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Chapter 17

Natural Orifice Transluminal Endoscopic Surgery (NOTES) Appendectomy: Review

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Abstract

Acute appendicitis continues to be one of the most prevalent surgical emergencies globally, traditionally addressed through open or laparoscopic appendectomy. In the past two decades, minimally invasive techniques have advanced considerably, leading to the development of Natural Orifice Transluminal Endoscopic Surgery (NOTES). NOTES: Appendectomy is an innovative technique that avoids abdominal incisions by accessing the peritoneal cavity through natural orifices, such as the trans gastric or transvaginal routes. This review aims to consolidate current evidence on NOTES appendectomy for managing acute uncomplicated appendicitis, with a focus on its feasibility, safety, clinical outcomes, advantages, limitations, and prospects. The existing literature indicates that NOTES appendectomy is technically feasible and offers potential benefits, including reduced postoperative pain, enhanced cosmetic outcomes, and expedited recovery. Nonetheless, challenges such as technical complexity, infection risk, limited instrumentation, and the learning curve remain. Although hybrid NOTES techniques, which incorporate laparoscopic assistance, have demonstrated promising results, pure NOTES appendectomy is still largely experimental. This chapter underscores the current status of NOTES appendectomy and stresses the necessity for standardized protocols and long-term outcome assessments.

Keywords: Acute appendicitis, Uncomplicated appendicitis, NOTES, Appendectomy, Trans gastric, Trans vaginal.

Introduction

Acute appendicitis represents one of the most prevalent general surgical emergencies and constitutes the primary reason for admissions to surgical wards. Its incidence ranges from 90 to 100 cases per 100,000 individuals in most Western countries. The condition predominantly affects pediatric and adult populations, with the highest occurrence in individuals in their second and third decades of life. Clinically, the most frequent symptom is abdominal pain localized to the right lower quadrant, accompanied by guarding and rigidity in the right iliac fossa upon examination. Diagnostic blood tests for acute appendicitis typically reveal inflammatory markers, such as leukocytosis and elevated C-reactive protein levels. In cases with atypical clinical presentations, imaging techniques, including ultrasound and computed tomography, are employed (Moris, 2021; Bhangu, 2015).

The management of acute appendicitis typically involves an appendectomy, which can be conducted either as an open appendectomy or a laparoscopic appendectomy. For patients with uncomplicated acute appendicitis who are not suitable candidates for surgery, non-operative treatment is a viable alternative (Becker, 2018).Laparoscopic appendectomy is considered the gold standard for surgical management due to its benefits, including reduced postoperative nausea and vomiting, decreased analgesia requirements, and earlier ambulation. Natural Orifice Transluminal Endoscopic Surgery (NOTES) appendectomy was developed to minimize postoperative morbidity and the incidence of incisional hernias. The most prevalent methods for NOTES appendectomy are the trans gastric and transvaginal approaches. This procedure necessitates specialized equipment and training, which contributes to increased costs (Weledji, 2023; Khashab, 2010). NOTES: Appendectomy offers advantages such as the absence of a surgical scar, reduced pain, and a quicker return to normal activities. However, it requires specific surgical platforms, maintenance of pneumoperitoneum during the procedure, and spatial orientation and triangulation of instruments, which differ from standard laparoscopic equipment. Additionally, closure techniques must be secure to prevent complications, particularly with the trans gastric approach (Huang, 2011).

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In this chapter, we analyze the roles of natural orifice transluminal endoscopic surgery (NOTES) appendectomy in managing acute appendicitis. We explore various methods of performing NOTES appendectomy, along with its advantages and disadvantages. A comprehensive literature review was conducted using PUBMED, the Cochrane Database of Systematic Reviews, Google Scholar, and Semantic Scholar. The search targeted 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 used 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 encompassed both adult and pediatric patients with acute appendicitis.

