A Steep Early Learning Curve for Endoscopic Submucosal Dissection in the Live Porcine Model

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Keywords

Endoscopic submucosal dissection · Gastrointestinal endoscopy · Learning curve · Animal models · Simulation · Training

Abstract

Background: Endoscopic submucosal dissection (ESD) is a demanding procedure requiring high level of expertise. ESD training programs incorporate procedures with live animal models. This study aimed to assess the early learning curve for performing ESD on live porcine models by endoscopists without any or with limited previous ESD experience. **Methods:** In a live porcine model ESD workshop, number of resections, completeness of the resections, en bloc resections, adverse events, tutor intervention, type of knife, ESD time and size of resected specimens were recorded. ESD speed was calculated. **Results:** A total of 70 procedures were carried out by 17 trainees. The percentage of complete resections, en bloc resections and ESD speed increased from the first to the latest procedures (88.2%–100%, 76.5%–100%, 8.6–31.4

mm²/min, respectively). The number of procedures in which a trainee needed tutor intervention and the number of adverse events also decreased throughout the procedures (4 to 0 and 6 to 0, respectively). During the workshop, when participants changed to a different type of knife, ESD speed slightly decreased (18.5 mm²/min to 17.0 mm²/min) and adverse events increased again (0–2). **Conclusions:** Through successive procedures, complete resections, en bloc resections, and ESD speed improve whereas adverse events decrease, supporting the role of the live porcine model in the preclinical learning phase. Changing ESD knives has a momentarily negative impact on the learning curve.

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Introduction

Endoscopic submucosal dissection (ESD) is a demanding technique that enables high en bloc resection rates, R0 resections and low rate of local recurrences regardless of lesion size as well as an accurate tumor histopathological

staging and grading with precise evaluation of resection margins [1–8]. On the other hand, it is associated with long procedure times and considerable risk of adverse events (such as bleeding and perforation) [9–11]. In addition, ESD has a difficult and prolonged learning curve [5, 9, 12, 13]. ESD training programs include acquiring basic knowledge, practicing on animal models (both *ex vivo* and *in vivo* models), visiting centers with a high ESD volume, attendance of hands-on training ESD workshops and only then proceeding to clinical practice, ideally under supervision of an expert during the first cases [14–18].

This is particularly relevant in Western settings where the number of ESD experts is limited and the possibility of starting ESD in superficial gastric neoplasms, which are the easiest and safest procedures, is limited due to the low prevalence of such lesions [5, 9, 12, 13]. Workshops using animal models are organized in training centers with the potential to improve the learning process and achieve initial competence in ESD [19–22]. This study aimed to assess the early learning curve for performing ESD on live porcine models by endoscopists without any or with limited previous ESD experience.

Methods

Study Design

This prospective study was conducted during a workshop for ESD training, co-organized by the European Association for Gastroenterology, Endoscopy and Nutrition (EAGEN) and the European Society of Gastrointestinal Endoscopy (ESGE). It included theoretical lectures and hands-on practice with live porcine models. The workshop had duration of 2 days and took place in the training center of the Erasmus School of Endoscopy at the Erasmus University Medical Center in Rotterdam, the Netherlands.

Animal Model

The use of the live porcine model for training purposes in the workshop was approved by local Ethical Committee for the welfare of animals in medical training. It was conducted under the National Experiments on Animals Act, revised in 2014 to implement the European Directive 2010/63 protecting animals used in research. Animal welfare and regulatory compliance were overseen by local Animal Welfare Body and government inspectors on behalf of the authorities (project license NL license # AVD1010020173286).

Procedures were conducted in accordance with the “Animal Research: Reporting of *in vivo* Experiments” (ARRIVE) Guidelines [23]. Live pigs (*Sus scrofa domestica*), weighing between 30 and 40 kg were used. Animals were given a liquid diet for 3 days and fasted for 8 h before the procedures. According to local protocol, with the support of the veterinarian staff throughout the course, general anesthesia with endotracheal intubation and mechanical ventilation was performed. Drugs were employed in the following sequence: premedication – ketamine 25–35 mg/kg IM and midazolam 1 mg/kg IM; induction – propofol 0.5–1 mg/kg IV; main-

tenance – isoflurane 1.5–2.5% ET PO, sufentanil 0.3–0.5 µg/kg IV, NaCl 0.9% 10 g/kg IV or gelofusine, propofol, and sufentanil as required. Animals were euthanized with pentobarbital overdose.

