Annals of COLOPROCTOLOGY

Original Article

Ann Coloproctol 2025;41(4):346-353
pISSN: 2287-9714 • eISSN: 2287-9722
https://doi.org/10.3393/ac.2025.00647.0092

Expanding the boundaries of minimally invasive surgery: the feasibility of robotic natural orifice transluminal extraction colectomy and robotic no-incision colectomy in colorectal practice

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Purpose: Minimally invasive surgery offers reduced trauma, accelerated recovery, and shorter hospital stays. Robotic technology further enhances laparoscopic precision, particularly in colorectal procedures. This study investigated the safety and effectiveness of robotic natural orifice transluminal extraction colectomy (R-NOTEC) and robotic no-incision colectomy (R-NIC), comparing these techniques to the conventional robotic colectomy.

Methods: Outcomes of patients undergoing robotic-assisted colorectal resection—either conventional robotic colectomy or R-NOTEC/R-NIC—using a single docking technique at a tertiary hospital over 3 years were analyzed. All patients were managed according to established Enhanced Recovery After Surgery protocols.

Results: In total, 100 patients were included, with 25 receiving R-NOTEC or R-NIC. The median age was 65 years (range, 30–82 years), and the median body mass index was 31.0 kg/m^2 (range, 20.1–43.0 kg/m^2). The median length of stay was significantly shorter in the R-NOTEC/R-NIC group than in the conventional robotic group (2.0 days vs. 3.4 days, P = 0.021). Other outcomes, such as circumferential resection margin status, lymph node yield, and mortality, were similar between groups. The R-NOTEC/R-NIC group exhibited a slightly lower complication rate, as well as less opioid use. No conversions to open surgery occurred in either group.

Conclusion: R-NOTEC/R-NIC offer significant promise in colorectal surgery by minimizing trauma, expediting recovery, and maintaining oncologic safety. Nevertheless, these procedures require specialized surgical expertise and careful patient selection. Further research should focus on long-term outcomes and standardization of these techniques.

Keywords: Colectomy; Minimally invasive surgical procedures; Robotic surgical procedures; Natural orifice endoscopic surgery; Quality of life

INTRODUCTION

Robotic platforms have markedly advanced the field of minimally invasive colorectal surgery by providing enhanced dexterity, three-dimensional visualization, and improved ergonomic precision [1–3]. Simultaneously, natural orifice transluminal endoscopic surgery (NOTES) and no-incision surgery (NIS) have emerged as innovative techniques designed to further minimize

Received: May 19, 2025; Revised: July 23, 2025; Accepted: July 24, 2025
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surgical trauma by eliminating abdominal wall incisions and retrieving specimens through natural orifices such as the anus or vagina [4–6].

The integration of robotics with these approaches—yielding robotic natural orifice transluminal extraction colectomy (R-NOTEC) and robotic no-incision colectomy (R-NIC)—potentially combines the advantages of incisionless surgery with the stability and accuracy provided by robotic systems. Reported benefits of R-NOTEC/R-NIC include reduced postoperative pain, fewer incision-related complications, faster recovery, and improved cosmetic outcomes [7–9]. Despite these advantages, widespread adoption remains limited. Concerns persist regarding intraperitoneal contamination, oncological adequacy, and the steep technical learning curve inherent to natural orifice surgery [10–13].

To address these limitations, we previously developed and published a refined R-NOTEC/R-NIC technique that incorporates specimen closure and retrieval using a protective bag, aiming to minimize contamination risk and streamline the operative workflow [14]. Although R-NOTEC has been practiced for nearly 2 decades, our adaptation introduces crucial safety optimizations—such as extracorporeal closure and protected extraction—that may enhance reproducibility and patient outcomes. While technical feasibility has been demonstrated, there remains a lack of prospective data evaluating safety and clinical effectiveness in routine clinical practice.

This study aimed to address this gap by prospectively evaluating perioperative and short-term postoperative outcomes in 100 consecutive patients undergoing robotic colorectal resections. Specifically, it compared R-NOTEC/R-NIC with conventional robotic colectomy to assess feasibility, safety, and recovery outcomes in standard clinical settings.

