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## Laparoscopic natural orifice specimen extraction-colectomy: A systematic review

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### Abstract

Over the last 20 years, laparoscopic colorectal surgery has shown equal efficacy for benign and malignant colorectal diseases when compared to open surgery. However, a laparoscopic approach reduces postoperative morbidity and shortens hospital stay. In the quest to optimize outcomes after laparoscopic colorectal surgery, reduction of access trauma could be a way to improve recovery. To date, one method to reduce access trauma is natural orifice specimen extraction (NOSE). NOSE aims to reduce access trauma in laparoscopic colorectal surgery. The specimen is delivered *via* a natural orifice and the anastomosis is created intracorporeally. Different methods are used to extract the specimen and to create a bowel anastomosis. Currently, specimens are delivered transcolonic, transrectal, transanally, or transvaginally. Each of these NOSE-procedures raises specific issues with regard to operative technique and application. The presumed benefits of NOSE-procedures are less pain, lower analgesia requirements, faster recovery, shorter hospital stay, better cosmetic results, and lower incisional hernia rates. Avoidance of extraction site laparotomy is the most

important characteristic of NOSE. Concerns associated with the NOSE-technique include bacterial contamination of the peritoneal cavity, inflammatory response, and postoperative outcomes, including postoperative pain and the functional and oncologic outcomes. These issues need to be studied in prospective randomized controlled trials. The aim of this systematic review is to describe the role of NOSE in minimally invasive colorectal surgery.

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**Key words:** Laparoscopy; Colorectal surgery; Natural orifice specimen extraction; Natural orifice specimen extraction-colectomy; Transcolonic; Transrectal; Transanal; Transvaginal; Transanal minimally invasive surgery; Gastrointestinal endoscopy

**Core tip:** Natural orifice specimen extraction (NOSE) will be the way forward to avoid abdominal wall incisions and reduce access trauma during laparoscopic colorectal resection. This systematic review addresses all aspects of NOSE in laparoscopic colorectal surgery and discusses the advantages and disadvantages of this technique. Moreover, a detailed discussion of all available studies concerning NOSE-procedures is given. Although different surgical techniques are being used, it is clear that worldwide experience with this minimally invasive procedure is increasing and that the barriers to the use of natural orifice transluminal endoscopic surgery procedures are decreasing.

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## INTRODUCTION

Laparoscopic colectomy and total mesorectal excision (TME) require a utility incision for specimen delivery and bowel anastomosis. Therefore, natural orifice specimen extraction (NOSE) could be the key to reducing access trauma in laparoscopic colorectal surgery (laparoscopic NOSE-colectomy), with the subsequent reduction of postoperative pain, improvement of patient recovery and a positive long-term outcome in matters such as cosmesis and incisional hernia rates. Because the length of the abdominal incision is directly related to the incisional hernia rate<sup>[1]</sup>, avoiding laparotomy might influence the rate of postoperative wound complications. In NOSE, the specimen is delivered *via* a natural orifice and the anastomosis is created intracorporeally. Although this procedure appears to be an attractive option to improve postoperative outcome, the literature regarding NOSE-colectomy has not been extensively investigated to date. The aims of this systematic review were to describe the role of NOSE in minimally invasive colorectal surgery, to examine the differences in the reported surgical techniques and the impact on postoperative outcome and to discuss the future of NOSE.

## TERMS AND DEFINITIONS

The terminology regarding NOSE should be uniform. In defining NOSE-colectomy, differentiation between transcolonic, transrectal, transanal and transvaginal specimen extraction is necessary. The authors propose that the site where the hollow viscus is opened should define the specimen extraction site: (1) Transcolonic NOSE-colectomy: the specimen is extracted *via* the colon through the rectum and anal canal; (2) Transrectal NOSE-colectomy: the specimen is extracted through the intact rectum and anal canal (*e.g.*, this could be performed during a sigmoid or high anterior resection); (3) Transanal NOSE-colectomy: the specimen is extracted through the anal canal (*e.g.*, this could be performed during a TME); and (4) Transvaginal NOSE-colectomy: the specimen is extracted *via* the vagina by a posterior colpotomy.

## LITERATURE SEARCH

Medline (PubMed) was systematically searched until the 1<sup>st</sup> of September 2013 using the following search criteria: laparoscopy and (transcolonic or transrectal or transanal or transvaginal extraction) or colectomy and (transcolonic or transrectal or transanal or transvaginal extraction) or (natural orifice specimen extraction) or (full laparoscopic) or (totally laparoscopic) or (“natural orifice specimen extraction” or “transcolonic” or “transrectal” or “transanal” or “transvaginal” and “laparoscopy” and “colorectal”). Randomized and controlled clinical trials or cohort observational studies (excluding case reports) were considered for inclusion. Studies reporting on pediatric surgery were excluded. To be included, studies had

to describe a NOSE-technique applied in laparoscopic colorectal surgery. First, the titles were screened and appropriate studies were selected. Of these studies, the full text was acquired. The language was restricted to English. Relevant data from the studies included were extracted with a standard fill-out form of predefined parameters regarding indications, operative approach (number of ports), anastomotic technique, duration of surgery, postoperative complications and length of hospital stay, and entered into an Excel database.