Participants

Trainees attending the workshop for ESD training were evaluated. Demographic data and previous endoscopic experience were collected. Identity protection and confidentiality of the collected data were guaranteed. Only the ones who wished to do so responded willingly and all had the possibility of not doing it if they wished. Accordingly, participant’s acceptance/consent was implicit, and written informed consent was not necessary.

Procedures

Standard Pentax® (Tokyo, Japan) flexible endoscopes and ERBE® (Tübingen, Germany) VIO 200s and VIO3 electrosurgical units were used. A soft, straight distal attachment cap from Olympus® (Tokyo, Japan) was mounted on the tip of the endoscope.

Direct assistance was assured by one of the participants, who acted according to the instructions of the endoscopist performing the procedure. International experts supervised this assistance and all the steps of the procedure, giving verbal instructions and intervening when deemed necessary (Fig. 1). All of them were highly experienced in clinical ESD (more than 10 years of continuous clinical practice) and in supervising ESD training courses (more than 5 years of continuous tutor practice).

Gastric ESD was conducted using ERBE® HybridKnives® (Tübingen, Germany) coupled with a high-pressure injection system, ERBERJET 2® (Tübingen, Germany) which allows for cutting, coagulation and submucosal injection with the same knife. The injection solution was physiological saline with a few drops of indigo carmine.

During the first procedures, the HybridKnife® I-type (which is a noninsulated needle-type knife) was used and during following procedures the HybridKnife® O-type (which is a partially insulated tip knife). Trainees were instructed to choose a place in the gastric mucosa, mark the outer margins of a pseudo-lesion with the tip of the knife, perform submucosal injection, and create a circumferential incision, followed by submucosal dissection and re-lifting the pseudo-lesion when needed. Bleedings were treated using submucosal injection, by coagulation with the knife, by using a bipolar hemostatic forceps, HemoStat-Y®, Pentax® (Tokyo, Japan) or by clip application, Instinct clip®, Cook Medical® (Winston-Salem, NC, USA). Resected specimens were retrieved at the end of each procedure, carefully stretched to *in vivo* size, and measured by an independent observer (RKM). Procedures were performed over the 2 days of the workshop.

Assessment

Parameters related to gastric ESD performance like number of resections, completeness of the resection (ability to completely resect the lesion), en bloc resection (ability to completely resect the lesion en bloc with all markings visible on the specimen), adverse events (intraprocedural bleeding and perforation), tutor intervention, procedure time (from the first submucosal injection after marking to the complete removal of the pseudo lesion), and size of resected specimens were recorded for each procedure. Only significant continued bleeding that did not subside spontaneously or with coagulation from the tip of the ESD knife and required the use of an hemostatic forceps or endoclip was considered an intraprocedural bleeding. Tu-

Fig. 1. Live porcine model endoscopy workstation.

Table 1. Background characteristics and endoscopic experience of participants

Age (years), median (IQR); mean (SE)	40 (36–47); 42 (6.5)
Gastroenterologists, <i>n</i> (%)	15 (88)
Academic or tertiary hospital, <i>n</i> (%)	9 (53)
Fully trained physicians, <i>n</i> (%)	15 (88)
Previous endoscopic experience	
Years performing endoscopy, median (IQR); mean (SE)	10 (6–15); 11.2 (4.8)
Colonoscopies: ≥ 201 /year; ≥ 601 total, <i>n</i> (%)	13 (76); 14 (82)
Upper endoscopies: ≥ 201 /year; ≥ 601 total, <i>n</i> (%)	14 (82); 14 (82)
ERCP: ≥ 1 /year; ≥ 101 total, <i>n</i> (%)	7 (41); 9 (53)
EUS: ≥ 1 /year; ≥ 201 total, <i>n</i> (%)	7 (41); 6 (35)
Esophageal EMR: ≥ 1 /year; ≥ 21 total, <i>n</i> (%)	12 (71); 8 (47)
Gastric EMR: ≥ 1 /year; ≥ 21 total, <i>n</i> (%)	14 (82); 10 (59)
Colonic EMR: ≥ 1 /year; ≥ 21 total, <i>n</i> (%)	14 (82); 13 (76)
Colonic EMR: ≥ 21 /year; ≥ 51 total, <i>n</i> (%)	11 (65); 12 (71)
EMR: inject and snare technique, <i>n</i> (%)	15 (88)
EMR: band and snare technique, <i>n</i> (%)	12 (71)
EMR: cap and snare technique, <i>n</i> (%)	12 (71)
ESD: ≥ 1 /year; ≥ 1 ESD total, <i>n</i> (%)	4 (24); 5 (29)

