ORIGINAL PAPER

DOI: http://dx.doi.org/10.15403/jgld-6540

Endoscopic Submucosal Dissection for Colorectal Lesions in a Community-based European Hospital: Experience and Learning Curve

Thomas Balanis[1,2], Gerhard Rogler[2], Radu Tutuian[1,2,3]

1) Clinic for Gastroenterology and Hepatology, Bürgerspital Solothurn, Solothurn;
2) University of Zurich, Zurich;
3) Bern University, Faculty of Medicine, Berne, Switzerland

Address for correspondence:
Prof. Dr. med. **Radu Tutuian**
Clinic for Gastroenterology and Hepatology
Bürgerspital Solothurn – Solothurner Spitäler (SoH)
Schöngrünstrasse 42
CH-4500 Solothurn, Switzerland
radu.tutuian@hin.ch

Received: 10.09.2025
Accepted: 01.12.2025

ABSTRACT

Background & Aims: Endoscopic submucosal dissection (ESD) has become an established technique for en-bloc resection of large or complex colorectal lesions. However, conventional ESD (C-ESD) can be technically challenging and time-consuming. For non-malignant lesions, ESD with snaring [hybrid ESD (H-ESD)] can facilitate lesion removal and save time. We present our experience and the associated learning curve in a regional hospital setting in Switzerland.

Methods: We retrospectively evaluated the outcomes of all ESD procedures performed between 2018 and 2024 in our hospital. The primary outcome was the recurrence rate at the first follow-up endoscopy. Secondary outcomes comprised en-bloc resections, procedural time and complication rates stratified by periods in the learning curve.

Results: Ninety patients (42 women; mean age 67 ± 12 years) were included in the study of which 51 underwent C-ESD and 39 H-ESD. The recurrence rate at first follow-up endoscopy was 8.8% (6/68) with no difference ($p>0.05$) between C-ESD (8.1%; 3/37) and H-ESD (9.7%; 3/31). The overall en-bloc resection rate was 63%, significantly higher ($p<0.001$) in the C-ESD group (98%) vs H-ESD (18%). Similarly, R0 resection rates were significantly ($p<0.001$) higher in C-ESD (86%) vs H-ESD (18%) groups. Procedural times were similar in the C-ESD (86 ± 44 min) and H-ESD (88 ± 45 min) groups. All parameters improved as the learning curve advanced. Complications requiring surgical intervention occurred in two cases (2.2%) one in the C-ESD and one in the H-ESD group.

Conclusions: Colorectal ESD is feasible and can be self-taught in non-tertiary hospitals, achieving outcomes comparable to those reported in specialized centers, under appropriate case selection. Although conventional ESD achieves higher en-bloc and R0-resections than hybrid ESD, the latter may serve as a rescue option in selected cases.

Key words: endoscopic submucosal dissection – ESD – rectum – colon – outcome.

Abbreviations: AE: adverse event; C-ESD: conventional endoscopic submucosal dissection; CRC: colorectal cancer; CT: computed tomography; ESD: endoscopic submucosal dissection; EMR: endoscopic mucosal resection; ESGE: European Society of Gastrointestinal Endoscopy; H-ESD: hybrid ESD; JNET: Japanese Narrow-band Imaging Expert Team classification; LST: laterally spreading tumor; LST-G: laterally spreading granular tumor; LST-NG: laterally spreading non-granular tumor; R0 resection: complete tumor resection with negative margins; R1 resection: tumor resection with positive margins; Rx resection: unevaluable resection margins; SGG: Swiss Society of Gastroenterology.

INTRODUCTION

Colorectal cancer (CRC) remains a leading cause of cancer-related mortality worldwide, highlighting the critical need for early detection and effective intervention strategies [1]. Colorectal polyps, making their identification and removal a key component of cancer prevention, often precede the development of CRC [2]. While endoscopic mucosal resection (EMR) is widely used for small to medium-sized polyps, it is often inadequate for larger, complex, or fibrotic lesions, where achieving complete resection is challenging. In such cases, endoscopic submucosal dissection (ESD) has emerged as an advanced technique, allowing for en-bloc resection and improved histological assessment [3, 4].

Originally developed in Japan for the management of early gastric cancer, ESD has since become a widely accepted

standard in many Asian countries [5, 6]. However, its role in colorectal neoplasia remains less established in Western regions, where the long learning curve, higher technical demands, and increased complication rates have hindered its widespread adoption [7]. To address these challenges, the European Society of Gastrointestinal Endoscopy (ESGE) has issued guidelines on ESD training, procedural competency, and structured educational programs, aiming to standardize its use across different healthcare settings [8].

Compared to EMR, colorectal ESD offers higher en-bloc resection rates while being less invasive with lower perioperative risks compared to surgical resections [9, 10]. The ability to remove lesions larger than 20 mm in a single piece is particularly important when histology reveals early carcinoma, as long as certain low-risk criteria for lymph node metastasis are met [11]. Despite these benefits, ESD is technically complex and requires significant expertise, leading to longer procedure times and higher complication rates, such as perforation and delayed bleeding, compared to EMR [5]. In contrast, piece-meal EMR may increase the risk of residual neoplasia and recurrence, especially in cases of high-grade dysplasia or superficial submucosal invasion [3]. This led to the development of hybrid-ESD (H-ESD), a modified technique in which snare resection is performed after a mucosal incision and partial submucosal dissection, offering a potentially more accessible alternative to conventional ESD (C-ESD) [12].

This study aims to evaluate the effectiveness and safety of ESD in a secondary regional hospital in Switzerland, analyzing clinical data collected over the past five years. In addition to assessing patient outcomes, recurrence rates, and safety profiles, the study will compare C-ESD with H-ESD.

METHODS

Patient Cohort

This study was a single-center retrospective analysis on endoscopic resections of large colonic lesions, conducted at Bürgerspital Solothurn, a local community hospital in Switzerland. This study was conducted in accordance with the Declaration of Helsinki. All participants were provided with a written informed consent form, clearly stating that their participation in the study was voluntary and that they had the right to withdraw at any time without facing any consequences. A Consent Form for the Further Use of Health-Related Personal Data and Biological Samples was obtained for the study EKNZ 2024-02422. The study was approved by the Ethics Committee Northwest and Central Switzerland (EKNZ) under the reference number EKNZ 2024-02422.

All patients scheduled for ESD between April 1, 2018, and December 31, 2024 were included in the study (Fig. 1). Lesions were identified and characterized during a prior colonoscopy performed by an accredited referring endoscopist. The indications for ESD followed ESGE guidelines [13] and included large lesions (>=20 mm), suspicion of superficial submucosal invasion, non-lifting morphology, recurrent or residual lesions, or technically difficult locations. Lesions <10 mm or with pedunculated morphology (Paris 0–Ip) were only included if there was endoscopic suspicion of malignancy.