## RESULTS

This literature search resulted in 12134 hits (flow diagram Figure 1). Reading the full text of 139 studies led to the exclusion of an additional 65 studies for a variety of reasons. After the exclusion of 33 case reports<sup>[2-34]</sup>, a total of 41 studies were included in this review<sup>[35-75]</sup>. One study reported on transcolonic NOSE, 12 studies on transrectal NOSE, 18 on transanal NOSE, and 10 on transvaginal NOSE. Three authors each described the results of two extraction sites in one article. Choi *et al.*<sup>[43]</sup> and Wang *et al.*<sup>[71]</sup> reported both transanal and transvaginal NOSE-colectomy, but only a minority of patients had undergone transvaginal specimen extraction, and the results were not reported separately. Franklin *et al.*<sup>[49]</sup> reported the outcome of both transrectal and transvaginal specimen extraction in one paper, and the results are included in both tables. During the past 10 years, the literature regarding NOSE techniques has evolved, focusing more predominantly on transrectal and transanal NOSE surgery (Figure 2).

## TRANSCOLONIC NOSE

The literature search yielded only two reports regarding transcolonic specimen extraction after a laparoscopic ileocolic or segmental colonic resection<sup>[25,48]</sup>. Both reports described a technique using a colonoscope for specimen extraction. Since the introduction of natural orifice transluminal endoscopic surgery (NOTES), the use of flexible instruments and scopes inserted *via* natural orifices has gained popularity in the surgical world and in the literature<sup>[76,77]</sup>. As such, this area of research can be observed as a bridge toward the application of NOTES procedures. Saad *et al.*<sup>[25]</sup> reported on a case of a laparoscopic transverse colectomy with colonoscopic retrieval of the specimen *via* the descending colon, sigmoid, rectum and anus. A double-stapled anastomosis was made and the postoperative course was uneventful. In a feasibility study, Eshuis *et al.*<sup>[48]</sup> prospectively studied 10 young patients (median age 31 years) with Crohn's disease in whom ileocecal resection was indicated. In this cohort, the specimen was extracted transcolonically with a colonoscope. In 2 patients, it was impossible to extract the specimen because the inflammatory mass was too bulky. In comparison with a conventional laparoscopic ileocecal resection, the operating time was significantly longer, which might have been due to the learning curve.

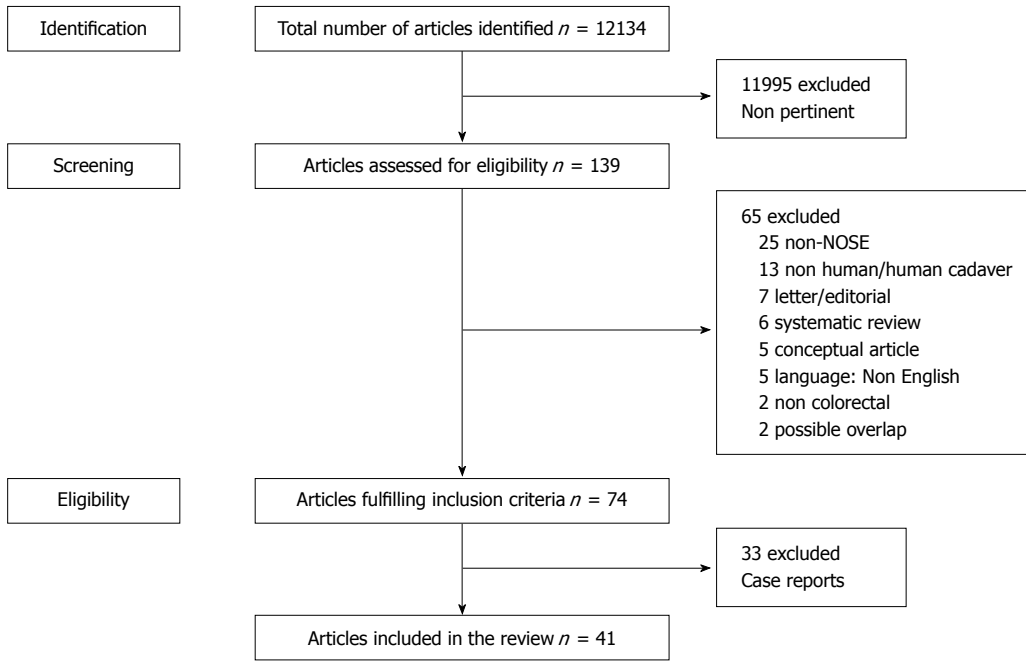


Figure 1 Study flow chart: Search strategy. NOSE: Natural orifice specimen extraction.

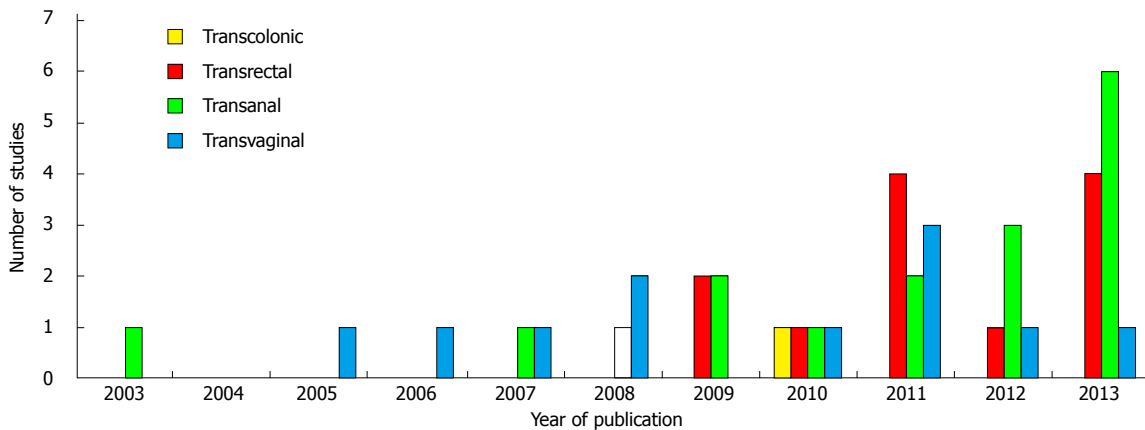


Figure 2 Evolution of publications on natural orifice specimen extraction-colectomy.