METHODS

Ethics statement

This study was approved by the Institutional Review Board of Euroclinic (No. 2020/04-RS). Informed consent was obtained from all participants, and confidentiality and anonymity were rigorously maintained. The study adhered to the principles of the Declaration of Helsinki, prioritizing the rights and well-being of all participants. This study is reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for reporting observational studies [15].

Study design

This was a prospective observational cohort study conducted at a high-volume robotic colorectal unit between January 2020 and December 2023. All patients referred for robotic colorectal resection were consecutively enrolled in a prospectively maintained database. The study was nonrandomized and observational in nature. The surgical team aimed to perform R-NOTEC or R-NIC in as many patients as clinically appropriate; however, the final decision regarding surgical approach (R-NOTEC/R-NIC vs. conventional robotic colectomy) was made intraoperatively, taking into account patient anatomy, oncologic safety, and intraoperative findings. All outcome variables and data collection protocols were defined at the outset of the study and applied prospectively and uniformly throughout.

Terminology

For the purpose of this study, we defined the 2 overlapping but distinct techniques. R-NOTEC was defined as robotic colorectal resection with specimen extraction via a natural orifice (typically transanal or transvaginal) without using any abdominal incision. Alternative terminology includes NOTES or natural orifice specimen extraction surgery (NOSES). In this study, the term "NOTES" is used only to describe the broader surgical field and is not used interchangeably with other terms. R-NIC is an expanded term encompassing R-NOTEC as well as other no-incision approaches in which the specimen is retrieved primarily through a stoma site. Both techniques are designed to eliminate abdominal incisions and utilize intracorporeal anastomosis. In this study, "R-NIC" includes all procedures performed without an abdominal incision.

Patients

Eligible participants were adults (≥18 years) with histologically confirmed colorectal cancer or benign colorectal conditions requiring surgical intervention. No exclusion criteria were applied based on age, comorbidities, prior surgeries, or disease stage. This inclusive design was intended to capture a realistic cross-section of patients undergoing robotic colorectal surgery, reflecting routine clinical practice. Although the majority of cases (84.0%) involved oncological resections, a minority of procedures addressed benign conditions or complex surgical indications, including panproctocolectomy, cytoreductive surgery, and Hartmann reversal procedure. This range reflects the real-world application of robotic surgery across a spectrum of colorectal pathologies. A flowchart illustrating patient screening, inclusion, and analysis is presented in Fig. 1.

Surgical technique

All procedures were performed by a single, experienced robotic colorectal surgeon using either the Da Vinci Si or Xi platform (In-

tuitive Surgical). The primary distinction between R-NOTEC/R-NIC and conventional robotic colectomy lies in the method of specimen extraction. All other operative steps, including port placement, dissection, and anastomosis, were carried out using the same standardized robotic approach in both groups.

The standardized robotic colectomy protocol included medial-to-lateral mobilization, high ligation of mesenteric vessels (when oncologically indicated), and complete mobilization of the colon or rectum as required. Intracorporeal anastomosis was the default strategy. For the conventional robotic group, a Pfannenstiel incision was made for specimen extraction. Following extraction, the proximal bowel was assessed with indocyanine green fluorescence to confirm adequate perfusion at the intended transection level. Once confirmed, the bowel was transected, and the anvil of the circular stapler was introduced into the lumen and secured with a continuous 2-0 Prolene (Ethicon Inc) purse-string suture in an in-and-out seromuscular fashion. To enhance safety and maintain sterility during specimen extraction, a protective endoscopic bag was used in all cancer cases.

Left-sided resections

In the R-NOTEC/R-NIC group, specimen retrieval was usually performed via the transanal route. In selected female patients, transvaginal extraction was used. Intracorporeal anvil placement was achieved transanally, with anastomosis completed using a circular stapler. Oncologic cases involving total mesorectal excision adhered strictly to the Quirke principles. A transanal purse-string suture was used to secure the anvil, consistent with the conventional robotic approach.

