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Natural Orifice Transluminal Endoscopic Surgery: Uses, Advantages, Complications and Cost

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ABSTRACT

Time has witnessed a steady decline in invasive surgical procedures. Laparoscopic surgeries have gradually replaced traditional open surgeries due to lesser postoperative morbidity, shorter hospitalization, faster convalescence, and better cosmetic outcome. Taking a step further, laparoscopy and endoscopy have been brought together for an advanced surgical technique called Natural Orifice Transluminal Endoscopic Surgery (NOTES). In NOTES, no scar is caused on the skin surface. The abdomen is approached through a natural orifice–mouth, anus, urethra or vagina and peritoneal cavity is accessed by puncturing a visceral organ. In this article, we have reviewed current applications of NOTES by explaining about post-operative pain, post-operative recovery time, duration of hospital stays, associated complications and cost.

A literature search on NOTES was carried out in different search engines like PubMed, etc. We had searched for research articles on natural orifice transluminal endoscopic surgery in the abdomen. Filters were applied as research articles from the past 5 years, full free text, and studies on human subjects only. Only those articles which provide us information on post-operative pain, post-operative recovery time, duration of hospital stay, associated complications and cost were selected.

Trans anal route provides access for many colonic and rectal surgeries. TAMIS and TEM are two examples of local excision of rectal tumors. The transvaginal route also provides access to plenty of gastrointestinal and urologic surgeries. All NOTES procedures are advantageous compared to conventional laparoscopic surgeries. In most surgeries' patient can be discharged after 1 to 3 days. NOTES have few complications like bleeding, a risk of perforation, sexual dysfunction, urinary incontinence but these are less frequent compared to conventional surgeries. NOTES is cost effective too.

Key words: Natural orifice, Transluminal, Endoscopy, Notes, Transvaginal, Transanal

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INTRODUCTION

Since nearly one or two decades, there has been a steady decline in invasive surgical procedures. After the first laparoscopic cholecystectomy which was performed during the mid-1980s, minimally invasive surgery has been welcomed by the patients and surgeons alike. Laparoscopic surgeries have gradually replaced traditional open surgeries due to lesser postoperative morbidity, shorter hospitalization, faster convalescence, and better cosmetic outcome [1].

On the other hand, endoscopy techniques are not being restricted to diagnostic procedures but have evolved to therapeutic procedures too, all thanks to the development of microelectronic techniques. Thus, taking a step further, laparoscopy and endoscopy have been allied together for a much-advanced surgical technique called Natural Orifice Transluminal Endoscopic Surgery (NOTES). The first NOTE Surgery was done by Jacques Marescaux in 2007 where he performed transgastric cholecystectomy [2]. In NOTES, even the minute scars caused by laparoscope on the skin surface are avoided by approaching into the abdomen through a natural orifice like mouth, anus, urethra, or vagina. A flexible endoscope is inserted into any of the above orifices and advanced into the peritoneal cavity by puncturing one of the viscera like stomach, colon, bladder, or vagina. NOTES have potential advantages compared to open surgery and laparoscopic surgery–a better cosmetic

result, lower anesthesia requirements, less pain, rapid recovery, and lesser chances of wound-related complications [1,3]. NOTES has been classified as 2 types–Direct target NOTES and distant target NOTES. In direct target NOTES, viscera are not punctured to gain access to another organ. E.g.: peroral endoscopic myotomy and per oral endoscopic tumor resection. Whereas in distant target NOTES a viscera must be punctured to approach another organ. E.g.: transvaginal cholecystectomy and transgastric appendicectomy [4].

NOTES is expected to be the next leading technique in surgery [3]. In this article, we intend to review the current applications of NOTES and compare it with standard procedures for those conditions. In the following text we have mentioned a disease/procedure as heading and have explained about utilization of NOTES in it, then have elaborated about post-operative pain, post-operative recovery time, duration of hospital stay, associated complications and cost of NOTES for that particular heading.