Surgical site-related complications were higher. Nevertheless, two theoretical advantages of this technique are the possibility to extract specimens throughout the colon and its applicability to both male and female patients. However, issues could be raised with regard to mechanical bowel preparation, sterility, size of the lesion/mass, and bowel protection. A major drawback is the need for mechanical bowel preparation to clean the colon and enable colonoscopy. Avoidance of bowel preparation is an important element of enhanced recovery programs and for right-sided colonic resections, it has been shown that mechanical bowel preparation can be omitted<sup>[78]</sup>. Another concern is the use of a non-sterile colonoscope and the perioperative opening of the bowel. This might cause leakage of bowel contents intra-peritoneally, which can lead to contamination and subsequent abscess formation. However, data from transrectal specimen extractions have not shown any impact on the inflammatory response or

infectious morbidity<sup>[45,58]</sup>. With regard to specimen size and patient characteristics (*e.g.*, BMI), there are no data showing cut-off values above which colonoscopic extraction is contra-indicated and double-stapled anastomosis is difficult to perform. Moreover, there are no studies on patients with a colorectal tumor, and oncological data for colonoscopic specimen extraction are still awaited. An ileocolic specimen is extracted through an unprotected colon, and this might be problematic when large T3 or T4 tumors require extraction. Furthermore, the best method for proceeding if a specimen becomes lodged in the colon during extraction remains to be determined. A final remark concerns the need for a joint effort by the surgical and gastroenterological team in many centers to make this hybrid procedure possible. Colonoscopy should be performed with CO<sub>2</sub> to coincide with laparoscopic insufflation. Issues relating to procedural costs and time still need to be investigated.

**Table 1 Studies reporting on natural orifice specimen extraction-colectomy**

Ref.	Type of study	Patients (n)	Type of surgery	Type of NOSE	Indication
Akamatsu <i>et al</i> <sup>[36]</sup> , 2009	Case series	16	Sigmoid resection	Transrectal	Malignant
Cheung <i>et al</i> <sup>[42]</sup> , 2009	Case series	10	Sigmoid resection	Transrectal	Malignant
Christoforidis <i>et al</i> <sup>[44]</sup> , 2013	Case-matched	11	Sigmoid resection	Transrectal	Benign
Costantino <i>et al</i> <sup>[45]</sup> , 2012	Case-matched	17	Sigmoid resection	Transrectal	Benign
Franklin <i>et al</i> <sup>[49]</sup> , 2013	Case series	277	Sigmoid and anterior resection	Transrectal	Benign and malignant
Fuchs <i>et al</i> <sup>[50]</sup> , 2013	Case series	15	Sigmoid resection	Transrectal	Benign
Han <i>et al</i> <sup>[53]</sup> , 2013	Case series	34	Sigmoid and anterior resection	Transrectal	Malignant
Leroy <i>et al</i> <sup>[58]</sup> , 2011	Case series	16	Sigmoid resection	Transrectal	Diverticulitis
Nishimura <i>et al</i> <sup>[61]</sup> , 2011	Case series	16	Sigmoid resection	Transrectal	Malignant
Saad <i>et al</i> <sup>[66]</sup> , 2010	Case series	8	Sigmoid resection	Transrectal	Benign and malignant
Wolthuis <i>et al</i> <sup>[73]</sup> , 2011	Case-matched	21	Sigmoid resection	Transrectal	Endometriosis
Wolthuis <i>et al</i> <sup>[74]</sup> , 2011	Case series	21	Sigmoid resection	Transrectal	Benign and malignant
Akamatsu <i>et al</i> <sup>[37]</sup> , 2009	Case series	7	TME	Transanal	Malignant
Bie <i>et al</i> <sup>[39]</sup> , 2013	Case series	131	TME	Transanal	Malignant
Choi <i>et al</i> <sup>[43]</sup> , 2009	Case series	13	TME	Transanal(11 patients)	Malignant
de Lacy <i>et al</i> <sup>[46]</sup> , 2013	Case series	20	TME	Transanal	Malignant
Dumont <i>et al</i> <sup>[47]</sup> , 2012	Case series	4	TME	Transanal	Malignant
Gaujoux <i>et al</i> <sup>[51]</sup> , 2011	Case series	2	TME	Transanal	Malignant
Hara <i>et al</i> <sup>[54]</sup> , 2011	Case series	9	Sigmoid resection	Transanal	Malignant
Kang <i>et al</i> <sup>[55]</sup> , 2012	Comparative	53	TME	Transanal	Malignant
Lacy <i>et al</i> <sup>[56]</sup> , 2013	Case series	3	TME	Transanal	Malignant
Lamadé <i>et al</i> <sup>[57]</sup> , 2010	Case series	3	RPC	Transanal	IBD (UC)
Marks <i>et al</i> <sup>[59]</sup> , 2010	Case series	79	TME	Transanal (36 TATA)	Malignant
Prete <i>et al</i> <sup>[64]</sup> , 2007	Case series	10	TME	Transanal	Malignant
Rullier <i>et al</i> <sup>[65]</sup> , 2003	Case series	32	TME	Transanal	Malignant
Sylla <i>et al</i> <sup>[67]</sup> , 2013	Case series	5	TME	Transanal	Malignant
Velthuis <i>et al</i> <sup>[70]</sup> , 2013	Case series	5	TME	Transanal	Malignant
Wang <i>et al</i> <sup>[71]</sup> , 2013	Case series	21	TME	Transanal (16 patients)	Malignant
Watanabe <i>et al</i> <sup>[72]</sup> , 2000	Case series	7	TME	Transanal	Malignant
Zorron <i>et al</i> <sup>[75]</sup> , 2012	Case series	2	TME	Transanal	Malignant
Abrão <i>et al</i> <sup>[35]</sup> , 2005	Case series	8	Sigmoid resection	Transvaginal	Endometriosis
Awad <i>et al</i> <sup>[38]</sup> , 2011	Case series	14	Right hemicolectomy	Transvaginal	Benign and malignant
Boni <i>et al</i> <sup>[40]</sup> , 2007	Case series	11	Sigmoid resection	Transvaginal	Endometriosis
Breitenstein <i>et al</i> <sup>[41]</sup> , 2006	Case series	2	Sigmoid resection (+ hysterectomy)	Transvaginal	Diverticulitis
Franklin <i>et al</i> <sup>[49]</sup> , 2013	Case series	26	Right hemicolectomy	Transvaginal	Benign and malignant
Ghezzi <i>et al</i> <sup>[52]</sup> , 2008	Case series	33	Sigmoid resection	Transvaginal	Endometriosis
McKenzie <i>et al</i> <sup>[60]</sup> , 2010	Case series	4	Right hemicolectomy	Transvaginal	Benign and malignant
Palanivelu <i>et al</i> <sup>[62]</sup> , 2008	Case series	7	Restorative proctocolectomy	Transvaginal	Fap
Park <i>et al</i> <sup>[63]</sup> , 2011	Case-matched	34	Right hemicolectomy	Transvaginal	Malignant
Tarantino <i>et al</i> <sup>[68]</sup> , 2011	Case series	34	Sigmoid resection	Transvaginal	Diverticulitis
Torres <i>et al</i> <sup>[69]</sup> , 2012	Case series	21	Sigmoid and high anterior resection	Transvaginal	Benign and malignant