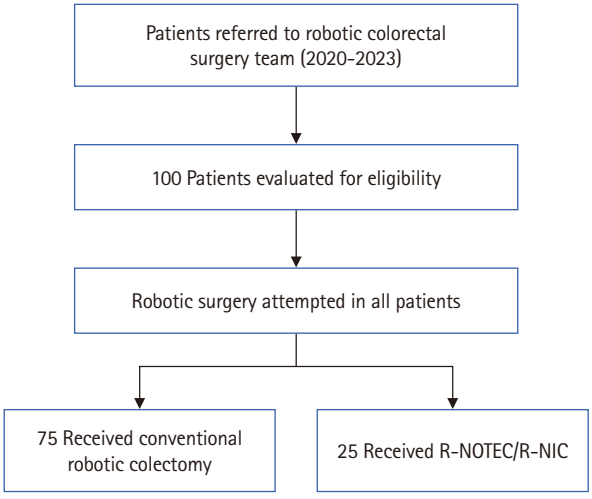

Fig. 1. Flowchart illustrating patient screening, inclusion, and analysis. R-NOTEC, robotic natural orifice transluminal extraction colectomy; R-NIC, robotic no-incision colectomy.

Right-sided resections

When indicated for oncologic reasons, a complete mesocolic excision with D3 lymphadenectomy was performed. Specimen extraction was carried out transvaginally in female patients or through an existing stoma site.

Outcome measures

The primary outcome of this study was length of hospital stay, which was chosen as a practical measure of postoperative recovery and healthcare resource utilization. Secondary outcomes included operative time, blood loss, intraoperative complications, conversion to open surgery, 30-day readmission, reoperations, and postoperative complications (graded by the Clavien-Dindo classification [13]). Oncologic outcomes, including lymph node yield, circumferential resection margin (CRM) status, and completeness of mesorectal excision, were analyzed only in patients undergoing surgery for malignant disease (n = 84).

Statistical analysis

Data were analyzed using IBM SPSS ver. 30.0 (IBM Corp). Categorical variables (e.g., sex, conversion, complications) were compared using the Hauck-Anderson test and Wald test with continuity correction. Continuous variables (e.g., age, body mass index [BMI], operative time, length of stay) were compared with the Mann-Whitney U-test. A P-value of <0.05 was considered statistically significant. Subgroup analysis was conducted for oncologic versus nononcologic patients to improve interpretability.

RESULTS

A total of 100 advanced robotic colorectal resections were performed, comprising 75 conventional robotic colectomies with specimen extraction via a Pfannenstiel incision and 25 procedures utilizing either the R-NOTEC or R-NIC approach. Eighty-nine patients (89.0%) were classified as high-risk, defined by the presence of at least 2 of the following criteria: BMI >30 kg/m^2, ultralow rectal tumor (<6 cm from the anal verge), history of ≥ 2 prior laparotomies, age >80 years, American Society of Anesthesiologists (ASA) physical status III or higher, previous major cardiac surgery, uncontrolled diabetes, or emergency presentation. This definition aligns with established high-risk criteria in the colorectal surgery literature [16]. The baseline characteristics according to surgical approach is summarized in Table 1.

Colorectal cancer was the surgical indication in 84 patients (84.0%), and 74 (74.0%) had a history of previous abdominal surgery. The median age of the cohort was 72 years (range, 30–82 years), and the median BMI was 31.0 kg/m^2 (range, 20.1–43.0 kg/m^2).

https://doi.org/10.3393/ac.2025.00647.0092

Table 1. Baseline demographics, surgical characteristics, and outcomes (n = 100)

