

Novel method for hybrid endo-laparoscopic full-thickness gastric resection using laparoscopic transgastric suture passer device

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Abstract

Background Current surgical methods for partial gastric full-thickness resections (FTRs) are limited by long operative times and risk of gastric content spillage, especially for lesions located at the posterior wall. We propose a simplified hybrid approach to FTR with reduced risk of spillage.

Methods Resection margins were marked by endoscopic electrocautery to simulate a gastric lesion in the upper third of the posterior wall in eight pigs. A custom-made laparoscopic “suture passer” was made of a sharpened bendable dissecting forceps. Full-thickness sutures were alternatively passed from the serosa side with the suture passer through the gastric wall and grabbed endoluminally using an endoscopic grasper and vice versa. These

transgastric sutures formed either a purse string (PS; $n = 4$) or a continuous horizontal mattress (HM; $n = 4$). Sutures were then fastened from the laparoscopic side, resulting in external outpouching of the lesion. The pouch was transected using 45-mm linear staplers. Operative time, resection margins, and number of staplers were evaluated.

Results The combined approach allowed one to precisely place the sutures around the pseudo lesions, despite the inflated stomach, and it included all target markings. PS and HM methods were similar regarding time for transgastric suture ($780 \text{ s} \pm 219.1 \text{ s}$ vs. $765 \text{ s} \pm 179.2 \text{ s}$, $p = .885$), resection margins ($1.3 \pm 1.0 \text{ cm}$ vs. $0.8 \pm 0.6 \text{ cm}$, $p = .248$), and number of staplers (3.8 ± 1.0 vs 3.3 ± 0.5 , $p = .405$). Stapling time ($600 \text{ s} \pm 189.7 \text{ s}$ vs. $330 \text{ s} \pm 24.5 \text{ s}$, $p = .028$) was significantly shorter in the HM technique.

Conclusion FTR with laparo-endoscopic transgastric suture application was feasible in the animal model. This technique allows one to achieve accurate resection margins with minimal risk of spillage.

This work will be presented at the upcoming EAES meeting, 4–6 June, Bucharest.

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Keywords Full-thickness resection · Hybrid laparo-endoscopic surgery · Gastric cancer

Driven by epidemiology factors, mass screening programs have substantially increased the detection of early gastric cancers (EGCs) in Eastern countries [1, 2]. This encouraging progress has stimulated the development of minimally invasive treatment strategies of EGC, with the aim to minimize the extent of resection and preserve remaining gastric function. Endoscopic submucosal dissection (ESD) techniques have replaced radical surgeries for EGC with no risk of lymph node metastasis. The possibility to expand

the ESD approach is limited by a significant chance of lymph node involvement, reaching up to 20 % in case of gastric cancer with submucosal invasion, and the inability to evaluate node metastasis status using an endoscopic approach [3, 4]. Endoscopic full-thickness resection (EFTR) complemented with sentinel lymph node biopsy using natural orifice transluminal endoscopic surgery (NOTES) technique is an appealing minimally invasive solution. However, this concept still remains investigational with several technical problems which remain to be solved [5, 6]. On the other hand, several hybrid approaches, using endoscopy and laparoscopic devices simultaneously, have been recently proven as feasible and effective options [7, 8]. An ideal full-thickness local resection technique should fulfill the following requirements: (1) It should achieve accurate resection margins in order to secure negative margins and to minimize the size of the specimen to preserve as much of the remaining stomach as possible; (2) it should prevent cancer cell contamination in the abdominal cavity; (3) it should allow for the perfect alignment of the suture line perpendicularly to the long axis of the stomach to prevent stenosis after resection and repair.

A procedure fulfilling all of these requirements is particularly demanding when the tumor is located in difficult locations, such as the posterior wall of the upper body of the stomach or adjacent to the gastroesophageal junction. We hypothesized that a transgastric full-thickness continuous suture around the tumor, which is performed with hybrid surgery using both laparoscopy and endoscopy, might allow for an easier resection of a gastric tumor located at the posterior wall of the stomach with accurate resection margins as well as an easier repair of the defect. The purpose of this study was to assess a novel hybrid full-thickness resection technique in the large animal model, using a custom-made prototype of laparoscopic transgastric suture passer.