FAP: Familial adenomatous polyposis; IBD: Inflammatory bowel disease; UC: Ulcerative colitis; TATA: Transanal transabdominal; TME: Total mesorectal excision; RPC: Restorative proctocolectomy.

## TRANSRECTAL NOSE

The technique and concept of a transrectal NOSE-colectomy was developed in the early 1990s<sup>[79,80]</sup>, and Franklin *et al*<sup>[80]</sup> were the first to publish results on a group of patients who underwent sigmoid resection with transrectal specimen extraction. In 2012, we reported a systematic review referring to 6 studies on transrectal NOSE<sup>[81]</sup>. To date, a total of 12 reports including a total of 462 patients have been published describing variations of the transrectal technique in different centers (Table 1). There is heterogeneity amongst studies with regard to operating ports (3 ports-25%, 4 ports-50%, 5 ports-25%), rectal protection (none-25%, rigid rectoscope-33%, camera sleeve or retrieval bag-42%), and anastomotic technique (double stapled-17% and tripled stapled-83%). Therefore,

postoperative outcome regarding morbidity and length of hospital stay cannot be compared between these studies. However, it is important to investigate and report surgery-related complications when the safety and feasibility of new techniques are evaluated (Table 2). Overall, anastomotic leakage was reported in 13 of 462 patients (2.8%), but this percentage is biased due to differences in anastomotic techniques and small uncontrolled case studies reporting a learning curve phenomenon. There were no randomized trials comparing transrectal NOSE to conventional laparoscopic resection, but 3 case-matched studies were identified. One study failed to show any benefit from transrectal NOSE<sup>[44]</sup>, while there was a significantly lower analgesic requirement in the transrectal NOSE-colectomy groups in the other 2 papers<sup>[45,73]</sup>. Moreover, a significantly shorter operative time was

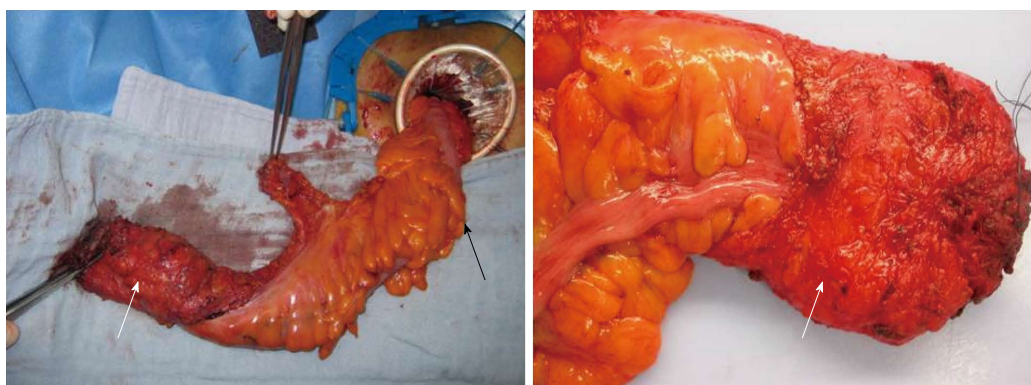
**Table 2** Operative details and outcome of natural orifice specimen extraction-colectomy