EMR, endoscopic mucosal resection; ERCP, endoscopic retrograde cholangiopancreatography; EUS, endoscopic ultrasonography; SE, standard error.

tor intervention was defined as a short hands-on assistance in procedures in which the tutor deemed it necessary, after which the endoscope was handed back to the trainee. Verbal guidance was allowed at any time during the workshop and was not recorded.

The type of knife used was documented. The surface area of the resected specimen was calculated using a pre-specified formula: surface area (mm^2) = largest diameter of specimen (mm) $\times$ smallest diameter of specimen (mm) $\times 0.25 \times \pi$. ESD speed was calculated accordingly: speed (mm^2/min) = surface area (mm^2) of resected specimen/time of procedure (min).

Statistical Analysis

The IBM Statistical Package for Social Sciences (SPSS Version 25.0.0; SPSS Inc, Chicago, IL, USA) was used for data analysis. Descriptive statistics were determined for all measures according to type of variables. Proportions were reported for dichotomous and ordinal variables. For continuous variables, the medians (with in-

terquartile range [IQR] 25–75) or means (with standard error) were described. Nonparametric tests were used to assess statistical differences (Wilcoxon signed-rank test). Proportions were compared with the χ^2 test. Significance level was defined as $p < 0.05$.

Results

From the 17 participants, background characteristics and endoscopic experience were obtained for 15 and are summarized in Table 1. Their median age was 40 years (IQR, 36–47). A total of 70 procedures (P) were performed by 17 trainees (Table 2). Each trainee performed a median of 4 procedures (IQR, 3.5–5.0).

Table 2. ESD procedures

	P1	p value (P1 vs. P2)	P2	p value (P2 vs. P3)	P3	p value (P3 vs. P4)	P4	p value (P4 vs. P5)	P5	p value (P5 vs. P6)	P6
N	17		17		16		13		6		1
Complete resection, n/N (%)	15/17 (88.2)	1.000	15/17 (88.2)	0.163	16/16 (100)	N/A	13/13 (100)	N/A	6/6 (100)	N/A	1/1 (100)
En bloc resection, n/N (%)	13/17 (76.5)	0.378 [†]	15/17 (88.2)	0.163 [†]	16/16 (100)	N/A	13/13 (100)	N/A	6/6 (100)	N/A	1/1 (100)
Tutor intervention, n	4	0.378 [†]	2	0.163 [†]	0	0.267	1	0.497	0	N/A	0
Type of knife-n	I-17		I-15		I-13		I-5		I-6		I-1
			O-2		O-3		O-8		No		No
Change of knife (n)	No		Yes (2)		Yes (3)		Yes (8)		No		No
Time, min, median (IQR)	39.0 (29.0–47.5)	0.704 [†]	34.0 (18.5–49.5)	0.010 [†]	21.0 (13.5–23.0)	0.969	20.0 (14.5–24.0)	0.598	17.0 (13.5–25.5)	N/A	9.0
Area /surface, mm ² , median (IQR)	263.9 (188.5–408.4)	0.094	392.7 (281.0–494.8)	0.650	312.2 (192.2–404.5)	0.675	296.9 (213.2–395.0)	0.116	412.3 (266.3–645.4)	N/A	282.7
Speed, mm ² /min, median (IQR)	8.6 (4.5–13.4)	0.006	14.8 (7.5–19.0)	0.100	18.5 (8.5–23.7)	0.152	17.0 (13.0–17.8)	0.028	24.7 (17.6–33.1)	N/A	31.4
Bleeding, n	3	0.297	1	0.331	0	N/A	0	N/A	0	N/A	0
Perforation, n	3	0.638	2	0.163	0	0.1099	2	0.3226	0	N/A	0

