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Review Article

Natural Orifice Transluminal Endoscopic Surgery (NOTES) Appendectomy: An Update: Review Article

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Abstract: Acute appendicitis remains one of the most common surgical emergencies worldwide, traditionally managed by open or laparoscopic appendectomy. Over the past two decades, minimally invasive techniques have evolved significantly, culminating in the development of Natural Orifice Transluminal Endoscopic Surgery (NOTES). NOTES Appendectomy represents an innovative approach that eliminates abdominal incisions by accessing the peritoneal cavity via natural orifices such as the trans gastric or transvaginal route. This review aims to synthesize current evidence on NOTES appendectomy in the management of acute uncomplicated appendicitis, focusing on feasibility, safety, clinical outcomes, advantages, limitations, and future directions. Existing literature suggests that NOTES appendectomy is technically feasible and provides potential benefits in terms of reduced postoperative pain, improved cosmetic outcomes, and faster recovery. However, challenges related to technical complexity, infection risk, limited instrumentation, and learning curve persist. While hybrid NOTES techniques combining laparoscopic assistance have shown promising results, pure NOTES appendectomy remains largely experimental. This review highlights the current state of NOTES appendectomy and emphasizes the need for standardized protocols and long-term outcome evaluation.

Keywords: Acute Appendicitis, Uncomplicated Appendicitis, NOTES, Appendectomy, Trans Gastric, Trans Vaginal.

INTRODUCTION

Acute appendicitis is one of the most common general surgical emergencies, and it accounts for the most common admission to the surgical ward. It has an incidence of 90 to 100 cases per 100,000 population in most Western countries. It is most seen in the pediatric and adult group with patients in the second and third decades of life being the most common age of presentation. The most common clinical presentation is abdominal pain in the right lower abdomen, and clinical examination reveals guarding and rigidity over the right iliac fossa. Blood investigations that are used to diagnose acute appendicitis include inflammatory markers like leukocytosis and elevated C-reactive protein levels, and imaging modalities like ultrasound and computerized tomography are used in cases with atypical clinical presentation (Moris, 2021; Bhangu, 2015).

The management of acute appendicitis involves performing an appendectomy, and this procedure can be performed as an open appendectomy or as a laparoscopic appendectomy. Non-Operative treatment is also an option in patients with uncomplicated acute appendicitis who may not be fit to undergo surgery (Becker, 2018). Laparoscopic appendectomy is the gold standard for the surgical management of acute appendicitis, due to its reduced postoperative nausea and vomiting, reduced analgesia usage, and early ambulation. Natural Orifice Transluminal Endoscopic Surgery (NOTES) appendectomy was introduced to reduce the post-operative morbidity and incisional hernia rate. The most common methods include the trans gastric and transvaginal approach. Natural Orifice Transluminal Endoscopic Surgery (NOTES) appendectomy requires special equipment and training, which is associated with an increase in cost (Weledji, 2023; Khashab, 2010).Natural Orifice Transluminal Endoscopic Surgery(NOTES) appendectomy has the advantage of an absence of surgical scar, reduced pain, and a faster return to normal activity, but it is associated with the need for specific surgical platforms, the maintenance of

pneumoperitoneum during the procedure, spatial orientation and triangulation of the instruments which differs from standard laparoscopic equipment and the closure techniques which must be secure to prevent complications from occurring, especially with the trans gastric approach (Huang, 2011).

In this review, we examine the roles of natural orifice transluminal Endoscopic Surgery (NOTES) appendectomy in the management of acute appendicitis. We will look at the various methods of performing NOTES appendectomy and its advantages and disadvantages. A comprehensive literature review was conducted utilizing PUBMED, the Cochrane Database of Systematic Reviews, Google Scholar, and Semantic Scholar. The search focused on randomized controlled trials, non-randomized trials, observational and cohort studies, case reports, clinical reviews, systematic reviews, and meta-analyses published from 1980 to 2026. The keywords employed in the search included "Acute appendicitis," "Uncomplicated appendicitis," "endoscopy," "NOTES," "Appendectomy,"" Trans gastric," and "Transvaginal." All articles were in English and were assessed through manual cross-referencing of the literature. Commentaries and editorials were excluded from this review. The study included both adult and pediatric patients with acute appendicitis.