Patients having lesions with endoscopic features suggestive of deep submucosal invasion or malignancy were referred for surgical treatment in accordance with ESGE guidelines [13]. The study compares C-ESD with H-ESD, although H-ESD was used only as "rescue option" in cases requiring intra-procedural conversion due to technical difficulties such as prolonged procedural times, submucosal fibrosis, poor lifting, or unstable endoscope positioning.

Exclusion criteria included the presence of lesions other than adenoma or adenocarcinoma, such as subepithelial tumors and procedures, which started from the beginning in piece-meal EMR technique (Fig. 1). All patients received information on the indication, risks, and benefits of ESD and gave their written informed consent prior to the procedure. Patients underwent mechanical bowel preparation before the intervention [13].

ESD Procedure

Patients received propofol-sedation, administered by a dedicated endoscopy nurse and all procedures were performed using CO_2 insufflation. Lesions were lifted using submucosal injection solutions with either Physiogel® dyed with indigo carmine, BlueEye® (Standard-Co Ltd , Korea), or EndoClot® (EndoClot Plus LTD, China). Incision and dissection were carried out using colonic DualKnife (Olympus Medical, Tokyo, Japan), and different ESD techniques were used based on lesion location, size, and morphology, including circumferential incision and dissection and traction-assisted ESD [14]. From 2018 till 2022 we used exclusively Physiogel® dyed with indigo carmine. BlueEye was used starting 2023, while EndoClot became available in 2024. Technique choice was guided by lesion morphology and location and it was up to the discretion of the endoscopist.

All procedures were initially attempted as C-ESD (Fig. 1A), with H-ESD (Fig. 1B) applied when technical difficulty or submucosal fibrosis prevented continuation. When technical difficulties such as submucosal fibrosis and instability of endoscope position were encountered, the procedure was converted to a H-ESD, completing the resection with a snare and monopolar current [15, 16]. The resected specimens were collected, pinned, fixated in formalin, and sent for histopathological evaluation [17].

Operator Experience

All ESD procedures were performed by a single operator (R.T.), who had prior expertise in EMR. His training in ESD began in dedicated programs offered by Olympus Europe and included ex-vivo models and animal models prior to starting to perform procedures in patients. The technique in humans was completed by multiple observer ships at expert centers across Europe.

Follow-up

Patients who on histology of the resected specimen, had no indication for surgery based on the Swiss Society of Gastroenterology (SGG) post-polypectomy surveillance guidelines [18], were scheduled for endoscopic surveillance 3- to 6-month after the initial intervention. Subsequent follow-ups were based on endoscopic findings based on the

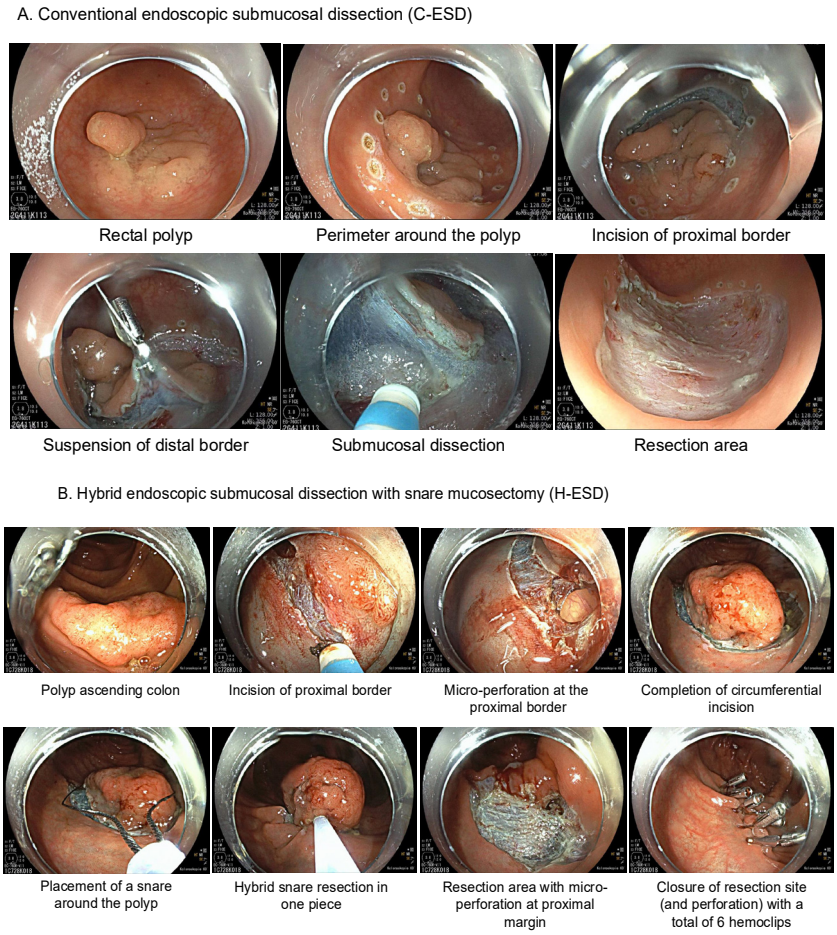

Fig. 1. Panel A: conventional ESD of a lesion in the rectum. Marking of a perimeter around the lesion followed by incision of the proximal border. Incision and suspension of the distal border with a counter-traction clip. Dissection of the entire polyp and removal in one piece. Panel B: hybrid ESD-EMR of a large polyp in the ascending colon. Circumferential incision, conversion to hybrid once a small intraprocedural muscle injury (Sydney classification type III) was noted. Additional lifting followed by en-bloc resection using a 25-mm snare and complete defect closure with six through the scope hemoclips..

above mentioned SGG guidelines. If an adenoma or tumor recurrence was detected during follow-up endoscopy, the lesion was resected endoscopically and sent for histological analysis. Recurrence was defined as histologically confirmed adenoma or carcinoma at the previous resection site. In cases where invasive neoplasia was suspected, targeted biopsies were taken. Patients who underwent curative resection of early adenocarcinoma were followed up with contrast-enhanced computed tomography scans and endoscopic surveillance [13, 18].

Parameters

For each patient, we extracted only non-identifiable personal data (i.e. age and gender). For each lesion we included its location (rectal, left colonic, transverse colonic, or right colonic), endoscopic appearance according to the Paris classification [19], Kudo pit pattern [20], and JNET classification [21]. Lesions categorized as laterally spreading tumors (LSTs) were subtyped as granular (LST-G), granular mixed-type, or non-granular (LST-NG), following ESGE guidelines [13]. Procedure-related data included the size of the resected specimen in millimeters, total procedural duration in minutes, and the type of resection performed, distinguishing between C-ESD and H-ESD.