Author	Ports	Protection	Anastomosis	Duration of surgery (min)	Morbidity (n, Dindo-score)	LOS (d)
Transrectal NOSE						
Akamatsu <i>et al</i> <sup>[36]</sup> , 2009	4	None	TS	Mean 180 (137-257)	Wound infection (1, 1)	Mean 11 (8-14)
Cheung <i>et al</i> <sup>[42]</sup> , 2009	5	TEO	TS	Median 127.5 (105-170)	None	Median 7 (4-18)
Christoforidis <i>et al</i> <sup>[44]</sup> , 2013	4	Camera sleeve	TS	Median 200 (120-360)	Abscess (1, 3a), leakage (3b) and trocar hernia (3b)	Median 6 (4-33)
Costantino <i>et al</i> <sup>[45]</sup> , 2012	3	None	TS	122 ± 36.5	Bleeding (1, 1), fever (2, 2), abscess (1, 2), leakage (1, 3b)	7.2 ± 4.9
Franklin <i>et al</i> <sup>[49]</sup> , 2013	4	Retrieval bag	TS	164.7 ± 47.5	Leakage (3, 3b)	6.9 ± 2.8
Fuchs <i>et al</i> <sup>[50]</sup> , 2013	3	TEA	TS	Mean 131 (55-184)	Bleeding (1, 1), ileus (1, 2)	NA
Han <i>et al</i> <sup>[53]</sup> , 2013	5	TEM and bag	DS	Mean 151.6 (125-185)	Leakage (6, 3b)	Median 9 (7-66)
Leroy <i>et al</i> <sup>[58]</sup> , 2011	3	None	TS	Mean 120.9 (std 41.9)	Epigastric pain (1, 1) and transient fever (3, 2)	6.1 ± 2.4
Nishimura <i>et al</i> <sup>[61]</sup> , 2011	5	Wound retractor	DS	Mean 241 (188-309)	Leakage (1, 2)	Median 6 (4-16)
Saad <i>et al</i> <sup>[66]</sup> , 2010	4	McCarteny Tube	TS	95-180	None	4-8 d
Wolthuis <i>et al</i> <sup>[73]</sup> , 2011	4	Retrieval bag	TS	Median 90 (85-105)	UTI (1, 2)	Median 6 (5-7)
Wolthuis <i>et al</i> <sup>[74]</sup> , 2011	4	Retrieval bag	TS	Median 105 (90-110)	Leakage (1, 3b)	Median 6 (5-7)
Transanal NOSE						
Akamatsu <i>et al</i> <sup>[37]</sup> , 2009	5	None	DS	Median 299 (255-343)	None	Mean 25 (14-49)
Bie <i>et al</i> <sup>[39]</sup> , 2013	NA	None	SS	Median 166 (120-280)	None	Median 10 (8-17)
Choi <i>et al</i> <sup>[43]</sup> , 2009	5	Retrieval bag	SS	260.8 ± 62.9	Bleeding (1, 3a), leakage and bleeding (1, 3b/3b)	Median 7 (6-14)
de Lacy <i>et al</i> <sup>[46]</sup> , 2013	3	None	DS	235 ± 56	Retention (2, 1), ileus (1, 2), dehydration (1, 2)	6.5 ± 3.1
Dumont <i>et al</i> <sup>[47]</sup> , 2012	1	None	Hand-sewn	Median 360 (270-460)	Leakage (1, 3b)	Median 13 (10-21)
Gaujoux <i>et al</i> <sup>[51]</sup> , 2011	1	None	Hand-sewn	195 and 210	None	5 and 6
Hara <i>et al</i> <sup>[54]</sup> , 2011	4	None	DS	Median 293 (220-342)	None	NA
Kang <i>et al</i> <sup>[55]</sup> , 2012	5 (6)	Retrieval bag	SS	Mean 357 std 66.8	Leakage (4), abscess (2)	9 ± 4.8
Lacy <i>et al</i> <sup>[56]</sup> , 2013	3	None	SS	125, 150, and 155	Dehydration (1, 2)	4, 5, and 5
Lamadé <i>et al</i> <sup>[57]</sup> , 2010	1 + TV assistance	None	DS	NA	None	11, 12, and 14
Marks <i>et al</i> <sup>[59]</sup> , 2010	3-6	None	Hand-sewn	NA	19% minor, 11% major	Median 5 (3-24)
Prete <i>et al</i> <sup>[64]</sup> , 2007	NA	None	Hand-sewn	NA	Leakage (1, 3b), hemorrhagic gastropathy (1, 2)	Mean 8.5 (6-10)
Rullier <i>et al</i> <sup>[65]</sup> , 2003	NA	None	Hand-sewn	Median 420 (300-600)	22% major	Median 9 (7-29)
Sylla <i>et al</i> <sup>[67]</sup> , 2013	4 (5)	None	Hand-sewn	274.6 ± 85.4	Urinary dysfunction (2, 2), ileus (1, 2)	4, 4, 4, 4, and 10
Velthuis <i>et al</i> <sup>[70]</sup> , 2013	1	Wound retractor	Hand-sewn and SS	Median 175 (160-194)	Ileus and pneumonia (1, 2), abscess (1, 3b)	NA
Wang <i>et al</i> <sup>[71]</sup> , 2013	3	Retrieval bag	DS	187 ± 35	Ileus (1, 2)	Mean 7.5 (2-11)
Watanabe <i>et al</i> <sup>[72]</sup> , 2000	5	None	Hand-sewn	280-450	Leakage (1, 3b)	NA
Zorron <i>et al</i> <sup>[73]</sup> , 2012	3	None	Hand-sewn	350 and 360	None	6
Transvaginal NOSE						
Abrao <i>et al</i> <sup>[35]</sup> , 2005	4	None	DS	Mean 177.5 (119-251)	None	Mean 4.13 (2-5)
Awad <i>et al</i> <sup>[38]</sup> , 2011	5	Retrieval bag	DS	Mean 229 (172-360)	Bleeding (1, 3b), ileus (3, 2)	Mean 9.6 (2-30)
Boni <i>et al</i> <sup>[40]</sup> , 2007	4	Retrieval bag	DS	240 ± 63	None	5 ± 2
Breitenstein <i>et al</i> <sup>[41]</sup> , 2006	4	None	DS	NA	<i>C. difficile</i> -colitis (1, 2), UTI (1, 2)	15 and 9
Franklin <i>et al</i> <sup>[49]</sup> , 2013	4	Retrieval bag	DS	159 ± 27.1	None	5.5 ± 2.5
Chezzi <i>et al</i> <sup>[52]</sup> , 2008	4	None	DS	Median 290 (200-390)	Seroma (1, 3b), retention (3, 2)	6.7 ± 1.8
McKenzie <i>et al</i> <sup>[60]</sup> , 2010	4	Retrieval bag	DS	Mean 212.3	Internal hernia (1, 3b)	3, 4, 5 and 34
Palanivelu <i>et al</i> <sup>[62]</sup> , 2008	5	Retrieval bag	DS	Mean 222.5 (165-280)	Leakage (1, 2)	Mean 25.5 (11-40)
Park <i>et al</i> <sup>[63]</sup> , 2011	5	Retrieval bag	DS	Mean 170.8 (std 46.4)	Ileus (1, 2), retention (1, 1), bleeding (2, 2)	7.9 ± 0.8
Tarantino <i>et al</i> <sup>[68]</sup> , 2011	4	Wound retractor	DS	Median 172.5 (107-312)	Leakage (1, 3b)	Median 6 (3-23)
Torres <i>et al</i> <sup>[69]</sup> , 2012	4	Wound retractor	DS	NA	NA	3-6