I, I-type, noninsulated tip, ERBE HybridKnife; O, O-type, partially insulated tip, ERBE HybridKnife; P, Procedure; N/A, not applicable. [†]No statistically difference was observed between P1 and P2, but it was noted when P1 was compared to P3 (P1 vs. P3, $p < 0.05$).

The percentage of complete resections was 88.2% in the first 2 procedures and 100% in the following ones. En bloc resections improved from 76.5% and 88.2% in the first 2 procedures respectively, to 100% during the subsequent procedures (P1 vs. P3, $p < 0.042$). The number of procedures in which a trainee needed hands-on intervention from the tutor also decreased throughout the procedures (4 in P1, 2 in P2 to 0 in P5 and P6; P1 vs. P3, $p < 0.042$). Median ESD speed increased from the first to the latest procedures: 8.6 mm²/min in P1 to 14.8 mm²/min in P2 (P1 vs. P2, $p = 0.006$), 24.7 mm²/min in P5 (P4 vs. P5, $p = 0.028$) and 31.4 mm²/min in P6. In contrast, ESD time decreased: 39 min in P1 to 34 min in P2, 21 min in P3 (P1 vs. P3, $p = 0.002$; P2 vs. P3, $p = 0.01$) and 9 min in P6. No significant variation in specimen's area occurred comparing successive procedures.

The first procedures were all performed with the non-insulated tip HybridKnife I-type. After 1 to 3 procedures, all trainees switched to the HybridKnife O-type.

Adverse events decreased throughout procedures (3 bleedings and 3 perforations in the P1 to 0 in P5 and P6). In total, there were 7 perforations (10%) and 4 bleedings (5.7%), managed with endoclips and hemostatic forceps. Perforations in P1 and P2 occurred with type I while perforations in P4 occurred with the O type. When a great number of participants ($n = 8$) changed to a different type of knife (P4), ESD speed slightly temporarily decreased (18.5 mm²/min on P3 to 17.0 mm²/min on P4) and the number of perforations increased again (0 on P3 to 2 on P4) (Fig. 2).

Discussion

In this study, we have demonstrated that through successive procedures within a hands-on training program, en bloc resection rates and ESD speed increase whereas adverse events decrease. Changing to a different ESD knife has a momentarily negative impact on the learning curve.

ESD training programs include hands-on practicing in live animal models [14–17]. Face, expert, and content validity of the live porcine model in training for endoscopic mucosal resection and ESD have been established in a previous study. This model is considered very realistic and procedures accurately resemble human cases. Moreover, the simulation process is highly appreciated as a learning tool [19]. Current virtual reality and mechanical simulators are not suitable for training advanced endoscopic resection due to the inability to sufficiently repro-

Fig. 2. En bloc resections and ESD speed.
^a *p* values refer to ESD speed comparisons; error bars on ESD speed represent IQR (25–75).

duce tissue properties like elasticity and tactile feedback resembling human tissue [24].

In general, the skill-lab setting with animal models provide the opportunity to train team coordination between the endoscopist and assistant, to gain familiarity with the devices and electrosurgical units, to adequate handle and position the scope and to rehearse the kind of movements typical and crucial to ESD, improving tip control [20, 25].

Some authors support the idea that ex vivo training is not sufficient to simulate clinical practice and that in vivo training is essential [26, 27]. Live animal models can achieve those characteristics and add breathing movements, heartbeats, peristalsis, intraluminal secretions and tissue reaction to injection, and electrocautery, which makes them closely related to the human setting. In addition, dealing with intraprocedural complications, such as bleedings and perforations can be trained as close as it gets to the human situation [15, 19, 25, 27, 28]. On the downside, availability of and the need to sacrifice animals, dedicated facilities, equipment, veterinarian support, and costs represent the disadvantage of the model [15, 25, 27–29]. For these reasons, ex vivo models are probably adequate in the initial learning phase and animal models should be reserved only for the subsequent stage of pre-clinical training.