We reviewed histopathological findings to assess the completeness of excision: a resection was classified as R0 if the lesion was removed en-bloc with histologically confirmed negative lateral and deep margins. In cases where resection margins were positive, the resection was categorized as R1, while specimens with unevaluable margins due to thermal artifacts or piecemeal removal were categorized as Rx. In cases with invasive neoplasia, additional parameters were documented, including tumor differentiation grade, depth of submucosal invasion, presence of lymphovascular invasion (yes/no), tumor budding, resection margin status, and whether surgical intervention was required following ESD [17].

Adverse Events

We categorized adverse events (AEs) as intraprocedural and delayed complications and classified according to severity using the Clavien–Dindo classification system. Intraprocedural bleeding was defined as persistent hemorrhage requiring

hemostasis with an instrument other than the ESD knife and/or thermal forceps (Coagrasper ®). Delayed bleeding was defined as the presence of melena or hematochezia, accompanied by a hemoglobin drop of ≥2 g/dL occurring more than 12h after endoscopic resection. Intraprocedural perforation was declared upon direct visualization of a muscularis propria defect, mesenteric fat or extraluminal structures and an attempt to close the defect was performed after the resection of the lesion resp. before the end of the intervention. Delayed perforation was defined as the presence of extramural air or peritoneal fluid accumulation more than 12 hours after endoscopic resection. For each AE, we noted if it was solved endoscopically, surgically or if the patient deceased.

Learning Curve

The first 30 cases were labeled as "early experience" and the rest (from the 31st onwards) as "established experience". We then compared the rate of ESD vs. hybrid ESD, rate of en-bloc / R0 vs piecemeal / non-R0 resections, procedural time and dissection speed in the "early" vs. "established" period.

Statistical Analysis

Results included medians with interquartile ranges for continuous variable and as percentages for categorical variables. We used either T-test or Mann-Whitney U tests to explore the significance of differences in continuous variables and either Chi-square test or Fisher's exact test to explore the significance of differences in categorical variables between the groups of C-ESD and H-ESD. A p-value < 0.05 was considered statistically significant. Due to the retrospective study design, no a priori sample size calculation was performed.

Nevertheless, we performed post-hoc analyses evaluating effect sizes and confidence intervals to address potential implications of underpowering. Sensitivity analyses were performed for loss-to-follow-up (best-case/worst-case assumptions) and for temporal changes across early (2018–2020) and late (2021–2024) periods to account for operator learning curve.

RESULTS

Between April 1, 2018, and December 31, 2024, 104 patients underwent endoscopic resection (C-ESD or H-ESD) for their large colorectal lesions. Ninety (90) patients were included in the final analysis, while cases involving subepithelial tumors or only piece-meal EMR were excluded. (Fig. 1) The number of procedures increased year by year as shown in Fig. 3.

The median age of included patients was 66 years, and 46.6% of the cohort were female. Fifty-one (56.7%) patients underwent C-ESD, while 39 (43.3%) patients underwent H-ESD. Baseline characteristics between the two groups were comparable, with no significant differences in polyp size, morphology, or location (Table I).

Lesion morphology was systematically classified using the Paris, Kudo, and JNET classification systems. According to the Paris classification, most lesions were type 0–IIa (n=56, 64%), followed by type 0–Is (n=23, 26%) and type 0–Ip (n=7, 8%). Mixed morphology (0–IIa + IIc) was observed in 3 lesions (3%), and 1 lesion (1%) was classified as type 0–IIc.

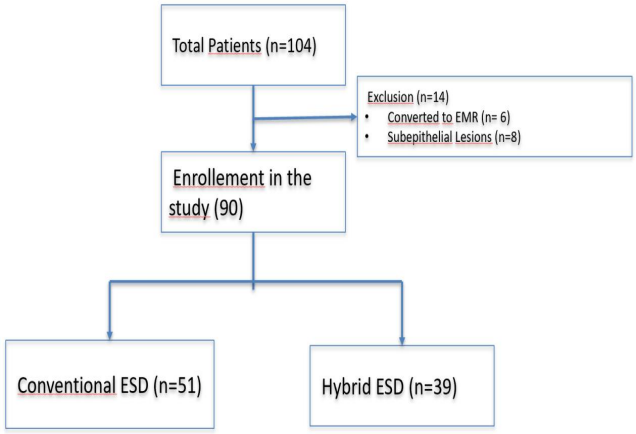

Fig. 2. Flow-chart of included and analyzed patients.

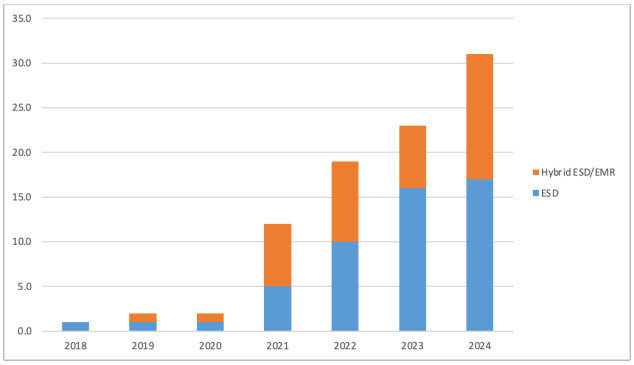

Fig. 3: Number of ESDs (conventional and hybrid) performed each year at our institution.

Regarding macroscopic subtype, LST were common: LST–NG flat elevated in 25 cases (27%), LST–G mixed type in 24 cases (26%), LST–G homogeneous in 9 cases (10%), and LST–NG pseudo-depressed in 2 cases (2%).

Pit pattern classification using the Kudo system was available for all lesions: type III-L was the most common (n=46, 51%), followed by type IV (n=18, 20%), type III-s (n=13, 14%), type II (n=10, 11%), and type Vi (n=3, 3%).

For vascular and surface pattern analysis under narrow-band imaging, JNET classification was performed in all cases. Most lesions were JNET type 2A (n=73, 80%), followed by type 1 (n=10, 11%), type 2B (n=6, 6.6%), and type 3 (n=1, 1%). In our cohort, 10/90 (11.1%) lesions were classified as JNET type 1, predominantly located in the right colon or transverse colon, with a median size of 19×15 mm (Surface area of approximately 288 mm^2). Although ESD was performed in these JNET type 1 lesions, this was limited to large, right-sided serrated polyps where en-bloc resection was attempted. Sensitivity analyses excluding these lesions confirmed that the main findings remained unchanged.

Procedural Outcomes

The median procedural time was 87 minutes (IQR 62-115 minutes). All C-ESD procedures were performed with a circumferential incision, and in five of them, traction-assisted techniques were used.

