapping	No	Yes
Luo et al.	2012	[148]	Tg gastrojejunostomy	No	Yes
Ikeda et al.	2011	[149]	Gastric full-thickness resection	No	Yes
Lacey et al.	2009	[150,112,87]	Hybrid sleeve gastrectomy	Yes	No
Michalik et al.	2011	[117]	Hybrid gastric band	Yes	No
Branco et al.	2011	[151]	Transvesical peritoneoscopy, liver biopsy, appendix manipulation	Yes	No
Truong et al.	2012	[152]	Hybrid liver resection	Yes	No
Shi et al.	2011	[153]	Pure liver resection	No	Yes
Lehman et al.	2014	[122]	Cholecystectomy	Yes	No

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Authors	Year	Reference	Operation	Human subjects	Animal subjects
			Peritoneum	Yes	No
			Gastric surgery	Yes	No
			Liver surgery	Yes	No
Bakker OJ et al.	2012	[101,102]	Tg pancreatic necrosectomy	Yes	No
Pallapothu et al.	2011	[103]	Cystogastrostomy	Yes	No
Targarona et al.	2009	[107]	Tv splenectomy	Yes	No

Table 1. Important upper GI NOTES procedures

3. Lower GI NOTES

3.1. Small bowel NOTES

Small intestinal anastomosis was performed in a porcine intestinal Tr NOTES model using two robotic arms and a camera inserted through the proctoscope and a rectal anterior wall incision [120]. NOTES gastroenterostomy with a biflanged lumen-apposing stent was reported recently by collaboration of French and US centres. The procedure was feasible and safe with only one minor complication [121]. This has the potential to treat variable distal gastric pathology by this type of NOTES anastomosis.

3.2. Appendicectomy

The first human NOTES procedure was Tg appendicectomy performed by Rao and Reddy in 2004 in India. Many cases were reported after that [122, 123]. German registry showed that more than 6% [182 cases] of human NOTES procedure was appendicectomy done by Tg and Tv routes. Not only slim patients but also morbidly obese patients benefited from NOTES appendicectomy [124]. A 5-mm trocar was inserted through the umbilicus and a 5-mm telescope was placed. A 12-mm trocar and a 5-mm grasper were inserted separately through the posterior fornix of the vagina under laparoscopic guidance. The appendix was divided with an endoscopic stapler through the Tv 12-mm trocar and removed from the same trocar [125].

3.3. Colonic NOTES

Pure NOTES resection and anastomosis of the large bowel were feasible, and the colorectal anastomosis was achieved using circular stapler [126]. Early clinical series of transanal TME with laparoscopic assistance (n = 72) were promising, with overall intraoperative and postoperative complication rates of 8.3% and 27.8%, respectively, similar to laparoscopic TME [127]. NOTES TME was feasible and safe in this series of patients with mid- or low rectal tumours [128]. Transanal full-thickness circumferential rectal and mesorectal dissections were per-

formed, and a colorectal anastomosis was performed using a circular stapler with a single stapling technique. During the transanal approach, the gastrotomy was closed using four endoscopic clips [129]. On large series of human cadavers, transanal NOTES rectosigmoid resection with TME was feasible and demonstrates improvement in specimen length and operative time with experience. Transrectal retrograde rectosigmoid dissection was achieved in all attempts and showed numbers of lymph nodes similar to the laparoscopic group [130, 131]. A transrectal endoscopic device was used for optic assistance, colon dissection, ileum section and specimen retrieval. Transrectal MA-NOS total colectomy was assisted by three laparoscopic ports: A 12-mm port is used as the terminal ileostomy site [132]. Hybrid Tv resection of descending colon was feasible on animal model. Only one 5-mm transumbilical port was added for safety [133]. Long-segment Hirschsprung's disease was managed by NOTES. Authors reported the technique, which starts by a rectal mucosectomy 0.5 cm proximal to the dentate line and extending proximally to the level of the intraperitoneal rectum. Three cannulas were inserted through the muscular sleeve into the abdominal cavity. After colonic mobilisation, the ganglionic distal bowel segment was pulled through the anus and resected and the colo-anal anastomosis was created [134], (see table 2).

Authors	Year	Reference	Operation	Human subjects	Animal subjects
Demura et al.	2013	[119]	Small bowel anastomosis	No	Yes
Barthet M et al.	2015	[120]	Gastroenterostomy	Yes	No
Lehman et al.	2014	[122]	Appendicectomy	Yes	No
Bernhardt J et al.	2012	[125]	Sigmoid colectomy	No	Yes
Chouillard et al.	2014	[127]	TME	Yes	No
Park SJ et al.	2013	[128]	Rectosigmoid resection	No	Yes
Telem DA et al.	2013	[129]	TME [cadavers]	Yes	No
Lacy AM et al.	2012	[131]	Hybrid total colectomy	Yes	No
Alba mesa et al.	2012	[132]	Descending colon resection	No	Yes
Li N et al.	2013	[133]	Hirschsprung's segment resection	Yes	No

Table 2. Important lower GI NOTES procedures

4. Further research

NOTES is evolving and refinement of the technique is warranted for feasibility, safety, operative time effectiveness and practicality. Three hot areas are expected to be the focus for further research:

1. Development of technology: this includes instruments, optics and working platforms.

http://dx.doi.org/10.5772/60552

2. Exploration of practicality of NOTES application in complex abdominal procedures and new fields like thoracic and retroperitoneal procedures.

3. Training: NOTES needs an advanced endoscopic and minimal access skills. Surgeons who already attended this level are those who are leading NOTES research in the respected academic institutions in the USA, Europe and Asia. What is needed is to organise an effective and specific dedicated training programme to produce NOTES trained surgeons. NOTES is expected to be an independent specialty that works to meet patient's expectation by making the most use of modern surgery and technology.

5. Conclusions

NOTES is gaining interest and popularity among surgeons. Many new procedures are reported as feasibility studies on animal models. Other procedures are starting to establish itself in clinical practice like NOTES cholecystectomy, appendicectomy and peritoneoscopy. Tv and Tg access routes are the commonest and closure technique is evolving to achieve a high degree of safety and effectiveness. Many new clinical procedures are introduced and currently are at experimental level. Development of the technology and instrumentation, effective training and support are expected to push NOTES further towards its long track of refinement and milestone journey towards an accepted and well-established standard technique.

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