METHODOLOGY

A literature search on NOTES was carried out in different search engines like PubMed, Medline, EBSCO, ProQuest, ScienceDirect, Scopus, and Google Scholar. We had searched for research articles on natural orifice transluminal endoscopic surgery in the abdomen. Filters were applied as research articles from the previous 5 years, full free text, and studies on human subjects only. Articles on NOTES for non-abdominal surgeries were excluded due to time and space constraints. We had selected only those articles which provide us information on post-operative pain, post-operative recovery time, duration of hospital stays, associated complications and cost.

Uses of natural orifice transluminal endoscopic surgery

Mesorectal excision for rectal tumor

Buess in 1983 first introduced Transanal Endoscopic Microsurgery (TEM). By TEM, local excision of rectal lesions is possible. Lesions situated up to 15-20 cm from the anal verge can be accessed via this route [5,6]. Development of TEM was followed by Transanal Endoscopic Operation (TEO) which incorporated laparoscopy in endoscopy [5,7]. Both TEO and TEM provide 3600 vision during resection, allows unfragmented excision of lesions with clear margins and facilitates dissection maneuvers, cutting, coagulation and suturing. Morbidity and mortality are lower in TEO and TEM compared to transabdominal resection techniques. Besides, the need for a permanent colostomy may also be avoided by TEO/TEM [8]. NCCN guidelines accept TEM for treatment of benign lesions, adenocarcinomas, adenomas, GIST, and incipient rectal tumors [5,9].

TEM and TEO are associated with certain complications–fecal incontinence is most common. This occurs due to the indwelling rectoscope throughout surgery. However, this incontinence is reversible does not occur with every patient [10,11]. On the other hand, the list of complications is longer with total mesolectal excision (TME) which is the gold standard surgery for rectal tumors [12]. Complications associated with TME are urinary incontinence, fecal incontinence, sexual dysfunction, and the need for temporary or permanent ostomies in around 10-30% of cases [13,14].

Post-operative recovery is much faster in trans-anal endoscopic surgeries compared to conventional surgeries. Oral feeding with water is initiated on postoperative day 1 and solid food is initiated on postoperative day 2. While postoperative hospital stays in trans-anal endoscopic surgeries ranges from 5 days to 13 days. Postoperative pain manifests as anal pain but is seen in hardly 2.0–4.0 % of cases [15]. NOTES for rectal tumor is cost-effective too compared to conventional surgeries because the cost of the surgery itself is less and shorter duration of hospital stay with faster recovery requires less amount of stay in ICU. The average cost of open resection in the UK is £4135 while that of TEM excision is £567 [16].

Transanal minimally invasive surgery for rectal lesions

Transanal minimally invasive surgery (TAMIS) was first reported by Atallah et al. [17] TAMIS has since then gained progressive popularity for treatment of mid and high rectal lesions. TAMIS is useful for T1 adenocarcinoma, large adenomas, GIST, carcinoid, etc. TAMIS has become a better option compared to Transanal Endoscopic Microsurgery and endoscopic submucosal dissection (ESD) in early rectal cancer. The

advantage with TAMIS compared to TEM is that patient's position needs not be changed during surgery as the operative channel allows a circumferential dissection. Secondly, traction on sphincter is quite less compared to TEM proctoscopy, this allows better postoperative outcome [18].

Common complications encountered with TAMIS are UTI, subcutaneous emphysema, hemorrhoid thrombosis, bleeding which obstructs camera view and unintentional entry into the abdominal cavity/pouch of Douglas [18,19].

TAMIS requires a patient to stay in the hospital overnight and full recovery occurs on 3rd days [18,20,21]. Exact figures regarding postoperative pain could not be found but most of the academic material stated that pain in TAMIS is less than that in conventional surgeries [22]. The cost of TAMIS is US$22,115 [23].

Sigmoid resection for diverticular disease

Recurrent diverticulitis of sigmoid colon requires resection of the sigmoid colon. The conventional procedure is laparoscopic sigmoid resection [24–26]. Transvaginal hybrid NOTES sigmoid resection offers certain benefits over conventional laparoscopic surgery. NOTES has less postoperative pain, quicker convalescence, lesser risk of wound infections and lesser risk of incisional hernia [24,25].