Table I. Clinical, endoscopic, histologic characteristics, and adverse events of conventional and hybrid ESD interventions

Parameters	All (n= 90)	Conv. ESD (n=51)	Hybrid ESD (n=39)	p
Age (mean)	66 (17-90)	53 (17-90)	67 (47-87)	1
Female Gender, n (%)	42 (47)	25 (49)	17 (43)	1
Admission at Hospital (n %)	55 (61)	33 (64)	22 (54)	0.6724
Endoscopy variable Procedure				
Procedural time- median, minutes (range)	87 (10-240)	87 (10-240)	88 (24-200)	0.842
Procedure speed, mean mm^2/min	6.2	7.5	5.4	0.04
Lesion location				
Right colon, n (%)	21 (23)	3 (5.8)	18 (46)	0
Transverse, n (%)	12 (14)	5 (10)	7 (18)	0.3509
Left colon, n (%)	14 (15)	11 (21)	3 (7)	0.0854
Rectum, n (%)	43 (48)	32 (62)	11 (28)	0.0014
Size-median, mm	28 (4-65)	28 (4-55)	27 (7-65)	0.1951
Paris classification n (%)				
Ip	7 (8)	5 (10)	2 (5)	0.456
Is	23 (26)	14 (27)	9 (23)	0.630
IIa	56 (64)	33 (65)	25 (64)	0.666
IIa+ IIc	3 (3)	1 (2)	2 (5)	0.582
IIc	1 (1)	0 (0)	1 (2.5)	0.443
Morphology n (%)				
Laterally spreading granular tumor (LST-G)	9 (10)	5 (10)	4 (10)	1
Laterally spreading granular tumor, mixed	24 (26)	12 (23)	12 (30)	0.4781
Laterally spreading nongranular tumor (LST-NG) flat elevated	25 (27)	12 (23)	13 (33)	0.3476
Laterally spreading nongranular tumor (LST-NG) pseudodepressed	2 (2)	1 (2)	1 (2.5)	1
JNET classification n (%)				
Type1	10 (11)	4 (8)	6 (15)	0.3197
Type 2a	73 (80)	43 (84)	30 (76)	0.4231
Type 2b	6 (6.6)	3 (6)	3 (7.6)	1
Type 3	1 (1)	1 (2)	0 (0)	1
Kudo classification, n (%)				
Type II	10 (11)	4 (8)	6 (15)	0.3197
Type III-s	13 (14)	6 (11)	7 (18)	0.5471
Type III-L	46 (51)	30 (58)	16 (41)	0.1361
Type IV	18 (20)	8 (15)	10 (25)	0.2925
Type V-i	3 (3)	3 (6)	0 (0)	0.2551
Grade of dysplasia n (%)				
Low-grade	60 (65)	33 (68)	26 (68)	1
High-grade	12 (13)	6 (12)	5 (13)	1
Cancer	4 (6)	3 (6)	1 (3)	0.3838
En-bloc resection	57 (63)	50 (98)	7 (18)	0
R0 resection	51 (56)	44 (86)	7 (18)	0
Adverse events, n (%)				
Complication rate	16 (17)	6 (11)	10 (25)	0.1025
Intraprocedural bleeding	4 (4)	2 (4)	2 (5)	1
Delayed bleeding	3 (3)	1 (2)	2 (5)	0.5767
Intraprocedural perforation	7 (7)	2 (4)	5 (12)	0.2321
Delayed perforation	2 (2)	1 (2)	1 (2.5)	1
Surgery	2 (2)	1 (2)	1 (2.5)	1
Death	0 (0)	0 (0)	0 (0)	1

ESD: endoscopic submucosal dissection; conv.: conventional.

En-bloc resection was achieved in 63% of lesions (C-ESD 98% vs. H-ESD 18%; p<0.001), and the overall R0 resection rate was 56% (C-ESD 86% vs H-ESD 18%; p<0.001). All piecemeal resections (mainly H-ESD) were classified as Rx resections as lateral or vertical margin involvement was assessed only for the en bloc specimens.

Submucosal invasion, piecemeal resection, and peri-interventional bleeding were identified as independent predictors of non-R0 resection. Histopathological characteristics are reported in Table I.

Approximately 60% of all lesions were had low-grade dysplasia (LGD) on histology but were initially selected for ESD based on endoscopic-morphologic criteria. Invasive colorectal cancers were identified in 4 (4.4%) patients. All these cases demonstrated SM1 invasion greater than 1000 μm in depth, without evidence of lymphovascular invasion. These cases were discussed at the interdisciplinary tumor board with three patients undergoing surgical resection and one patient opted for endoscopic surveillance.

Adverse Events

There were 3 cases of post-ESD bleeding, two of them occurring in the H-ESD group and one of them in C-ESD group and all were managed conservatively. There was a total of 7 cases of intraprocedural perforations (5 in the H-ESD group and 2 in the C-ESD group, p=0.2321). All periinterventional perforations were managed endoscopically at the time of the ESD without requiring additional interventions. These perforations were recognized during the procedure and managed endoscopically without conversion to surgery. According to the Clavien–Dindo classification, these perforations were grade II events, as they required pharmacological treatment (antibiotics) and close clinical monitoring but no surgical intervention. The average time to full resolution (clinical and radiological) was 2.3 days (range: 1–5). However, two patients required emergency surgical repair due to delayed perforations (Clavien–Dindo grade IIIb). Both surgeries were uneventful, and patients were discharged after 5 and 7 days, respectively.

Delayed post-ESD bleeding occurred in 3 patients (2 in the H-ESD group, 1 in the C-ESD group). All three cases were managed conservatively with fluid resuscitation and observation; no transfusions, endoscopic interventions or surgery were required and the bleedings resolved spontaneously within 24-48 hours in all cases. These were classified as Clavien–Dindo grade I events.

Follow-up and Recurrence

A total of 68 patients completed follow-up with a median surveillance period of 4 months. Recurrence was defined as histologically confirmed adenoma or carcinoma at the previous resection site. There was 31.1% loss to follow-up due to declined surveillance or missed data due to external referral. In a best-case scenario (all lost patients recurrence-free), the overall recurrence was 8.8%; in a worst-case scenario (all lost patients recurred), the rate reached 33.3%.

No cancer recurrences were observed following curative ESD resection of invasive adenocarcinoma. Adenoma recurrence occurred in 6 patients (8.8%), with all cases managed endoscopically. R1 resection status and intra-procedural AEs independently predicted recurrences (Table II).

Table II. Follow up after 3-6 months

Parameter, n (%)	All (n=68)	ESD (n=37)	Hybrid ESD (n=31)	p
Recurrence/Residual polyp	6 (8.8)	3 (8.1)	3 (9.7)	0.787
Grade of dysplasia				
Low-grade	6 (100)	3 (100)	3 (100)	1
High- grade	0 (0)	0 (0)	0 (0)	1
Endoscopic therapy	6 (100)	3 (100)	3 (100)	1
Surgery	0 (0)	0 (0)	0 (0)	1

For abbreviations see Table I.

Comparison H-ESD vs C-ESD

At first follow-up, recurrence rates were 8.1% (3/37) in C-ESD and 9.7% (3/31) in H-ESD (risk difference +1.7 percentage points, 95%CI: −12.6 to +17.9; risk ratio 1.19, 95%CI: 0.29–4.84). These wide confidence intervals preclude firm conclusions on equivalence or non-inferiority.