*C. difficile*: Clostridium difficile; DS: Double stapled; LOS: Length of stay; NA: Not available; SS: Single stapled; TEA: Transanal endoscopic applicator; TEM: Transanal endoscopic microsurgery; TEO: Transanal endoscopic operation; TS: Triple stapled; TV: Transvaginal; UTI: Urinary tract infection.

observed when comparing transrectal NOSE-colectomy with conventional laparoscopic colectomy<sup>[73]</sup>. Transrectal NOSE appears to be a valid option for specimen extraction and the creation of a colorectal anastomosis because of its applicability in both sexes and its frequent indica-

tions in left-sided colonic disease such as diverticulitis, endometriosis, adenoma and carcinoma. Moreover, the straightness of the rectum and relatively easy access to the peritoneal cavity further contribute to the feasibility of the procedure. Additionally, it can be easily stan-



**Figure 3 Transanal natural orifice specimen extraction.** A laparoscopic transanal transabdominal-total mesorectal excision (TME) was performed. The TME-specimen with the vascular pedicle (black arrow) and colon used for the reconstruction and the hand-sewn anastomosis (white arrow) can be observed.

standardized and taught. Even so, all studies reporting on transrectal NOSE-colectomy have described different surgical approaches and methods of rectal protection and anastomosis, leading to a considerable bias when the results from these studies are interpreted. Moreover, patient selection appears to be of paramount importance, and the limiting factors include a BMI > 30 kg/m<sup>2</sup>, a bulky mesocolon, large tumors, the presence of a rectal stricture and proximal diverticular disease<sup>[81]</sup>. In addition to the above-mentioned technical difficulties and differences, the bacteriological impact on the peritoneal cavity secondary to intraoperative colo- and rectotomy might be a concern. Although some studies did not report intraperitoneal abscesses<sup>[45,58]</sup>, this complication has not yet been studied in a large prospective controlled study.

## TRANSANAL NOSE

TME optimizes outcome in patients with rectal cancer<sup>[82]</sup> and most patients now have the prospect of a restorative procedure to avoid a permanent colostomy<sup>[83]</sup>. Recent meta-analyses have shown that laparoscopic TME is feasible and safe, with an outcome comparable to open TME but with short-term benefits regarding postoperative recovery<sup>[84,85]</sup>. However, laparoscopic TME is a demanding procedure involving a significant learning curve<sup>[86]</sup>. One of the most difficult steps of laparoscopic TME is the mobilization and transection of the most distal part of the rectum. Specimen retrieval and the construction of a colonic J-pouch require an abdominal wall incision. The length of the incision will be adapted to the size of the specimen and the tumor. This extraction site is not without risk of morbidity. Wound infections rates of 9% have been documented albeit usually only local septic complications<sup>[87]</sup>. Additionally, acceptance of a shorter distal resection margin (1 cm)<sup>[88]</sup>, neo-adjuvant chemoradiation with an increased interval to surgery (> 7 wk)<sup>[89]</sup> and the surgical technique of intersphincteric dissection have all increased the rates of “sphincter-preserving” surgery in patients with distal rectal cancer<sup>[83]</sup>. If intersphincteric dissection is required, the mobilized rectum can be extracted *via* the muscular anal canal avoiding any further abdomi-