Transvaginal NOTES for sigmoid resection are associated with complications such as delayed vaginal wound healing, impaired sexual function, and transvaginal microbiological contamination of peritoneal cavity [24,27]. Pain after transvaginal NOTES sigmoid resection stays for up to POD 6 to such an extent that daily analgesics are required for POD 5. Pain intensity decreases after POD 5. The total duration of recovery and hospital stay is of 6 days maximum after surgery [28]. Sexual function is restored 3 months after surgery [24,29]. Transvaginal hybrid NOTES sigmoid resection costs around US$12,235 while conventional laparoscopy costs US$10,320 [30].

Transvaginal endoscopic appendectomy

The vaginal approach is the most used approach in NOTES as it is easy to disinfect and allows safe access to the peritoneal cavity. Incision created for NOTES in the vagina can be closed manually [31]. Appendectomy can be done transvaginal using rigid endoscope. Duration of surgery is quite less compared to open abdomen removal and laparoscopic surgery. Even the blood loss is also minimal. Conventional surgeries for appendectomy require the patient to remain nil by mouth for at least 3 days while in transvaginal endoscopic appendectomy oral feeding with liquids can be started on POD1 and semi-solid food from POD2 onwards. Besides, transvaginal NOTES provide better cosmetic outcome as compared to conventional surgeries [32,33]. Duration of hospital stay in transvaginal endoscopic appendectomy ranges from 2 to 3 days. Pain after transvaginal NOTES stays up to POD3 and it does not require analgesics after POD1 [34,35]. Commonly encountered complications after transvaginal NOTES for appendectomy are urinary tract infection, vaginal cuff granulation tissue repair. Sexual activity is restored 2 weeks after surgery [36]. Transvaginal endoscopic appendectomy costs about 11,300 to 12,700 Chinese Renminbi while conventional laparoscopy appendectomy costs about 12,900 to 16,700 Chinese Renminbi [37].

Transanal endorectal pull through (TERPT) for hirschsprung's disease

Hirschsprung's disease (HD) is a congenital condition that occurs due to the absence of ganglion cells in the submucosal and myenteric plexuses of the colon [38]. Surgical management of HD has evolved from open procedures requiring multiple stages (eg: Duhamel's retrorectal pull-through procedure) to a transanal endorectal pull-through (TERPT) procedure which requires an only single stage [39]. Common complications which occur with TERPT are wound infection, bleeding, leakage at the anastomosis site, pelvic abscess, retraction of pull through segment, enterocolitis, stricture, and constipation [40,41]. Post-operative recovery occurs in 3.5 to 15 weeks [42]. Data could not be found on exact duration of post-operative pain, but one study stated that post-operative pain was negligible such that any analgesic was not required, and oral feeding could be started the next day [43]. Duration of hospital stay in TERPT ranges from 4.5 weeks to 11.5 weeks [44]. Cost of TERPT is GBP3200 while that of open technique is GBP6300 [45].

Endoscopic ultrasound-guided transduodenal drainage of idiopathic retroperitoneal abscess

Application of NOTES is not confined to major surgeries but also useful for minor procedures

such as drainage of the abscess. Idiopathic retroperitoneal abscesses are insidious in onset and occult in nature. These have a high mortality rate if not drained appropriately. Therefore, early diagnosis and appropriate drainage plays a crucial role here [46]. Retroperitoneal abscesses occur due to infections of retroperitoneal organs and due to diseases like malignancies, trauma, perforation, and immunosuppression [47].

Conventionally, a retroperitoneal abscess is drained by computed tomography (CT) or ultrasonography (USG) guided percutaneous drainage. But these procedures have a disadvantage of inadequate visualization–A blood vessel may come in the path of the puncture needle. On the other hand, Endoscopic ultrasound (EUS) gives better spatial resolution and superior anatomic detail than USG and CT guided aspiration. EUS allows a clear view of the needle and assessment of blood flow along the needle's path. EUS-guided drainage can also be performed for peri-pancreatic fluid collection [48–50]. A double pigtail plastic stent along with endoscopic Naso biliary drainage (ENBD) tube is inserted into the abscess cavity via duodenum. This provides a histological and bacteriological evaluation of abscess. Such self-retaining endoscopic catheter allows repetitive washing. Sagami et. al. had washed a retroperitoneal abscess 6 times a day for 14 days. Full recovery occurred 31 days after placement of ENBD. The patient was discharged 41 days after placement of ENBD [51]. Endoscopic ultrasound-guided transduodenal drainage is associated with few complications such as pain, leak, bleeding, and the possibility of permanent external drainage [52–54]. Post-procedural pain subsides in 48 hours [55]. This procedure costs US$ 5446 to 12990 [56].