Further data are summarized in Table IV: The mean procedure time was similar in the two groups (87 min vs 86 min). The mean procedure speed was also not significant different between the two groups. (6.8 vs 4.8 mm^2/min). The en bloc and R0 resection rates were significant lower in the H-ESD group vs the C-ESD group (98%vs 18%, p<0.001, 86% vs 18% p<0.001). The overall rate of AEs was trended lower in the C-ESD group but not statistically significant. (p=0.1025). Adverse events were more frequent with H-ESD after adjustment (RD +0.25, 95% CI +0.03 to +0.45). Temporal analysis revealed improved en-bloc and R0 resection rates in the late period (91% vs. 78%) and lower AE rates (6% vs. 11%) compared to the early period, consistent with an operator learning curve.

There were 3 cases of post-ESD bleeding, two of them occurring in the H-ESD group and one of them in C-ESD Group that were managed conservatively. There was a total of 7 cases of intraprocedural perforations (5 in the H-ESD group and 2 in the C-ESD group, p=0.2321). All periinterventional perforations were managed endoscopically at the time of the ESD without requiring additional interventions.

There was a total of 2 cases of delayed perforation (1 in the H-ESD and 1 in the C-ESD groups, p=1). Both patients underwent surgical resection of the perforated segment. Of note is that in both cases, no residual polyp was noted in the histology of the surgical specimens (Table III).

Subgroup Analysis According to Location

Subgroup analyses were performed comparing outcomes in subgroups according to location (colon vs rectum) (Table IV). The en-bloc resection rate and the R0 resection rate are significantly higher in C-ESD compared to H-ESD in both rectal and colonic lesions. (p<0.001). There is no significant difference in procedure time and procedure speed between C-ESD and H-ESD in either the rectum or colon (p=1) (Table IV).

Table III. Clinical outcomes of conventional ESD vs hybrid ESD

Outcome	C-ESD (n=51)	H-ESD (n=39)	Risk Difference (95%CI)	Odds Ratio (95% CI)	p
En-bloc resection, n (%)	50 (98)	7 (18)	80 (67–89)	112.0 (21.4–586.6)	0
R0 resection, n (%)	44 (86)	7 (18)	68 (51–80)	27.1 (9.2–80.2)	0
Causes of incomplete resection					
Piecemeal resection, n (%)	0 (0)	30 (77)	-77 (-89 to -60)	0.01 (0.001–0.1)	<0.0001
Positive lateral margin, n (%)	6 (11)	1 (2.5)	8.5 (-2 to 20)	4.7 (0.5–41.7)	0.1338
Positive vertical margin, n (%)	1 (2)	1 (2.5)	-0.5 (-7 to 10)	0.8 (0.05–12.7)	1
Procedure time, mean, min	87	86	N/A	N/A	1
Procedure speed, mean mm^2/min	6.8	4.8	N/A	N/A	1
Adverse events					
Delayed bleeding, n (%)	1 (2)	2 (5)	-3 (-12 to 6)	0.4 (0.03–4.5)	0.5767
Perforation, n (%)	1 (2)	1 (2.5)	-0.5 (-9 to 10)	0.8 (0.05–12.7)	1

C-ESD: conventional endoscopic submucosal dissection; H-ESD: hybrid endoscopic submucosal dissection.

Table IV. Subgroup analysis of clinical outcomes according to location

	Rectum			Colon		
Outcome	C-ESD (n=32)	H-ESD (n=11)	p	C-ESD (n=19)	H-ESD (n=28)	p
En-bloc resection, n (%)	31 (97)	1 (9)	0	19 (100)	6 (21)	0
R0 resection, n (%)	29 (90)	1 (9)	0	15 (78)	6 (21)	0.0002
Procedure time, mean ± SEM, min	93.6 ± 8.8	121.2 ± 14.1	1	75.7 ± 7.2	76.2 ± 7.3	1
Procedure speed, mean ± SEM, mm^2/min	8.3 ± 0.8	6.9 ± 1.4	1	5.9 ± 0.9	4.3 ± 0.6	1

For abbreviations see Table III.

Learning Curve

It took us 4 years (from August 2018 till August 2022) to complete the first 30 procedures ("early experience"), whereas the other 60 procedures were completed slightly over 2 years (from September 2022 till December 2024). En-bloc and R0 resection rates in the rectum increased from 61% in the early phase to 84% in the established phase, the procedural time in the rectum decreased from 124 ± 10 min to 84 ± 10 min while intraprocedural AE (bleeding / microperforations) rates decreased from 23% to 7%. These findings (summarized in Table V) indicate a temporal trend consistent with an operator learning curve.

DISCUSSION

This retrospective study highlights the implementation and outcomes of colorectal ESD in a non-tertiary hospital setting. Our findings confirm the growing body of evidence indicating that ESD can be successfully implemented outside specialized high-volume centers, provided that structured training programs and appropriate procedural protocols are followed [22-25]. The observed outcomes suggest that favorable results, including a recurrence rate of approximately 8% for adenomas, can be achieved even in community hospitals [15]. The numbers of annual procedures reflect the challenges

Table V. Subgroup analysis of procedural details and complications according to "early" vs. "established" experience

	Rectum			Colon		
Outcome	"early" (n=18)	"established" (n=25)	p	"early" (n=12)	"established" (n=35)	p
En-bloc resection, n (%)	11 (61)	21 (84)	0.090	6 (50)	19 (54)	0.797
R0 resection, n (%)	11 (61)	19 (76)	0.294	6 (50)	15 (43)	0.797
Procedure time, mean ± SEM, (min)	123.7 ± 9.8	84.1 ± 9.9	0.009	82.7 ± 12.9	73.7 ± 5.5	0.229
Procedure speed, mean ± SEM (mm^2/min)	8.1 ± 1.3	7.9 ± 0.8	0.443	4.7 ± 1.2	5.4 ± 0.7	0.315
Complications, n (%)	6 (33)	3 (12)	0.09	3 (25)	4 (11)	0.254
Intraprocedural bleeding	2 (11)	1 (4)	ns	0 (0)	1 (3)	ns
Intraprocedural micro perforation	2 (11)	0 (0)	ns	3 (25)	2 (6)	ns
Delayed bleeding	1 (6)	2 (8)	ns	0 (0)	0 (0)	ns
Delayed perforation / surgery	1 (6)	0 (0)	ns	0 (0)	1 (3)	ns

of implementing these procedures in community hospitals requiring patience in the first years but a steady increase in the number of referrals and procedures in the subsequent years.

Our findings are consistent with recent large-scale European datasets [15] . The German Endoscopic Submucosal Dissection Registry analyzed over 1000 colorectal ESD procedures and reported en-bloc and R0 resection rates of 92.4 % and 78.8%, respectively [26]. Our C-ESD subgroup compares favorably to these benchmarks, underscoring the feasibility of achieving comparable outcomes even in lower-volume, non-tertiary centers.