Materials and methods

Animals

A total of eight swine (*Sus scrofa domesticus*, ssp large white, 30–40 kg) were used in this non-survival study. In accordance with the ethical principle of reduction, pigs were included in the present experimental study at the end of a different experimental protocol (No. 38.2014.01.064), which received full approval by the local Ethical Committee on Animal Experimentation (ICOMETH) and by the French Ministry of Superior Education and Research (MESR, reference No. 04297.01). All animals were managed according to the directives of the European

Community Council (2010/63/EU). Pigs were fasted for 24 h before surgery with free access to water. Premedication by intramuscular injection of ketamine (20 mg/Kg) and azaperone (2 mg/Kg) (Stresnil; Janssen Cilag, Belgium) was administered 10 min before surgery. Induction was achieved by intravenous propofol (3 mg/Kg) combined with rocuronium (0.8 mg/Kg). Anesthesia was maintained with 2 % isoflurane. At the end of the procedure, animals were humanely killed with an intravenous injection of a lethal dose of potassium chloride.

Instruments

The laparoscopic transgastric suture passer prototype was manufactured by grinding the tip of laparoscopic bendable instrument (Roticulator™ Endo Dissect™; Covidien, Mansfield, USA). The length of the opening jaw was 17 mm, and the diameter remains less than 2 mm for about two-thirds of the tip and thicken to 4.3 mm at the end of the jaw (Fig. 1A, B). A 30° laparoscopic system (Karl Storz, Tuttlingen, Germany) and a single-channel upper gastrointestinal endoscopy system (Karl Storz, Tuttlingen, Germany) were used, and one monitor for each visual system was shared by both endoscopist and laparoscopic surgeons. An endoscopic needle knife or a triangle tip electro-surgical knife (Olympus, Tokyo, Japan) was used for marking the target lesion by means of coagulation, and an endoscopic alligator jaw grasper (Olympus, Tokyo, Japan) was used for the endoscopic part of this hybrid laparo-endoscopic procedure.

Procedures

A 3- to 5-cm-diameter round-shaped target lesion was marked by means of endoscopic coagulation. Coagulated dots represented resection margins. In one case, an injectable phantom tumor model made up of alginate, gelatin, and calcium was implanted endoscopically before marking the periphery of the phantom tumor (video clip 1). Once the pneumoperitoneum was established using four 12-mm-sized laparoscopic ports, a partial omentectomy was performed to expose the posterior side of the stomach. Since the posterior side of the porcine stomach is easily flipped upward when inflated with endoscopy, two stay sutures were placed at the greater curvature side of the target lesion and pulled to simulate the status of human stomach. These sutures were used to achieve tension to ease punctures of the gastric wall using the suture passer device (Fig. 2).

In four pigs, a purse-string suture was placed adjacent to resection markings. The suture passer device was introduced into the peritoneal cavity with a 2/0 monofilament suture grasped at the tip and bent into the desirable angle depending on the puncture site. The suture passer

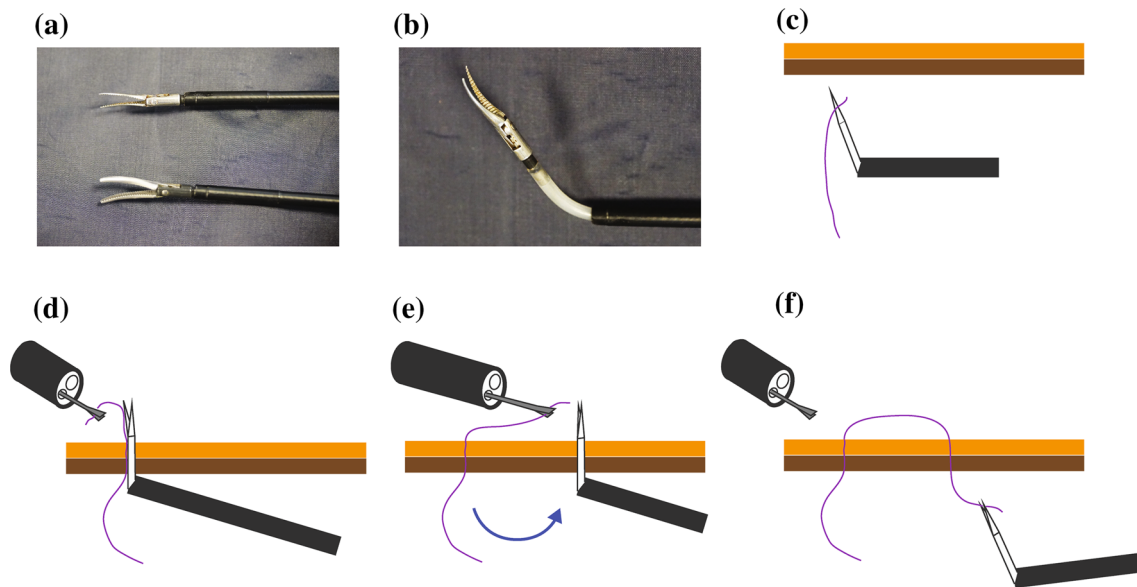


Fig. 1 **A** Laparoscopic bendable dissecting forceps (*lower side*) was switched to a suture passer device (*upper side*), **B** the angle of bending is adjustable **C–F** collaborative transgastric suturing by laparoscopy and endoscopy