Characteristic	Conventional robotic colectomy (n = 75)	R-NOTEC/R-NIC (n = 25)	P-value
Age (yr)	72 (30–82)	71 (40–78)	0.743
Sex			0.668
Female	32 (42.7)	12 (48.0)	
Male	43 (57.3)	13 (52.0)	
Patient risk			> 0.999
Low	8 (10.7)	3 (12.0)	
High	67 (89.3)	22 (88.0)	
Procedure type			
Ultralow anterior resection	40 (53.3)	15 (60.0)	0.646
Right colectomy	28 (37.3)	2 (8.0)	0.005
Other	7 (9.3)	8 (32.0)	0.010
Length of stay (day)	3.4 (1–28)	2 (1–10)	0.021
Lymph node yield	35 (15–79)	31 (12–65)	> 0.999
Conversion to open surgery	0 (0)	0 (0)	> 0.999
Complication			
Major (Clavien-Dindo III–IV)	4 (5.3)	1 (4.0)	0.466
Surgical site infection	3 (4.0)	0 (0)	0.236
Postoperative opiod use	20 (26.7)	0 (0)	0.003

Values are presented as median (range) or number (%).
R-NOTEC, robotic natural orifice transluminal extraction colectomy; R-NIC, robotic no-incision colectomy.

Table 2. Oncological outcomes of cancer patients with ultralow anterior resections (n = 55)

Outcome	Conventional robotic colectomy (n = 40)	R-NOTEC/R-NIC (n = 15)	P-value
CRM negative (CRM ≥ 1 mm)	40 (100)	15 (100)	> 0.999
Total mesorectal excision (Quirke grade III)	40 (100)	15 (100)	> 0.999
Lymph node yield	35 (15–79)	31 (12–65)	> 0.999

Values are presented as number (%) or median (range).
R-NOTEC, robotic natural orifice transluminal extraction colectomy; R-NIC, robotic no-incision colectomy; CRM, circumferential resection margin.

The surgical procedures performed included 55 ultralow anterior resections, 30 right colectomies with complete mesocolic excision and D3 lymphadenectomy, 5 subtotal colectomies, 3 panproctocolectomies, 2 excisions of an anal pouch, 2 cases of cytoreductive surgery, and 3 Hartmann reversal procedures. The mean operative time was 230 minutes (range, 185–340 minutes), with no conversions to open surgery in any group.

The overall median length of hospital stay was 3 days (range, 1–28 days), but this was significantly shorter in the R-NOTEC/R-NIC group compared to the conventional robotic group (2.0 days vs. 3.4 days, P = 0.021).

Surgical site infections were observed in 3 patients in the conventional group, while none occurred in the R-NOTEC/R-NIC group (P = 0.236). The need for postoperative opioid use was significantly lower in the R-NOTEC/R-NIC group compared to the conventional group (0% vs. 26.7%, P = 0.003).

Of the 84 patients with cancer, oncologic outcomes were analyzed in the 55 who underwent ultralow anterior resections. The median lymph node yield was 35 (range, 15–79). All patients had negative CRM findings (CRM ≥ 1 mm), and all total mesorectal excisions were classified as Quirke grade III (Table 2).

The major complication rate (Clavien-Dindo grade III–IV) was 5.7% in the conventional group and 4.0% in the R-NOTEC/R-NIC group (P = 0.466) (Table 1). Three patients required reoperation within 30 days. The 90-day mortality was 1%, with a single death due to pulmonary embolism in the conventional group.

Subgroup analysis revealed that right colectomy was significantly more frequent in the conventional group (8.0% vs. 37.3%, P = 0.005), while complex "other" procedures (such as subtotal colectomy, Hartmann reversal procedure, and panproctocolectomy) were more common in the R-NOTEC/R-NIC group (32.0% vs. 9.3%; P = 0.010). There was no significant difference in the distribution of ultralow anterior resection between the groups (60.0% vs. 53.3%; P = 0.646) (Table 1).

DISCUSSION

Robotic surgery provides several advantages over conventional laparoscopic approaches, including 3-dimensional visualization, elimination of tremor, and wristed instrument articulation, which together enable superior dexterity and precision in confined anatomical spaces. These features allow surgeons to perform more complex and technically demanding procedures with greater control and accuracy, ultimately contributing to improved patient outcomes [17]. The emergence of techniques such as R-NOTEC and R-NIC represents a substantial advancement in minimally invasive colorectal surgery, further enhancing postoperative recovery and patient satisfaction.