Endoscopic anterior fundoplication for gastroesophageal reflux disease

Gastroesophageal reflux disease (GERD) occurs due to inappropriate transient LES relaxation or decrease of resting basal pressure [57]. It is a chronic, relapsing disease with multiple adverse effects on daily routine [58]. Therefore, a long-term management plan is required for many cases. Proton pump inhibitors (PPI) are effective in almost all GERD cases. But ~40 % of GERD cases have no response or incomplete response to PPI [59]. PPI therapy is quite effective for esophagitis and heartburn, but it is less effective for symptomatic regurgitation [60,61]. Such cases may require additional drugs [62]. Common adverse effects encountered with prolonged use of PPI's are increased risk of bone fracture, infections, interference with antiplatelets, malabsorption of vitamins and minerals [63,64].

The primary alternative to chronic use of PPI is Laparoscopic Nissen's Fundoplication (LNF) which has yielded good results [65]. But there plenty of LNF cases who have experienced bloating, flatulence, diarrhea, dysphagia, and the inability to belch or vomit [66]. Incisional hernias have also been reported in 3 % LNF cases [67].

To overcome these complications, Endoscopic anterior fundoplication using transoral endoscopic device has been developed as an alternative. In this, fundoplication is done transorally using video and ultrasound-guided surgical stapler [68]. Zacherl et al. reported that 72 GERD patients who have undergone transoral endoscopic fundoplication, 42 did not require PPI or any antacid, 23 required 50% of the previous dose they were using prior to surgery and 7 had to continue the same dose of PPI. Complications encountered after this surgery were pain in 3 cases, fever in 4 cases, pneumomediastinum in 1 case, pneumothorax in 2 cases, pneumoperitoneum in 1 case, Pleural effusion in 1 case, Esophageal leak in 1 case, Upper GI bleed in 1 case. Post-operative pain is encountered in few cases and it subsides in 1 – 4 days. Recovery occurs in 2 weeks. Patient is required to stay in the hospital for 1 to 3 days [69]. The cost of laparoscopic Nissen fundoplication (LNF) is US$716/QALY and that of endoscopic fundoplication is US$1,067/QALY over a 30-year time frame. (QALY=quality-adjusted life-year) [70]. Considering the shorter hospital stay, faster recovery and lesser complications, endoscopic fundoplication would be more economical than laparoscopic fundoplication.

Flexible transgastric endoscopic liver cyst fenestration

Laparoscopic fenestration of liver cyst is recognized as one of the standard treatment methods for nonparasitic hepatic cysts [71]. However, Dong Wang et al. have done cyst fenestration via NOTES. An endoscope is inserted via mouth into the stomach. The peritoneal cavity was accessed via gastrostomy done on the

anterior wall of the body of the stomach. Upon identifying the site of the liver cyst, the cyst wall is cut open and drained. A part of the cyst wall can be respected for histopathological examination. The gastrostomy opening is closed using hemoclips. The endoscope is then withdrawn. Common complications encountered with trans gastric endoscopic liver cyst fenestration were throat pain, right hypochondriac pain, and abdominal distension. Minor bleeding is observed in a few cases. Visualization of cyst becomes a problem if the cyst is in segment VIII, for this laparoscopic assistance is required. Else fenestration can be done with NOTES alone. Post-operative pain lasts for 2 days maximum. Full recovery occurs after 2 days. The patient can be discharged from hospital 2 days after NOTES. A repeat endoscopy may be performed after 7 days to check for wound healing of gastrostomy [72].