Discussion

Natural Orifice Transluminal Endoscopic Surgery (NOTES)

Natural orifice transluminal endoscopic surgery (NOTES) represents a progression in minimally invasive surgical techniques aimed at minimizing surgical trauma, reducing or eliminating scars, and enhancing recovery. The primary routes for NOTES include the trans gastric and transvaginal approaches, with the trans anal route remaining experimental. The procedure employs flexible endoscopy; however, challenges in maintaining pneumoperitoneum and accessing the surgical site have necessitated the development of hybrid NOTES, which incorporates a laparoscopic port to facilitate the surgery (Nabi, 2026; Keller, 2013; Pearl, 2008); Targarona, 2010).The transgastric approach is universally applicable to both male and female patients, though it requires an endoscope of sufficient length, and the spatial orientation and stabilization of the endoscope are complex. Specimen retrieval is challenging, and complete closure of the gastrotomy may necessitate laparoscopic assistance. In contrast, both flexible and rigid endoscopes can be used in the transvaginal approach due to the shorter distance. The insertion site can be closed under direct vision, and the orientation is akin to traditional laparoscopy. However, this approach is limited to female patients and raises concerns regarding the risk of dyspareunia and infertility (Atallah, 2015).Initial experiences with NOTES indicate that the integration of flexible long graspers and a flexible operative platform can enhance its efficacy. Additionally, the use of a uterine manipulator can improve visualization and ensure safe vaginal access (Horgan, 2009; Sodergren, 2009).

Natural Orifice Transluminal Endoscopic Surgery (NOTES) Appendectomy

Natural orifice transluminal endoscopic surgery (NOTES) is a technique for conducting endoscopic interventions on internal organs via natural orifices. The primary objective of NOTES is to eliminate the need for skin incisions, thereby minimizing postoperative pain and expediting recovery. The procedure employs both flexible and rigid endoscopic instruments. The most prevalent routes for NOTES appendectomy are the trans gastric and transvaginal routes. NOTES can also be executed in a hybrid form, wherein a transabdominal port is introduced to aid the procedure. These hybrid methods mitigate risks such as inadequate visualization, bleeding, and challenges in organ manipulation (Moreira-Pinto, 2011). NOTES appendectomy can be conducted using either the trans gastric or transvaginal approach. The trans gastric approach applies to all patients but necessitates a longer endoscope, and it is frequently performed as a hybrid procedure. Conversely, the transvaginal approach is restricted to female patients and can utilize both rigid and flexible endoscopes (Coomber, 2012).

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

Nezhat et al. conducted a retrospective assessment of 42 patients who underwent transvaginal NOTES appendectomy. The procedure utilized a stapler for the appendectomy, and the specimen was extracted through the vaginal route. The average post-operative hospital stay was 1.5 days, with no reported morbidity or mortality associated with the procedure (Nezhat, 2009).Similarly, Khan et al. investigated 16 patients who underwent hybrid NOTES transvaginal appendectomy. This procedure involved the use of a trans umbilical port for laparoscope insertion, pneumoperitoneum introduction, and assistance in the NOTES appendectomy. The study reported no morbidity or mortality, along with decreased post-operative pain and a shorter duration of hospital stay (Khan, 2016).

Yagci et al. conducted a systematic review on transvaginal appendectomy, incorporating 112 studies. The findings indicated a mean operative time of 53.3 minutes, a conversion rate of 3.6%, and a complication rate of 8.2%. The average hospital stay was 1.9 days (Yagci, 2014). In another systematic review by Slouha et al., 20 studies involving 1429 patients were analyzed. All procedures were executed as hybrid transvaginal NOTES appendectomies, demonstrating reduced complications and no requirement for analgesia upon discharge (Slouha, 2024). Palanivelu et al. performed transvaginal NOTES appendectomies on six patients with acute appendicitis, reporting a mean operative time of 103.5 minutes and a hospital stay of 1 to 2 days. However, five out of the six patients required conversion to a hybrid NOTES to maintain pneumoperitoneum and complete the operation (Palanivelu, 2008). Bernhardt et al. conducted a retrospective study comparing hybrid transvaginal NOTES appendectomy with laparoscopic appendectomy, involving 10 patients. The transvaginal NOTES appendectomy was associated with a longer operative time but resulted in a shorter recovery period and higher patient satisfaction (Bernhardt, 2015). Knuth et al. prospectively evaluated hybrid transvaginal NOTES appendectomy in 13 patients with acute appendicitis, reporting no post-operative morbidity and no conversions to open appendectomy. This study concluded that hybrid NOTES appendectomy is a safe procedure for selected patients with acute appendicitis (Knuth, 2014). Shin et al. also investigated the role of hybrid transvaginal NOTES appendectomy, affirming its safety and efficacy in managing acute appendicitis (Shin, 2010). Roberts et al. compared transvaginal NOTES appendectomy with traditional laparoscopic appendectomy in a study involving 40 patients, with 18 undergoing transvaginal NOTES appendectomy and 22 undergoing conventional laparoscopic appendectomy. The study found no differences in operative time, length of hospital stays, or post-operative analgesia usage between the procedures, concluding that transvaginal NOTES appendectomy is a safe procedure associated with faster recovery (Roberts, 2012).