DISCUSSION

Natural Orifice Transluminal Endoscopic Surgery (NOTES)

Natural orifice transluminal endoscopic surgery (NOTES) is described as a natural evolution of minimally invasive surgery to eliminate surgical trauma, reduce or eliminate surgical scars, and improve recovery. The routes for performing Natural orifice transluminal endoscopic surgery include the trans gastric and transvaginal, which are the most popular, with the trans anal route still in the experimental stage. The equipment that is used includes flexible endoscopy, but difficulty in maintaining the pneumoperitoneum and access to the surgical site has made pure NOTES difficult, and a conversion to a hybrid NOTES, where a laparoscopic port is used to aid in the surgery (Nabi, 2026; Keller, 2013; Pearl, 2008); Targarona, 2010). The trans gastric approach has the advantage of universal availability for both male and female patients, but the endoscope has to be of adequate length; the spatial orientation and stabilization of the endoscope are complex. Retrieval of the specimen is difficult, and closure of the gastrotomy has to be complete and may require laparoscopic assistance. Both the flexible and rigid endoscopes can traverse the trans vaginal approach, as the distance is shorter. The site of insertion can be closed under direct vision, and the orientation is similar like for traditional laparoscopy. The disadvantages include that the procedure can only be performed in females and concern of risk of dyspareunia and infertility (Atallah, 2015). The initial experience of natural orifice transluminal endoscopic surgery (NOTES) suggests that the addition of flexible long graspers and a flexible operative platform can aid in improving its performance. The use of a uterine manipulator can aid in visualization and safe vaginal access (Horgan, 2009; Sodergren, 2009).

Natural Orifice Transluminal Endoscopic Surgery (NOTES) Appendectomy

Natural orifice transluminal Endoscopic Surgery (NOTES) is described as a procedure for endoscopic intervention on internal organs performed through a natural orifice. The primary goal of NOTES is to avoid skin incision, thereby reducing postoperative pain and facilitating faster recovery. The instruments used to perform NOTES include both flexible and rigid endoscopic equipment. The most common routes for NOTES appendectomy include the trans gastric and the transvaginal route. NOTES can be performed as a hybrid form where a transabdominal port is inserted to assist in the procedure. These hybrid approaches reduce risks such as inadequate visualization, bleeding, and difficulty in organ manipulation (Moreira-Pinto, 2011). NOTES Appendectomy can be performed as a trans gastric or a transvaginal approach. The trans gastric approach can be performed in all patients but requires an endoscope that is longer, and most procedures are performed as a hybrid approach, while the transvaginal approach can only be performed in females, and both the rigid and flexible endoscopes can be used for this (Coomber, 2012).

Transvaginal and Trans gastric Natural Orifice Transluminal Endoscopic Surgery (NOTES) Appendectomy

Nezhat *et al*., retrospectively assessed 42 patients who had undergone transvaginal NOTES appendectomy. The appendectomy was performed with a stapler, and the specimen was removed via the vagina. The mean post-operative stay was 1.5 days, and there was no morbidity or mortality from the procedure (Nezhat, 2009). Khan *et al*., conducted a study on 16 patients who had undergone hybrid NOTES transvaginal appendectomy. A trans umbilical port was used to insert a laparoscope and introduce the pneumoperitoneum and to assist in the NOTES appendectomy. The procedure was associated with no morbidity or mortality, and it was associated with reduced post-operative pain and reduced length of hospital stay (Khan, 2016).

A systematic review on transvaginal appendectomy was conducted by Yagci *et al*., A total of 112 studies were included, and the mean operative time was 53.3 minutes, the conversion rate was 3.6%, and the complication rate was 8.2%. The mean length of hospital stay was 1.9 days (Yagci, 2014). Another systematic review on transvaginal appendectomy was conducted by Slouha *et al*., A total of 20 studies with 1429 patients were included in this study. All the procedures were performed as a hybrid transvaginal NOTES appendectomy. This study showed that the hybrid NOTES appendectomy was associated with reduced complications and no need for analgesia on discharge

(Slouha, 2024). Palanivelu *et al.,* had performed a transvaginal NOTES appendectomy on 6 patients with acute appendicitis, and the mean operative time was 103.5 minutes, and the hospital stay was 1 to 2 days, but 5 out of the 6 patients required a conversion to a hybrid NOTES to maintain the pneumoperitoneum and complete the operation (Palanivelu, 2008). Hybrid transvaginal NOTES appendectomy was compared with laparoscopic appendectomy in a retrospective study by Bernhardt *et al*., A total of 10 patients were included in this study, and the transvaginal NOTES appendectomy was associated with a longer operative time but was associated with a shorter recovery time and better patient satisfaction (Bernhardt, 2015). Knuth *et al*., prospectively assessed hybrid transvaginal NOTES appendectomy in 13 patients with acute appendicitis. There was no post-operative morbidity, and there were no conversions to open appendectomy. This study concluded that hybrid NOTES appendectomy is a safe procedure for selected patients with acute appendicitis (Knuth, 2014). Another study by Shin *et al.,* on the role of hybrid transvaginal NOTES appendectomy was safe and effective for the management of acute appendicitis (Shin, 2010). Transvaginal NOTES appendectomy was compared with traditional laparoscopic appendectomy by Roberts *et al.,* A total of 40 patients were included in this study, and 18 patients underwent transvaginal NOTES appendectomy and 22 underwent conventional laparoscopic appendectomy. There were no differences regarding the operative time, length of hospital stays, and post-operative analgesia usage between the procedures. This study showed that transvaginal NOTES appendectomy is a safe procedure and is associated with a faster recovery (Roberts, 2012).