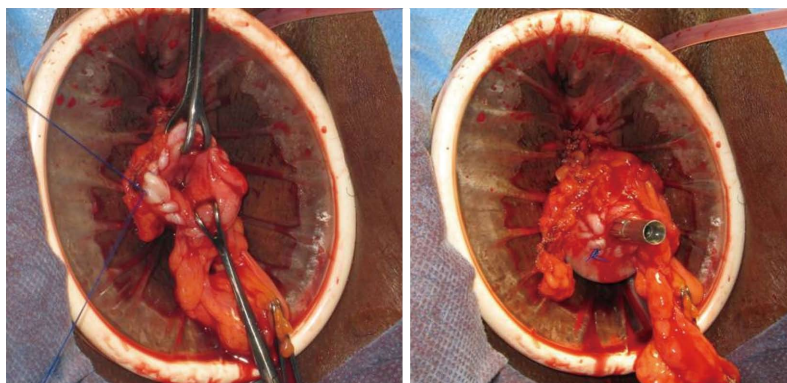
nal incision. During this perineal or transanal phase, a neorectum (*e.g.*, rectoplasty<sup>[65,90]</sup>, terminolateral anastomosis<sup>[91]</sup> or colonic J-pouch<sup>[92,93]</sup>) or a straight coloanal anastomosis can be created. In both cases, mobilization of the splenic flexure is most often necessary. In 1997, Teramoto *et al.*<sup>[94]</sup> described a new technique of laparoscopic TME with intersphincteric dissection and “per anum” specimen retrieval. From that same group data from a small cohort of patients were reported by Watanabe *et al.*<sup>[72]</sup> and Teramoto *et al.*<sup>[94]</sup>. In 2003, Rullier *et al.*<sup>[65]</sup> added coloplasty to this technique, and Person *et al.*<sup>[23]</sup> described the original technique for totally laparoscopic low anterior resection with transperineal handsewn colonic J-pouch anastomosis for low rectal cancer. A similar technique of pouch reconstruction during perineal rectosigmoidectomy for total full-thickness rectal prolapse was described in 1998. These authors advised the creation of a colonic pouch to improve functional results. In 2007, Prete *et al.*<sup>[64]</sup> published results using the same technique in a small series of 10 patients. Since then, the number of publications regarding transanal NOSE techniques has gradually increased (Table 1, Figure 2). Although almost all studies have reported cases concerning colorectal malignant disease with the performance of a TME, specimens were extracted *via* an unprotected anus in 14 of 17 studies (82%). In laparoscopic resections for malignancies, port-site metastases were an issue almost 20 years ago and a temporary moratorium was called<sup>[95,96]</sup>. Thus, a word of caution may be of value when specimens containing a tumor are extracted through an unprotected orifice (Figure 3). Whether this new approach has similar oncologic outcomes regarding local recurrence, disease-free survival and cancer-specific survival have yet to be studied in prospective trials comparing transanal TME with conventional TME. Operative techniques differ amongst studies with a different number of ports used and different ways of creating a coloanal anastomosis: hand-sewn in 50% of studies, single-stapled in 22%, and double-stapled in 28% (Table 2). Due to these differences in technique, it is impossible to perform inter-study comparisons of data concerning operative details; such as duration of surgery and postoperative outcome, *e.g.*, complications and length

of hospital stay. The ongoing evolution of minimally invasive laparoscopic surgery has led to the introduction of robotic surgery to perform TME<sup>[97,98]</sup>. The use of robotic platforms has influenced the treatment of complex pelvic disorders and for a TME the learning curve involves 21-23 cases<sup>[99-101]</sup>. The high-definition 3D system, ergonomic positioning of the surgeon, instrument articulation with greater precision and absence of tremor might lead to a higher accuracy, a more precise dissection and, possibly, fewer postoperative complications. However, a major limitation for the use of a robotic platform is its high cost. Only 1 study reported on the use of robotics in transanal NOSE<sup>[55]</sup>, describing a cohort of 53 patients who underwent robotic-assisted laparoscopic TME with transanal specimen extraction. The short-term postoperative outcome was comparable to that of a group of 66 patients, but robotic assistance in transanal NOSE-TME was associated with less pain and faster recovery. In reviewing the literature regarding transanal NOSE, the differences must be highlighted between techniques describing laparoscopic TME with the anus as the extraction site and techniques describing transanal TME. Both procedures are transanal NOSE techniques, but in the latter, TME is performed in a reversed way. A laparoscopic low anterior resection with transanal pull-through and hand-sewn anastomosis could be indicated in patients requiring TME with coloanal anastomosis for distal rectal tumors. Transanal rectal excision by transanal minimally invasive surgery is an option to improve the difficult visualization of the distal rectum, particularly in obese male patients with a narrow pelvis. Recent publications concerning transanal rectal excision, or so-called “down-to-up” or reversed TME, show the feasibility and safety of this new technique, reporting intact TME specimens and adequate lymph node harvest. In the future, large prospective studies should focus on the functional and oncological outcomes. If laparoscopy can be omitted in this setting, true NOTES might become possible in a consecutive series of patients.