Although NOTES techniques have been described for more than a decade, their widespread adoption has been limited by concerns regarding intra-abdominal contamination and oncological safety—particularly when specimens are left open in the abdomen or extracted without adequate protection. Our previously published technique addresses these issues by ensuring that all specimens are closed or stapled intra-abdominally and retrieved

through an Alexis retractor using a protective endobag [14]. In oncologic cases, this method preserves tumor isolation throughout extraction. Additionally, performing the purse-string suture extracorporeally during extraction reduces operative time compared to robotic suturing.

In our study, despite the smaller sample size of the R-NOTEC/R-NIC group, outcomes favored these approaches over conventional robotic colectomy, with several findings reaching statistical significance. Patients in the R-NOTEC/R-NIC group experienced a shorter median hospital stay (2.0 days vs. 3.4 days), indicating faster recovery and reduced resource utilization. The complication rate (4.0% vs. 5.7%) and surgical site infection rate (0% vs. 4%) were both lower in the R-NOTEC/R-NIC group, suggesting improved postoperative safety and fewer adverse events.

Analgesic use was significantly lower in the R-NOTEC/R-NIC group compared to the conventional robotic group. No patients in the R-NOTEC/R-NIC group required postoperative opioids, whereas 20 patients (26.7%) in the conventional group received at least 1 dose ($P=0.003$). Although no formal quality of life questionnaires were administered, these findings indicate that the minimally invasive nature of R-NOTEC/R-NIC may reduce opioid requirements and contribute to greater patient comfort and satisfaction during recovery.

In our cohort, only a small number of right colectomies were performed using the R-NOTEC/R-NIC approach. This limited use reflects our assessment that the potential benefit of creating an internal opening for specimen delivery is minimal for right-sided cases and may introduce unnecessary risks, such as inadvertent injury to adjacent structures.

The greater frequency of complex "other" procedure (such as panproctocolectomies, Hartmann reversal procedure, and cytoreductive surgery) in the R-NOTEC/R-NIC group compared to the conventional approach underscores our belief that this advanced technique can significantly improve outcomes, and we endeavor to implement it whenever feasible.

Oncologic outcomes, including lymph node yield and CRM clearance, were comparable across all techniques. Notably, lymph node yield was assessed only in cancer patients (84.0%), highlighting the ability of robotic approaches to achieve thorough lymphadenectomy.

Regarding operative time, our previously described and published technique eliminates additional time for purse-string closure, as this step is completed transanally rather than robotically. Similarly, bacteriological concerns are mitigated by not leaving the specimen open within the abdomen and by the routine use of a retrieval bag, thus eliminating the risk of spillage [14].

Comparative literature on NOTES or natural orifice NIS versus traditional robotic techniques remains limited; however, available studies corroborate our findings that R-NOTEC/R-NIC is associated with enhanced safety and faster recovery [18].

A recent propensity score–matched analysis by Houqiong et al. [19], involving 182 patients, demonstrated that the NOTES group experienced significantly faster recovery of gastrointestinal function ($P=0.014$), smaller incisions ($P<0.001$), reduced postoperative pain ($P<0.001$), decreased need for additional analgesia ($P<0.001$), and improved functional outcomes ($P<0.001$). However, no significant differences were observed in disease-free survival ($P=0.757$) or overall survival ($P=0.234$).

Similarly, Li et al. [20] compared short- and long-term outcomes between robotic NOSES and conventional robotic resections in 39 matched patient pairs. The NOSES group experienced significantly less intraoperative blood loss, earlier return of bowel function, reduced need for analgesia, and a shorter time to oral intake, with comparable long-term survival outcomes between groups.

Ye et al. [21] examined short-term outcomes in 50 patients undergoing transabdominal specimen extraction and 33 undergoing NOSES for mid-rectal cancer. Their results favored the NOSES group for reduced operative time, faster gastrointestinal recovery, smaller incisions, and less pain. Although the overall complication rate was slightly higher in the NOSES group (27.3% vs. 22.0%), this difference was not statistically significant. No major differences were observed in hospital stay or postoperative anal function.