Trans gastric NOTES appendectomy involves assessing the peritoneal cavity by puncturing the anterior wall of the stomach and introducing the endoscope into the peritoneal cavity. Most cases are performed as a hybrid procedure with the introduction of a laparoscopic port in the right lower quadrant to aid in the appendectomy. Trans gastric NOTES appendectomy is safe and feasible, but it requires a longer endoscope to reach the appendix and specific equipment like specialized graspers for manipulation of the appendix and to maintain pneumoperitoneum in the abdomen. The closure of the gastric puncture site is difficult and must be secure to prevent gastric leakage (Park, 2010). A prospective study on trans gastric NOTES appendectomy was conducted by Kaehler *et al*., A total of 15 patients underwent the procedure, and only 2 patients developed intra-abdominal fluid collection, but there were no other complications, and the average stay in hospital was 3 days (Kaehler, 2013). Hybrid trans gastric NOTES appendectomy was compared with a conventional laparoscopic appendectomy by Schoenberg *et al*., A total of 65 patients were included in this study, with 30 undergoing Hybrid trans gastric NOTES appendectomy and 35 undergoing a conventional laparoscopic appendectomy. There were no differences in postoperative complications and length of hospital stay, but the operative time was longer in the Hybrid trans gastric NOTES appendectomy (Schoenberg, 2017).

Trans vaginal NOTES appendectomy and trans gastric NOTES appendectomy were compared by Bulian *et al*., in the management of acute appendicitis. A total of 217 cases were taken from the NOTES registry in Germany, with 181 patients undergoing trans vaginal NOTES appendectomy and 36 undergoing trans gastric NOTES appendectomy. There were no differences regarding the post-operative complications, the need for additional trocars, and the length of hospital stay between the procedures. The procedure time and conversion rates were lower in the trans vaginal NOTES appendectomy, and this gave it an advantage over the trans gastric NOTES appendectomy in the management of acute appendicitis (Bulian, 2017).An international multi-center trial on clinical natural orifice surgery was conducted by Zorron *et al*., 51 patients had undergone NOTES appendectomy, with 37 undergoing trans vaginal NOTES appendectomy and 14 undergoing trans gastric NOTES appendectomy. The operative time, post operative complications, and length of hospital stay were longer in the trans gastric NOTES appendectomy group (Zorron, 2010).

A systematic review and meta-analysis on the major clinical outcomes between transvaginal NOTES and conventional laparoscopy were conducted by Yang *et al*., Thirteen studies with 1340 patients were included in this study, and there were no differences regarding intra-operative and post-operative complications between the procedures. Transvaginal NOTES were associated with reduced pain and a shorter period of recovery. This study recommended the use of Transvaginal appendectomy as safe and reliable for the surgical management of acute appendicitis (Yang, 2019).

Table I

Parameter	Transvaginal NOTES appendectomy	Trans gastric NOTES appendectomy
Technical feasibility	Well-established and most used NOTES route due to easier access and closure (Tarragona, 2010)	Feasible but technically challenging; limited clinical adoption. (Tarragona *et al*., 2010)
Operative time	53 min (25–130 min) -(Yagci ,2014)	94.5 mins-(Schoenberg 2017)
Length of hospital stay	1.9 days (Yagci,2014)	1-3 days (Schoenberg 2017)
Closure of the access site	Relatively easy and secure closure of vaginal incision (Tarragona, 2010)	Technically difficult gastric closure; major limitation (Schoenberg 2017)

Parameter	Transvaginal NOTES appendectomy	Trans gastric NOTES appendectomy
Main limitation	Gender restriction; cultural concerns (Slouha,2024)	Technical difficulty, longer operative time, closure issues (Slouha, 2024)

Table comparing transvaginal NOTES appendectomy and Trans gastric NOTES appendectomy.

CONCLUSION

NOTES: Appendectomy represents an exciting advancement in minimally invasive surgery, offering the potential for truly scarless procedures. While current evidence demonstrates feasibility and safety in selected patients, particularly with hybrid approaches, widespread adoption remains limited by technical challenges, lack of standardization, and limited high-quality data. At present, NOTES appendectomy should be considered an experimental or specialized technique performed in centers with appropriate expertise. Future research, including well-designed randomized controlled trials and technological innovations, will determine its role in the routine management of acute uncomplicated appendicitis.

Conflict of Interest: There is no conflict of interest.

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