Similarly, the multicenter cohort study by Winter et al. [27] reported that technical success, AEs, and recurrence rates in European centers remain heterogeneous, largely influenced by operator experience and institutional infrastructure. This underscores the importance of structured training and institutional commitment for safe implementation, a point that aligns with our single-operator experience.

The en-bloc resection rate (63%) and R0 resection rate (56%) in our study are comparable to those reported in Western centers [3, 15, 23]. However, they are slightly lower than the rates observed in high-volume Asian centers, where en-bloc resection rates often exceed 90% [6]. This discrepancy may be due to differences in procedural volume, endoscopist experience, and availability of advanced equipment. A key aspect to consider is that the lower en-bloc and R0 resection rates in our study resulted from the piecemeal resection technique used in H-ESD. When analyzing only C-ESD, we achieved en-bloc and R0 resection rates of 98% and 86%, respectively, aligning with high-volume tertiary centers [22]. These results suggest that C-ESD can be successfully performed in non-tertiary hospitals with proper technique and training.

Adenoma recurrence was observed in 8.8% of cases, which aligns with the 4.7% recurrence rate reported in large Asian studies [28] and remains significantly lower than the recurrence rates associated with EMR [29-31]. Our findings can be contextualized by comparison with recent large-scale EMR studies. Bourke et al. [29] reported long-term outcomes from a prospective series of over 1,600 large laterally spreading colorectal lesions treated with EMR, with a recurrence rate of approximately 16% after standard piecemeal EMR and around 4–6% when combined with adjunctive margin ablation using snare-tip soft coagulation (STSC). Surprisingly, in a recent multicenter prospective trial, von Renteln et al. [32] investigated EMR followed by hybrid argon plasma coagulation (h-APC) in 220 patients with ≥20 mm lesions. They demonstrated a recurrence rate of only 1.3%, and 0% when complete margin ablation was achieved. Adverse events in that study were rare, with delayed bleeding in 2.3% and perforation in 0.9% of cases.

While EMR combined with margin treatment may be sufficient for most benign nonfibrotic lesions, ESD remains the preferred modality for en-bloc resection, accurate histological assessment, and curative treatment of early CRC [33]. Certain morphologies, particularly LST-G mixed type and LST-NG, have been associated with a higher risk of covert submucosal invasion, supporting the rationale for en-bloc resection via ESD in selected cases [34].

A recent multicenter prospective study by Gauci et al. [35] investigated the prevalence of endoscopically curable low-risk cancer among ≥20 mm nonpedunculated right-sided polyps. They found a low prevalence (0.78%) of such low-risk cancers, questioning the routine use of ESD in these lesions. In our cohort, invasive cancer was diagnosed in 4.4% of patients all of them in the left colon and rectum, and curative endoscopic resection was achieved in selected cases. These findings support the careful use of ESD in selected patients, especially where lesion morphology and expert endoscopic assessment suggest a malignancy risk. Our results complement Gauci et al. [35] by illustrating that, even in non-tertiary settings, curative outcomes can be achieved with structured training and proper selection criteria.

Performing ESD in the colorectum is inherently challenging due to factors such as maintaining proper visualization, achieving adequate traction, and navigating the natural movement of the colonoscope. The H-ESD technique simplifies the procedure by combining submucosal dissection with snare resection. In our study, procedural times for H-ESD and C-ESD were similar, which can be attributed to the use of H-ESD as a rescue technique in difficult cases [16]. Furthermore, ESD in the rectum is often considered technically less demanding than in other segments of the colon, which may explain the comparable procedure times between H-ESD and C-ESD in this anatomical location [36, 37]. In our study all procedures were initially attempted as C-ESD, with H-ESD applied when technical difficulty or submucosal fibrosis prevented continuation. Our comparisons are descriptive and hypothesis-generating.

Hybrid ESD may be of particular value in proximal colonic lesions, where the technical complexity of C-ESD typically results in longer procedural times. In non-tertiary settings, H-ESD could serve as an intermediate step between EMR and C-ESD, allowing to perform resections safely in timely manner. However, prior studies have demonstrated lower en-bloc and R0 resection rates for H-ESD compared to C-ESD [12, 16]. Our study supports these findings, reinforcing the need for further research to identify specific lesions best suited for H-ESD without compromising oncologic outcomes.

Although JNET type 1 lesions are usually considered candidates for EMR, in our study ESD was selectively performed for large, right-sided serrated lesions with challenging morphology, where en-bloc resection was targeted to avoid piecemeal EMR. This selective approach is clinically justified in cases where lesion size and morphology would otherwise compromise complete resection. Importantly, in a sensitivity analysis excluding JNET type 1 lesions, all key differences between conventional and hybrid ESD (en-bloc and R0 resection rates) persisted. We therefore emphasize that outside such contexts EMR remains the standard approach, and ESD should only be considered for carefully selected serrated lesions.

Consistent with previous meta-analyses [10], our results confirm that C-ESD offers superior en-bloc and R0 resection rates compared to hybrid approaches. However, the role of H-ESD remains relevant for certain lesion types, particularly those with fibrotic submucosal layers where standard dissection techniques are more challenging. Additionally, H-ESD may be preferable in elderly or frail patients with a higher surgical risk, where reducing procedural time may be prioritized

overachieving a technically complete ESD [12]. It should also be noted that H-ESD is mostly a rescue technique that is applied if difficulties are encountered during ESD, and most data report poorer technical outcomes [12, 16]. The higher rate of AEs with H-ESD likely reflects its use as a rescue technique in technically difficult cases. In contrast, recurrence rates remained statistically inconclusive after adjustment, underlining the limited power of our dataset for this endpoint. Thus, more comparative data are needed to understand the role of H-ESD in selected cases.

Our study also emphasizes the impact of intraprocedural AEs, such as bleeding, on recurrence risk. Prior studies have highlighted that intraprocedural bleeding can impair submucosal visualization, making complete resection more difficult and increasing recurrence risk [15]. We observed a similar trend in our cohort, suggesting that endoscopists should be aware of this factor and implement strategies to minimize its effects.

Concerns about ESD safety, particularly perforation risk, remain a key barrier to widespread adoption [3]. In our study, the perforation rate ranged from 2% (delayed perforations) to 7% (intraprocedural microperforations), aligning with previously published data. Importantly, all intraprocedural microperforations were successfully managed endoscopically, with no procedure-related mortality, underscoring the feasibility of ESD in non-tertiary centers with proper training, adherence to protocols, and most importantly, proper case selection [24].