A previous study demonstrated that the mean resection time was significantly diminished for porcine gastric ESDs in the second half of the cases, although all proce-

dures were carried out by a single endoscopist and both ex vivo and in vivo models were used [25]. In an ex vivo model, performing 30 gastric ESDs led to decreased procedure times, a lower perforation rate and improvement in en bloc resection rate [30]. In ex vivo stomach pig models, to achieve a predefined level of competence, trainees needed 23–25 procedures in one study [31]. In a bovine ex vivo model, an ESD goal was achieved by 71% of trainees in a software learning group (84% at the 30th procedure) and 61% in the control group (50% at the 30th procedure) [32]. In a bovine ex vivo model, complete resections were achieved in 92%, with 89% en bloc. Perforations occurred in 6% and the mean procedure time was 33 min with an average dissection speed of 5.2 mm²/min [33]. A study on ex vivo porcine colonic model, with an overall en bloc resection of 94.4% and perforation of 14.4%, demonstrated an inflexion of the learning curve at the 9th ESD procedure [34]. A summary of the studies is presented in Table 3.

In our study, we highlight that we addressed ESD speed (which increased throughout the procedures), instead of time or surface area alone. We find that the increment in speed better reflects the acquisition of skills or learning curve of the trainee. The use of only a single parameter-like procedure time or surface area is a poor measure for improved performance because these measures are highly related to each other. It will take more time to resect a larger lesion and vice versa. Another important observation is that the rate of adverse events did

Table 3. Studies on training in ESD

Study [ref.]	Type of model	Organ	ESDs, n	Complete resection, n (%)	En bloc resection, n (%)	Time, min, mean (SD) or median (IQR)	Area/surface, mm ² , mean (SD) or median (IQR)	Speed, mm ² /min, mean (SD) or median (IQR)	Bleeding, n/N (%)	Perforation, n/N (%)	Key findings
Parra-Blanco et al. [25]	In and ex vivo, porcine	Stomach and esophagus	30	28 (93.3)	27 (90)	81.3 (46.6); for gastric cases: 98.9 (62.4) 1st 13 ESDs; 61.7 (17.6) latest 8 ESDs	Mean size 45.2 mm (17.8)	NA	5/22 in vivo (22.7)	1/22 in vivo (4.5)	For gastric ESD, mean time was significantly longer in the first half of the study than in the second half
Kato et al. [30]	Ex vivo, porcine	Stomach	120 (beginners)	120 (100)	53/60 (88.3) 1st 30 ESDs to 60/60 (100) 2nd 30 ESDs	32.8 (NA) 1st 30 ESDs; 15.2 min (NA) 2nd 30 ESDs	868 1st 30 ESDs; 859 2nd 30 ESDs	26.4 1st 30 ESDs; 56.7 2nd 30 ESDs	NA	8/120 (6.7) total; 8 in 1st 30 ESDs; 0 2nd 30 ESDs	After 30 ESD cases, procedure time decreased, en bloc resection of 100% and no perforation were achieved
Bhatt et al. [31]	Ex vivo, porcine	Stomach	55	NA	38 (69.1) total 5/20 (25) 1st 20 ESDs; 18/20 (90) 2nd 20 ESDs; 15/15 (100) latest 15 ESDs	39.0 (30.0–58.0); 60.0 (51.0–65.0) 1st 20 ESDs; 36.5 (31.5–45.0) 2nd 20 ESDs; 28.0 (19.0–33.0) latest 15 ESDs	NA	NA	NA	8/55 (14.5) total 3/20 (15.0) 1st 20 ESDs; 5/20 (25) 2nd 20 ESDs; 0/15 latest 15 ESDs	Endoscopist 1 reached competency at 23 procedures; endoscopist 2 reached competency at 25 procedures Competency was defined as consistent en bloc resection of a 30 mm area within 30 min without perforation
Ploche et al. [32]	Ex vivo, bovine	Colon	1,170	797 (68.1) total; NA 414/544 (76.1) software group; 383/569 (67.3) control group; only for procedures <75 min	NA	34.1 (13.4) software group; 32.3 (14.0) control group	NA	52 (29) software group; 64 (36) control group	NA	51/1,113 (4.6) total; 22/544 (4) software group; 29/569 (5.1) control group; only for procedures <75 min	Success was achieved in 70.9% in the software group and 61.2% in the control group For the 30th procedure, the rate of complete resection was superior in the software group (84.2%) compared with the control group (50.0%) Software group used self-learning software. Control group observed an ESD procedure video Successful ESD: complete en bloc resection without any perforation performed in less than 75 min