For lower rectal cancer, robotic NOTES has demonstrated safety and benefit, with improvements in pain control, promotion of gastrointestinal recovery, and reduction of incision-related complications [22]. Additional matched analyses highlight further advantages, including reduced visual analogue scale pain scores, earlier return of bowel function, decreased surgical stress, and fewer postoperative complications [23].

Another innovative advancement is the natural orifice intracorporeal anastomosis with specimen extraction (NICE) technique. First described by Minjares-Granillo et al. [24] in 2018, NICE enables intracorporeal anastomosis even in left-sided resections. In their cohort of 20 patients undergoing elective sigmoid or rectosigmoid colectomy, only one required an abdominal incision. The mean operative time was 222 minutes (range, 146–344 minutes), mean time to first flatus was 23 hours, and mean hospital stay was just over 2 days. Sixteen patients were discharged on postoperative day 2, with only 1 readmission for pelvic fluid collection.

In 2024, Haas et al. [25] conducted a 1:1 matched case-control study comparing 83 patients undergoing NICE with 83 patients receiving traditional laparoscopic left-sided resections. NICE was associated with significantly faster return of bowel function (23.6

https://doi.org/10.3393/ac.2025.00647.0092

hours vs. 40.7 hours; P = 0.005), shorter hospital stay (2.2 days vs. 3.1 days; P < 0.001), and lower analgesic requirements (70.5 morphine-equivalents vs. 94.6 morphine-equivalents; P = 0.010), with no differences in operative time or complication rates.

NICE has also demonstrated efficacy in high-BMI patients [26] and in complex cases, such as diverticulitis with fistulas or abscesses [27]. As shown by Costantino et al. [28], the risk of abscess formation and overall complication rates are not elevated with intracorporeal NOTEC anastomosis. Reduced hospital stays have been consistently observed in other studies of NICE [29, 30], likely attributable to the avoidance of abdominal wall incisions and reduced trauma associated with intracorporeal techniques [9, 31].

Despite these benefits, NOTES and NICE procedures are currently performed in fewer than 1% of colorectal operations worldwide [32, 33]. We hope that our findings contribute to the growing body of evidence supporting the safety, feasibility, and patient-centered benefits of these techniques, thereby encouraging broader adoption in clinical surgical practice.

Limitations

One limitation of this study is the relatively small sample size, which may have reduced the statistical power to detect differences between the robotic techniques. A larger cohort would increase confidence in the observed advantages of R-NOTEC/R-NIC, particularly regarding analgesia use and postoperative recovery, and further validate the potential benefits of these minimally invasive approaches.

The heterogeneity of the cohort, which included both benign and malignant pathologies as well as a broad range of procedural complexity, reflects real-world surgical practice but may confound interpretation of clinical outcomes. Future studies incorporating stratified or matched subgroups would offer more granular insights into the benefits of R-NOTEC and R-NIC for specific patient populations. Additionally, generalizability may be limited, as all procedures were performed by a single, highly experienced surgeon; outcomes may differ in less experienced hands or at other institutions.

Conclusions

R-NOTEC/R-NIC represent significant advancements in colorectal surgery, in line with the core principles of minimally invasive procedures. Although this study is limited by its sample size, it provides early evidence that these techniques offer distinct advantages over the conventional robotic colectomy, especially in terms of length of stay, recovery, pain control, complication rates, and patient satisfaction. Despite the technical challenges and steep learning curve associated with these approaches, when performed by experienced surgeons and with careful patient selection, they can be both safe and effective. Further research should focus on long-term oncological outcomes, standardization of surgical techniques, and strategies for broader implementation. With ongoing refinement, NOTES and NIS may become standard practice in robotic colorectal surgery, ultimately contributing to improved surgical care and enhanced patient outcomes.

ARTICLE INFORMATION

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Funding

None.

Author contributions

Conceptualization: TP, AP; Data curation: TP; Formal analysis: TP, KE; Investigation: TP, KE; Methodology: TP, KE; Project administration: TP, AP; Resources: TP, AP; Software: TP, KE; Supervision: TP, AP; Validation: TP, KE; Visualization: TP, AP; Writing–original draft: TP, KE; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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