The successful implementation of ESD outside tertiary care centers highlights the necessity of structured training programs. Hands-on experience, simulation-based training, and mentorship from experienced endoscopists are critical for improving procedural competency. ESGE guidelines emphasize the importance of structured ESD training, focusing on lesion selection, submucosal injection techniques, and effective complication management [8]. Expanding ESD training beyond high-volume centers may improve accessibility to minimally invasive curative treatment options for patients in underserved regions. In order to ensure the safe and effective implementation of colorectal ESD in non-tertiary centers, adequate operator training and institutional infrastructure are essential. The ESD operator in our study underwent structured self-directed training on ex vivo animal models and attended hands-on workshops and observerships in high-volume ESD centers across Europe. This foundational experience was crucial in building procedural competence and minimizing complications during the initial human cases. Furthermore, institutional support, including access to high-definition endoscopy equipment, appropriate electrosurgical units, carbon dioxide insufflation, and trained anesthesia and nursing teams, is indispensable for patient safety. A multidisciplinary approach involving gastroenterologists, surgeons, pathologists, and anesthesiologists facilitates optimal case selection and management of potential AEs. Temporal analyses further demonstrated improvements in technical outcomes and safety over time, reflecting the operator learning curve. These findings underscore the importance of structured training and gradual implementation. Importantly, our approach aligns with a growing number of Western non-tutored ESD series, which have demonstrated that safe and effective implementation is feasible outside of formal long-term fellowships, provided that structured self-directed training and careful case selection are applied [24].

We believe that with appropriate training pathways and institutional readiness, ESD can be safely introduced and performed even in non-tertiary hospital settings.

Our findings demonstrate a clear and clinically meaningful learning effect in colorectal ESD within a community-based European hospital. After the first 30 procedures, both efficiency and safety improved substantially, reflected by a significant reduction in procedure time and a notable decrease in complication rates. These trends are highly consistent with data from European and Western centers that implemented ESD in predominantly self-taught environments. Recent studies from Nilsen et al. [38] and Steinbruck et al. [39] highlight that Western endoscopists typically require 30–40 colorectal ESD cases to reach procedural stability. Improvements in efficiency, particularly reduced procedure time, precede gains in histologic outcomes, which depend heavily on lesion morphology, fibrosis, and case selection. Our results parallel these observations: although en-bloc and R0 rates improved numerically, the most pronounced performance changes occurred in AEs and procedure time.

This study has several limitations. The retrospective design introduces the possibility of selection bias, and the single-center setting may limit the generalizability of our findings. Additionally, some patients were lost to follow-up, potentially leading to underestimation of recurrence rates. All procedures were conducted under the same senior endoscopist and operator learning curve and protocol changes should be acknowledged as a limitation of the study. As noted, H-ESD was used in technically challenging cases. We now emphasize that the comparison between groups is exploratory. The recurrence analysis was clearly underpowered. At first follow-up, the observed risk difference of +1.7% between C-ESD and H-ESD was accompanied by wide 95% confidence intervals (−12.6 to +17.9), excluding neither clinically meaningful benefit nor harm. With 31% of patients lost to follow-up, recurrence estimates varied between 8.8% and 33.3% depending on assumptions. Therefore, recurrence findings should be interpreted as exploratory rather than conclusive. The absence of ASA scores and comorbidity indices is acknowledged also as a limitation restricting comparability with other ESD series. Despite these limitations, our study provides valuable evidence supporting the feasibility of ESD in non-tertiary settings.

Future research should focus on prospective multicenter studies to validate our findings and further explore the role of H-ESD in specific lesion types. Additionally, strategies for mitigating the impact of intraprocedural AEs, such as novel traction devices and advanced hemostatic techniques, should be investigated. Finally, cost-effectiveness studies comparing ESD to surgery and EMR in community hospitals may provide further insights into the optimal management of complex colorectal lesions.

CONCLUSIONS

Our study suggests that colorectal ESD can be feasibly and safely implemented in a non-tertiary hospital setting, achieving

acceptable clinical outcomes when performed under structured training and adherence to standardized protocols. While C-ESD offers superior en-bloc and R0 resection rates, H-ESD may serve as a pragmatic rescue technique in selected non-malignant lesions, with acceptable recurrence rates despite lower en-bloc resection. However, our results stem from a single-operator, retrospective series with a relatively small sample size and short-term follow-up, which limits generalizability. Further prospective studies in larger and more diverse cohorts are warranted. Nevertheless, with appropriate case selection, ESD represents a viable minimally invasive alternative to surgery for complex colorectal lesions in selected non-tertiary settings.

Conflicts of interest: None to declare.

Authors' contributions: R.T. conceived and designed the study. T.B. and R.T. collected data, drafted the manuscript text and prepared the figures. G.R critically revised the manuscript for important intellectual content. All authors read and approved the final version of the manuscript.