Transvaginal natural orifice transluminal endoscopic surgery assisted living donor nephrectomy

Currently, laparoscopic living donor nephrectomy (LLDN) is universally accepted gold standard method for kidney procurement [73]. However, with the growing popularity of laparoscopic experience, technique, and instruments, less invasive methods are being developed. A new laparoscopic method with minimal invasion, such as transvaginal natural orifice transluminal endoscopic surgery assisted living donor nephrectomy (TVNALDN) is being described for reducing morbidity by avoiding surgical incisions and external scars [74]. We could not find any study which had stated about complications of NOTES specifically for nephrectomy via the transvaginal route. However, Wei et. al. 2016 had published about TVNALDN in porcine model and they mentioned that peritoneal rupture was observed in 2 pigs out of 6 [75]. Since this surgery is still in its nascent stage, much information could not be gathered regarding postoperative pain, duration of hospital stays and cost.

Transurethral endoscopic submucosal en bloc dissection for non-muscle invasive bladder cancer

Transurethral resection of bladder tumor (TURBT) is presently considered as the standard treatment for non-muscle invasive bladder cancer (NMIBC). But there is a high recurrence rate of post-TURBT tumor. This recurrence probably occurs due to tumor cell implantation or incomplete resection of the primary tumor [1]. TURBT also interferes with pathological staging hence leads to less effective post-operative plans [2].

Endoscopic submucosal dissection (ESD) is emerging as new technology. It is reported to be safe and effective for treating epithelial tumors such as a gastric and colonic tumor [76]. This method confirms the highest chance of en bloc resection of tumor tissues. This allows for precise tumor grading and staging. Chance of tumor cell implantation into the bladder wall is also reduced by endoscopic approach. Thus, decreasing chances for tumor recurrence. Fewer complications are seen in ESD compared to TURBT. TURBT runs the risk of hemorrhage, bladder perforation, and obturator nerve reflexes. These complications are reduced drastically by endoscopic approach. Post-operative pain has not yet been reported. Hospital stay in ESD is reduced by 1 day. 3 – 4 days of hospital stay is required for ESD while 4–5 days are required for TURBT. Recovery occurs in 3 days [77]. Since transurethral endoscopic submucosal dissection for bladder cancer is in its nascent stage, exact figures regarding costs could not be found.

DISCUSSION

Like the advent of laparoscopic procedures, which had greatly influenced surgical treatments in the past 3 decades, NOTES will bring another major revolution in surgery. NOTES avoid large skin incisions, so postoperative pain, cosmetic deformity, and other complications are reduced. Recovery also occurs at a faster rate [33]. Before proceeding with the global adoption of this novel technique, limitations of engineering and clinical limitations must be pondered upon.

The transanal route provides access for many colonic and rectal surgeries. TAMIS and TEM are good trans anal techniques for local excision of benign and malignant tumors of the rectum. TEM permits full-thickness excision and satisfies precise resection with margins. Additionally, using TEM, one can also suture rectal wall defects post-tumor resection. Risk of bowel perforation is minimal [78].

Similar to trans anal route, the transvaginal route also provides access to plenty of gastrointestinal and urologic surgeries [79]. There is concern about sexual dysfunction after transvaginal NOTES. But literature says that sexual

dysfunction is not common, and many women had their sexual routine restored in 2 weeks after surgery [80,81]. Each of the NOTES procedures are advantageous compared to conventional laparoscopic surgeries. In most of the surgeries, the patient can be discharged in 24 hours generally. Certain cases may take a maximum of 3 days if there are any complications [82].

NOTES have few complications but are quite less compared to conventional surgeries and the incidence of these complications is also less compared to conventional surgeries. They are cost effective too. For a few cases, the cost of NOTES is higher than laparoscopy but considering the reduced hospital stay, reduced disability and reduced loss of pay from work; NOTES is economical compared to laparoscopy.

CONCLUSION

NOTES is still in evolving stage and needs to be explored for more diseases in more number of cases. Due to the limitation of space, we have presented about abdominal surgeries only via oral, vaginal, urethral and anal route. But NOTE has plenty of scope in other systems which can be accessed through various other natural orifices.

CONFLICT OF INTEREST

None.

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