Table 3 (continued)

Study [ref.]	Type of model	Organ	ESDs, n	Complete resection, n (%)	En bloc resection, n (%)	Time, min, mean (SD) or median (IQR)	Area/surface, mm ² , mean (SD) or median (IQR)	Speed, mm ² /min, mean (SD) or median (IQR)	Bleeding, n/N (%)	Perforation, n/N (%)	Key findings
Pioche et al. [33]	Ex vivo, bovine	Colon	64	59 (92.2)	57 (89.1)	33.3 (15.6)	1,500 (370)	52 (20)	NA	4/64 (6.2)	Adult bovine colon model is more homogeneous than a calf: with calf colons, failure rates were higher and speed was lower. Time procedure decreased throughout the study. A learning curve appeared at the speed of 49 and 59 mm ² /min.
Gromski et al. [34]	Ex vivo, porcine	Colon	90	NA	85 (94.4)	49.6 (29.6)	NA	NA	NA	13 (14.4)	Significant improvement after 9th ESD. Suggestion of at least 9 ex vivo procedures prior to live animal or proctored colonic ESD training.
Teoh et al. [36]	In vivo, porcine	Stomach, esophagus	32 total; 23 gastric; 9 esophageal	NA	NA	52.09 (24.67) gastric ESD; 32.50 (8.45) esophageal ESD	Mean size 266 mm (118)	NA	13/32 (40.6)	20/32 (62.5) total; 15 gastric (65.2); 5 esophageal (55.6)	High rate of complications: in gastric ESD, 65.2% and 56.5% of participants had perforations and bleedings, respectively. There was a higher proportion of perforations with noninsulated knives.
Kasapidis et al. [21]	In vivo, porcine	Gastric	76	NA	72 (94.7)	48 (4.4) 1st day; 43 (4.8) 2nd day	NA	138 (20) 1st day; 163 (23) 2nd day	9/76 (11.8) total; 5 1st day; 4 2nd day	4/76 (5.3) total; 2 1st day; 2 2nd day	ESD time and cutting speed differed significantly between the 1st and 2nd day. Similar adverse events between the 1st and 2nd day.
Chapelle et al. [22]	In vivo, porcine	Gastric	58	58 (100)	58 (100)	46 (NA) in ESD2; 78 (NA) in ESD4	488 (NA) in ESD2; 2,634 (NA) in ESD4	9.7 (4.8–15.7) in ESD1; 30.4 (14.3–37.0) in ESD4	2/58 (3.4)	3/58 (5.2)	Increase in ESD speed marked between the first 2 ESDs compared with the 4th and 5th. Improved endoscopist capability from the 3rd ESD.
NA, not available; SD, standard deviation.											

not increase when trainees started performing faster ESDs. The number of adverse events decreased as performance and speed improved during the learning phase.

ESD speed in live models varies between studies from means of 5–10 mm²/min [35] in the first procedures to 22–30 mm²/min [21, 22] in the later ones. This is in line with our results that varied from median 8.6 mm²/min in the first procedure to 24.7 mm²/min and 31.4 mm²/min in the last ones.

We observed a momentarily decrease in ESD speed and a slight increase in perforation number when trainees switched to a different knife with different properties. Complete and en bloc resection rates were unaffected. ESD performance improved up to that point and introducing a new type of knife immediately had a negative impact on ESD performance. This finding supports the idea that each individual has to get used to a particular type of knife and changing it leads to an adaptive phase. This phenomenon was observed despite the fact that we switched to a potentially “safer” knife because of its partial insulation at the tip. Therefore, we collected supporting evidence for one key informal advice that ESD experts often provide, which is to maintain experience with the same knife and not change frequently the type of knife used.