REFERENCES

1. Ferlay J, Autier P, Boniol M, et al. Cancer incidence and mortality in Europe in 2006. Ann Oncol. 2007;18:581–592. doi:10.1093/annonc/mdl498
2. Zauber AG, Winawer SJ, O'Brien MJ, et al. Colonoscopic polypectomy and long term prevention of colorectal cancer deaths. N Engl J Med. 2012;366(7):687–696. doi:10.1056/NEJMoa1100370
3. Jacques J, Schaefer M, Wallenhorst T, et al. Endoscopic en bloc versus piecemeal resection of large nonpedunculated colonic adenomas: a randomized comparative trial. Ann Intern Med. 2024;177(1):29–38. doi:10.7326/M23-1812
4. Tutticci N, Bourke MJ. Advanced endoscopic resection in the colon: innovations and limitations. Expert Rev Gastroenterol Hepatol. 2014;8(2):161–177. doi:10.1586/17474124.2014.866894
5. Fujiya M, Tanaka K, Dokoshi T, et al. Efficacy and adverse events of EMR vs ESD for colon neoplasms: a meta-analysis. Gastrointest Endosc. 2015;81(3):583–595. doi:10.1016/j.gie.2014.07.034
6. Saito Y, Uraoka T, Yamaguchi Y, et al. Prospective multicenter study of 1111 colorectal ESDs. Gastrointest Endosc. 2010;72(7):1217–1225. doi:10.1016/j.gie.2010.08.004
7. Hassan C, Repici A, Sharma P, et al. Efficacy and safety of endoscopic resection of large colorectal polyps: meta-analysis. Gut. 2016;65(5):806–814. doi:10.1136/gutjnl-2014-308481
8. Pimentel-Nunes P, Libânio D, Bastiaansen BAJ, et al. ESGE Guideline update 2022: colorectal ESD. Endoscopy. 2022;54(6):591–622. doi:10.1055/a-1754-3479
9. de Neree Tot Babberich MPM, Bronzwaer MES, Andriessen JO, et al. Outcomes of surgical resections for benign colon polyps: a systematic review. Endoscopy. 2019;51(10):961–972. doi:10.1055/a-0965-3943
10. Fuccio L, Hassan C, Ponchon T, et al. Clinical outcomes after endoscopic submucosal dissection for colorectal neoplasia: systematic review and meta-analysis. Gastrointest Endosc. 2017;86(1):74–86.e17. doi:10.1016/j.gie.2016.12.036
11. Kikuchi R, Takano M, Takagi K, et al. Management of early invasive colorectal cancer: risk and guidelines. Dis Colon Rectum. 1995;38(12):1286–1295. doi:10.1007/BF02048322
12. McCarty TR, Bazarbashi AN, Thompson CC, et al. Hybrid vs conventional ESD: systematic review. Endoscopy. 2020. doi:10.1055/a-1266-1855
13. Ferlitsch M, Hassan C, Bisschops R, et al. Colorectal polypectomy and EMR: ESGE Guideline Update 2024. Endoscopy. 2024;56(7):516–545. doi:10.1055/a-2304-3219
14. Bordillon P, Pioche M, Wallenhorst T, et al. Double clip traction for colonic ESD: multicenter study of 599 cases. Gastrointest Endosc. 2021;94(4):698–708. doi:10.1016/j.gie.2021.01.036
15. Maselli R, Spadaccini M, Belletrutti R, et al. Endoscopic submucosal dissection for colorectal neoplasia: outcomes and predictors of recurrence. Endosc Int Open. 2022;10:E127–E134. doi:10.1055/a-1551-3058
16. Yang D, Hasan MK, Jawaid S, et al. Hybrid versus conventional colorectal ESD: multicenter randomized controlled trial. Am J Gastroenterol. 2024;119(12):2436–2443. doi:10.14309/ajg.0000000000002897
17. Taşkın OC, Aslan F, Kulaç I, et al. Pathologic evaluation of large colorectal ESDs: 279 cases. Int J Surg Pathol. 2020;28(6):600–608. doi:10.1177/1066896919894333
18. Truninger K, Lugli A, Koeberle D. Nachsorge nach koloskopischer Polypektomie und entferntem Kolorektalkarzinom: Revidierte Konsensus Empfehlungen. Swiss Med Forum. 2022;22(21–22):349–355.
19. The Paris endoscopic classification of superficial neoplastic lesions. Gastrointest Endosc. 2003;58(6 Suppl):S3–S43. doi:10.1016/S0016-5107(03)02159-X
20. Kudo S, Tamura S, Nakajima T, et al. Diagnosis of colorectal lesions by magnifying endoscopy. Gastrointest Endosc. 1996;44(6):814–821. doi:10.1016/S0016-5107(96)70061-6
21. Okamoto Y, Oka S, Tanaka S, et al. Effect of educational lecture on the diagnostic accuracy of Japan NBI Expert Team classification for colorectal lesions. BMC Gastroenterol. 2021;21:110. doi:10.1186/s12876-021-01676-x
22. Draganov PV, Aihara H, Karasik MS, et al. Endoscopic submucosal dissection in North America: a large prospective multicenter study. Gastroenterology. 2021. doi:10.1053/j.gastro.2021.02.036
23. Gupta N, Rodríguez Ruiz G, Siddiqui UD, et al. ESD for colorectal lesions: U.S. experience. Surg Endosc. 2021. doi:10.1007/s00464-020-08262-4
24. Ramos Zabala F, Parra Blanco A, et al. Unsupervised colorectal endoscopic submucosal hydrodissection: feasibility and learning curve. Eur J Gastroenterol Hepatol. 2020;32(7):804–812. doi:10.1097/MEG.0000000000001761
25. Rönnow CF, Uedo N, Toth E, et al. ESD of 301 large colorectal neoplasias: specialized center Europe. Endosc Int Open. 2018;6(10):E1340–E1348. doi:10.1055/a-0655-8034
26. Fleischmann C, Probst A, Ebigbo A, et al. ESD in Europe: results of 1000 lesions from the German ESD registry. Gastroenterology. 2021;161(4):1168–1178. doi:10.1053/j.gastro.2021.06.063
27. Winter K, Kasprzyk P, Nowicka Z, et al. Resection of early colorectal neoplasms using ESD: retrospective multicenter cohort. J Clin Med. 2024;13(22):6989. doi:10.3390/jcm13226989
28. Yamada M, Saito Y, Takamaru H, et al. Long-term clinical outcomes of colorectal ESD in 423 cases: retrospective study. Endoscopy. 2017;49(3):233–242. doi:10.1055/s-0042-122140
29. Bourke MJ, Sidhu M, Swan MP, et al. EMR for large sessile colonic polyps: outcomes and predictors of recurrence. Cancers (Basel). 2023;15(15):3805. doi:10.3390/cancers15153805
30. Moss A, Bourke MJ, Williams SJ, et al. EMR outcomes and submucosal cancer prediction. Gastroenterology. 2011;140(6):1909–1918. doi:10.1053/j.gastro.2011.02.062

31. Moss A, Williams SJ, Hourigan LF, et al. Long-term adenoma recurrence after wide-field EMR: Australian ACE study. Gut. 2015;64(1):57–65. doi:10.1136/gutjnl-2013-305973
32. von Renteln D, Schmidt A, Familiari P, et al. Hybrid argon plasma coagulation reduces recurrence after EMR of large colorectal polyps: prospective multicenter trial. Endoscopy. 2024;56(4):341–348. doi:10.1055/a-2101-1234
33. Cong ZJ, Hu LH, Ji JT, et al. Long-term prognosis after colorectal ESD for laterally spreading tumors. Gastrointest Endosc. 2016;83(4):800–807. doi:10.1016/j.gie.2015.08.054
34. D'Amico F, Amato A, Iannone A, et al. Risk of covert submucosal cancer in patients with granular mixed laterally spreading tumors. Clin Gastroenterol Hepatol. 2021;19(7):1395–1401. doi:10.1016/j.cgh.2020.05.056
35. Gauci J, Whitfield A, Medas R, et al. Prevalence of endoscopically curable low-risk cancer among large (≥20 mm) nonpedunculated polyps in the right colon. Clin Gastroenterol Hepatol. 2023;23(4):555–563. doi:10.1016/j.cgh.2024.07.017
36. Rahmi G, Hotayt B, Chaussade S, et al. Endoscopic submucosal dissection for superficial rectal tumors: prospective multicenter French study. Endoscopy. 2014;46(7):670–676. doi:10.1055/s-0034-1365810
37. Repici A, Hassan C, Pagano N, et al. High efficacy of ESD for rectal LST >3 cm. Gastrointest Endosc. 2013;77(1):96–101. doi:10.1016/j.gie.2012.08.036
38. Nilsen JA, Juul FE, Egeland A, et al. Colorectal ESD in a Nordic community hospital: learning curves and clinical outcomes. Scand J Gastroenterol. 2025;60(11):1043–1052. doi: 10.1080/00365521.2025.2553279
39. Steinbrück I, Faiss S, Dumoulin FL, et al. Learning curve of ESD in unsupervised Western settings: a retrospective multicenter analysis. Surg Endosc. 2023;37(4):2574–2586. doi:10.1007/s00464-022-09742-5