## TRANSVAGINAL NOSE

Transvaginal NOSE using a posterior colpotomy has extensively been reported during gynecologic laparoscopic procedures<sup>[102-104]</sup>. Although the peritoneal cavity is entered by deliberately opening the vagina, it appears that a vaginotomy or so-called colpotomy will not increase postoperative morbidity. A colpotomy is safe and does not lead to surgical site infections or dyspareunia<sup>[105,106]</sup>. Moreover, a randomized trial showed less postoperative pain when comparing transvaginal and transumbilical specimen extraction for adnexal masses<sup>[107]</sup>. In 1996, Redwine *et al.*<sup>[108]</sup> first described a segmental colectomy with transvaginal extraction and hand-sewn anastomosis for bowel endometriosis. A combined laparoscopic-transvaginal approach, with transvaginal specimen extraction, has been published for the treatment of colorectal diseases. Moreover, several authors have reported short-

term results (Table 1). A total of 11 studies including 194 patients were found regarding transvaginal specimen extraction in laparoscopic colorectal surgery. The main advantage of transvaginal NOSE is the possibility to extract large specimens from both right-sided and left-sided colonic resections, but this approach is only applicable in female patients with a non-intact hymen who give informed consent. No randomized controlled trials could be found and apart from 1 case-matched study, only small case series were included. Multiple variants of transvaginal NOSE-colectomy have been described, making the evidence poor. Four studies have reported right-sided disease and 6 studies left-sided disease (Table 2). Palanivelu *et al.*<sup>[62]</sup> described the results of 7 female patients with familial adenomatous polyposis, who underwent restorative proctocolectomy with ileoanal pouch anastomosis. All specimens were extracted through the vagina in a retrieval bag. A 15 cm ileoanal pouch was created completely laparoscopically with endostaplers, and the anvil of the circular stapler was inserted and secured by a purse string. The double-stapled anastomosis was performed in a standardized manner. One patient developed an anastomotic leakage, requiring drainage and antibiotics. The mean length of hospital stay was 25.5 d in this series. For a right hemicolectomy, a double-stapled anastomosis was performed in all cases and the specimen was extracted in a retrieval bag to protect the vagina. The difficulty concerning laparoscopic right hemicolectomy is the creation of an intracorporeal anastomosis<sup>[109]</sup>. Both the ileum and colon should be cleaned of mesentery and omental fat to allow adequate and safe stapling and this can sometimes be difficult in obese patients. Moreover, the remaining enterocolostomy should be closed with an intracorporeal suture. However, specimen extraction and extracorporeal anastomosis can also pose a problem in obese patients, risking bleeding and twisting of the terminal ileum<sup>[110,111]</sup>. The mean BMIs were 31.7, 24.5, and 23.9 kg/m<sup>2</sup> in the studies of Awad *et al.*<sup>[38]</sup>, McKenzie *et al.*<sup>[60]</sup>, and Park *et al.*<sup>[63]</sup>, respectively, indicating that intracorporeal anastomosis is feasible in this group of patients. These authors reported small case series concerning laparoscopic right hemicolectomy with transvaginal NOSE and intracorporeal anastomosis for benign and malignant right-sided colorectal disease. The mean operative times were 229 min and 212 min for Awad *et al.*<sup>[38]</sup> and McKenzie *et al.*<sup>[60]</sup>, respectively, but only 171 min for Park and colleagues. Park *et al.*<sup>[112]</sup> had already published their experience with transvaginal NOSE in 2010. Therefore, the shorter operative times included in this review could reflect the learning curve. Franklin *et al.*<sup>[49]</sup> had a mean operative time of 159 min in their cohort of 26 patients. Postoperative ileus, internal hernia and bleeding for which reintervention was necessary in 2 patients contributed to the observed postoperative morbidity. This led to a mean length of hospital stay of more than 1 wk in 3 studies and to a mean of 5.5 d in the study published by Franklin *et al.*<sup>[49]</sup>. Six authors reported transvaginal NOSE for sigmoid and high anterior resection in a total of 109 patients. The indications were



**Figure 4 Transvaginal natural orifice specimen extraction.** The sigmoid colon has been resected, and the anvil from a 29 mm circular stapler has been sutured into the proximal colon with a purse string. Note the wound retractor protecting the vagina.

endometriosis, diverticular disease and cancer. In all studies, 4 ports were used and intracorporeal anastomoses were performed with the double-stapling technique (Figure 4). In 3 studies, the vagina was protected using either a retrieval bag or a wound retractor<sup>[40,68,69]</sup>. One anastomotic leak was reported requiring reintervention. The length of hospital stay was approximately 6 d in the largest series. In conclusion, transvaginal NOSE-colectomy could have a place in laparoscopic colorectal surgery to treat both right-sided and left-sided disease. It might pave the way for transvaginal NOTES and scarless surgery in selected patients.

## CONCLUSION

A state-of-the-art review was presented concerning laparoscopic NOSE-colectomy. The reduction of incision-related morbidity is one of the goals of modern minimally invasive laparoscopic colorectal surgery. Abdominal wall incisions can still cause postoperative morbidity, such as infection, pain and trocar-site incisional hernia. In addition to reports on operative and oncological outcome, surgical technique and novel methods to reduce access trauma have become important issues in current practice. This narrative review described the technical possibilities and shortcomings in laparoscopic NOSE-colectomy. A new era has dawned to further minimize access trauma and to explore new surgical strategies in bridging conventional laparoscopic surgery to pure human NOTES procedures. NOSE could be the next step in minimizing minimally invasive surgery. Although NOSE theoretically has the potential to improve outcome in laparoscopic colorectal surgery, its implementation in daily practice and its assumed benefits have yet to be studied in prospective controlled trials.

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