There were 7 perforations which correspond to 10% of the procedures. This denotes the difficulty of the technique and is in line with other published studies: 5.2–62.5% [21, 22, 36] in live animal models and 4.6–14.5% in ex vivo models [30–34].

The fact that a plateau phase was not reached in this study is in all likelihood related to the limited number of ESD procedures performed by each endoscopist and supports the need and rationale for further training in the animal model. A minimum of 10–30 ESD procedures in the animal model is suggested, before moving to human cases [14, 30, 37]. This study supports this conclusion and the importance of using live porcine models to train endoscopists in ESD.

Concerning the strengths of this study, we highlighted its prospective design, the objective nature of the parameters that were assessed by an independent observer and the diverse origin and background of the trainees. This supports the generalization of the results. It is also important to emphasize that ESD performance improved dramatically in a 2 days course and that each knife is operated differently.

With regard of limitations, we stress that trainees can have different background characteristics and distinct skills and learning curves. We underline the limited num-

ber of procedures, the fact that locations on the pig stomach were not assessed and that the porcine colon was not included. Tutors varied from different groups, although presenting similar characteristics. Also, procedures were performed on healthy tissue with no pathological findings, as opposed to clinical practice, where neoplastic changes might affect submucosal tissue and thereby hampering submucosal dissection. Nevertheless, this is a known limitation of training in porcine model, but still experts agree that it represents the closest resemblance possible to the human setting, as was previously demonstrated [19].

In conclusion, training in live animal models improves ESD performance measures supporting its role in teaching programs. Distinct ESD knives are operated differently.

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Statement of Ethics

The workshop was approved by the local Ethics Committee of Erasmus MC, University Medical Center, Rotterdam, The Netherlands, for the welfare of animals in medical training (Ref. No. AVD1010020173286). It was conducted under the National Experiments on Animals Act, revised in 2014 to implement the European Directive 2010/63 protecting animals used in research. Procedures were conducted in accordance with the “Animal Research: Reporting of in vivo Experiments” (ARRIVE) Guidelines. Only the endoscopists who wished to participate did it willingly and all had the possibility of not doing it if they wished. Invitees were informed that data would be analyzed and participation was voluntary. Identity protection and confidentiality of the collected data were guaranteed according to General Data Protection Regulation. Accordingly and in agreement with the Ethics Committee, completing the questionnaire implied the participant’s implicit acceptance/consent. Therefore, the requirement for written informed consent was waived.

Conflict of Interest Statement

Ricardo Küttner-Magalhães, Ricardo Marcos-Pinto, and Carla Rolanda have no conflicts of interest or financial ties to disclose. Mário Dinis-Ribeiro reports research grants from Olympus and Fujifilm. Marco J. Bruno reports consultant support for industry and investigator-initiated studies from Boston Scientific and Cook Medical, consultant support for investigator-initiated studies from Pentax Medical, Mylan, ChiRoStim, and 3M. Arjun D. Koch reports speaker fees from Cook Medical, ERBE, Pentax and Boston Scientific.

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Author Contributions

All authors have contributed and agreed on the content of the manuscript. Ricardo Küttner-Magalhães contributed to the study conception, study design, data acquisition, data analysis, data interpretation, manuscript writing, and critical revision. Mário Di-

nis-Ribeiro contributed to the study conception, study design, study supervision, data analysis, data interpretation, and critical revision of the manuscript. Marco J. Bruno contributed to the study conception, study design, and critical revision of the manuscript. Ricardo Marcos-Pinto contributed to data interpretation and critical revision of the manuscript. Carla Rolanda contributed to the study conception and design, data interpretation, and critical revision of the manuscript. Arjun D. Kock contributed to the study conception and design, study supervision, data analysis, data interpretation, and critical revision of the manuscript. All authors read and approved the final version of the manuscript.

Data Availability Statement

All data generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

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