Trans gastric NOTES appendectomy entails the evaluation of the peritoneal cavity through the puncture of the stomach's anterior wall, allowing the insertion of an endoscope into the peritoneal cavity. Typically, this procedure is executed as a hybrid approach, incorporating a laparoscopic port in the right lower quadrant to facilitate the appendectomy. While trans gastric NOTES appendectomy is both safe and feasible, it necessitates the use of a longer endoscope to access the appendix, as well as specialized equipment such as graspers for appendix

manipulation and maintenance of pneumoperitoneum within the abdomen. Securing the closure of the gastric puncture site is challenging and crucial to prevent gastric leakage (Park, 2010). Kaehler et al. conducted a prospective study on trans gastric NOTES appendectomy involving 15 patients, of whom only 2 developed intra-abdominal fluid collection, with no other complications reported. The average hospital stay was 3 days (Kaehler, 2013). Schoenberg et al. compared hybrid trans gastric NOTES appendectomy with conventional laparoscopic appendectomy in a study comprising 65 patients, with 30 undergoing the hybrid procedure and 35 undergoing the conventional approach. The study found no differences in postoperative complications or length of hospital stay; however, the operative time was longer for the hybrid trans gastric NOTES appendectomy (Schoenberg, 2017).

Bulian et al. conducted a comparative study on transvaginal NOTES appendectomy and trans gastric NOTES appendectomy for the treatment of acute appendicitis. The study utilized data from the NOTES registry in Germany, encompassing 217 cases, with 181 patients undergoing transvaginal NOTES appendectomy and 36 undergoing trans gastric NOTES appendectomy. The findings indicated no significant differences in postoperative complications, the requirement for additional trocars, or the duration of hospital stay between the two procedures. However, the transvaginal NOTES appendectomy demonstrated reduced procedure time and conversion rates, providing an advantage over the trans gastric approach in managing acute appendicitis (Bulian, 2017). Additionally, an international multicenter trial on clinical natural orifice surgery, conducted by Zorron et al., involved 51 patients who underwent NOTES appendectomy, with 37 undergoing the transvaginal approach and 14 the trans gastric approach. In this trial, the trans gastric NOTES appendectomy group exhibited longer operative times, increased postoperative complications, and extended hospital stays (Zorron, 2010).

Yang et al. conducted a systematic review and meta-analysis to compare the major clinical outcomes of transvaginal NOTES with conventional laparoscopy. The analysis included thirteen studies encompassing 1,340 patients. The findings indicated no significant differences in intra-operative and post-operative complications between the two procedures. However, transvaginal NOTES was associated with reduced pain and a shorter recovery period. The study concluded that transvaginal appendectomy is a safe and reliable method for the surgical management of acute appendicitis (Yang, 2019).

Table 1: Comparative Analysis of Transvaginal NOTES and Transgastric NOTES Appendectomy

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)
Main limitation	Gender restriction; cultural concerns (Slouha,2024)	Technical difficulty, longer operative time, closure issues (Slouha,2024)

Table 1 comparing transvaginal NOTES appendectomy and Trans gastric NOTES appendectomy.

Conclusion

NOTES Appendectomy signifies a significant advancement in minimally invasive surgery, with the potential to achieve scarless procedures. Although current evidence indicates its feasibility and safety in selected patients, particularly through hybrid approaches, its widespread adoption is hindered by technical challenges, a lack of standardization, and limited high-quality data. Currently, NOTES appendectomy should be regarded as an experimental or specialized technique, to be conducted in centers with the requisite expertise. Future research, including rigorously designed randomized controlled trials and technological advancements, will be essential in determining its role in the routine management of acute uncomplicated appendicitis.

Declaration

Conflict of interest: There is no conflict of interest.

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