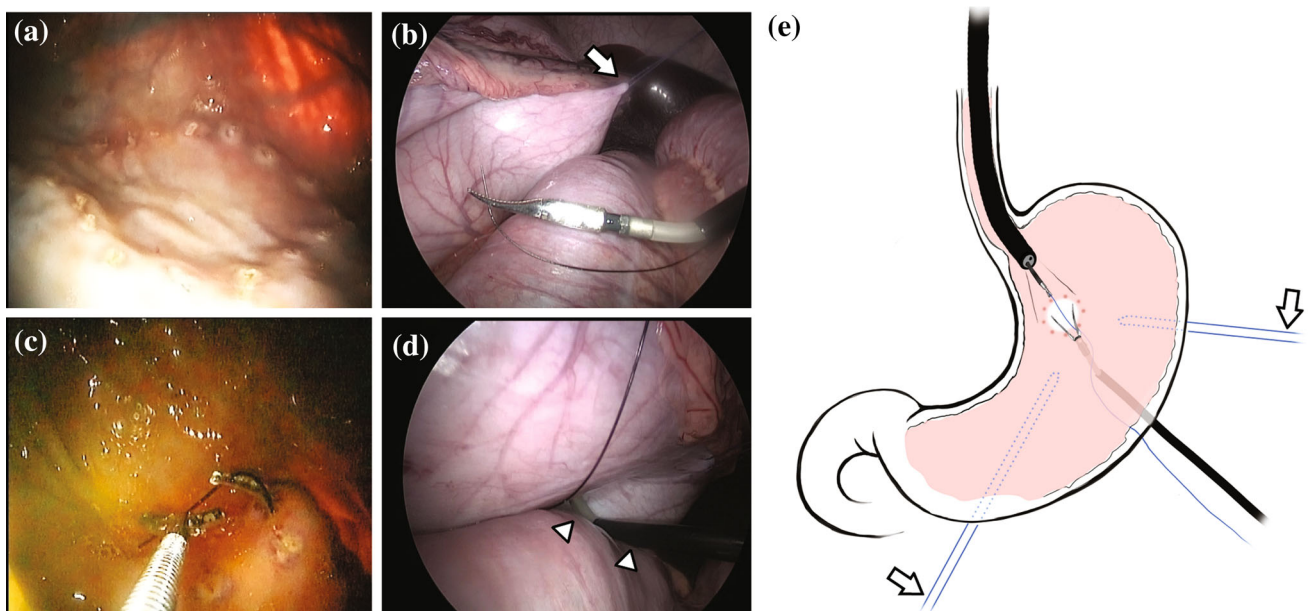


Fig. 2 **A** Marking of the resection margin. **B** Two stay sutures were placed proximally and distally to the lesion in the greater curvature area (*arrow*). The suture passer device was introduced in the abdominal cavity with a monofilament suture and was bent. **C** Endoscopic view showing cooperative movements between the suture passer device and the endoscopic grasper. **D** The transgastric

suture was possible under endoscopic guidance, even when the serosal side was not fully visible due to the inflation of the lumen. **E** Conceptual drawing of the procedure. Two sutures placed in the serosal side (*arrow*) to immobilize the stomach and maintain tension. *Arrow's head* suture passer device

penetrated the gastric wall externally to resection markings and transferred the suture to the endoscopic alligator jaw grasper (Fig. 1C–F). The empty suture passer was moved outside of the gastric lumen and penetrated the gastric wall in the next target, and received the suture from the endoscopic grasper and was retracted toward the outside of the

stomach. The procedure was started from the greater curvature side of the lesion. It was repeated until the purse-string suture surrounded the target lesion completely (Fig. 3). The stomach was then deflated, and stay sutures were removed. The stomach was rotated upward, and the two ends of the suture were pulled. An Endo-GIA® linear

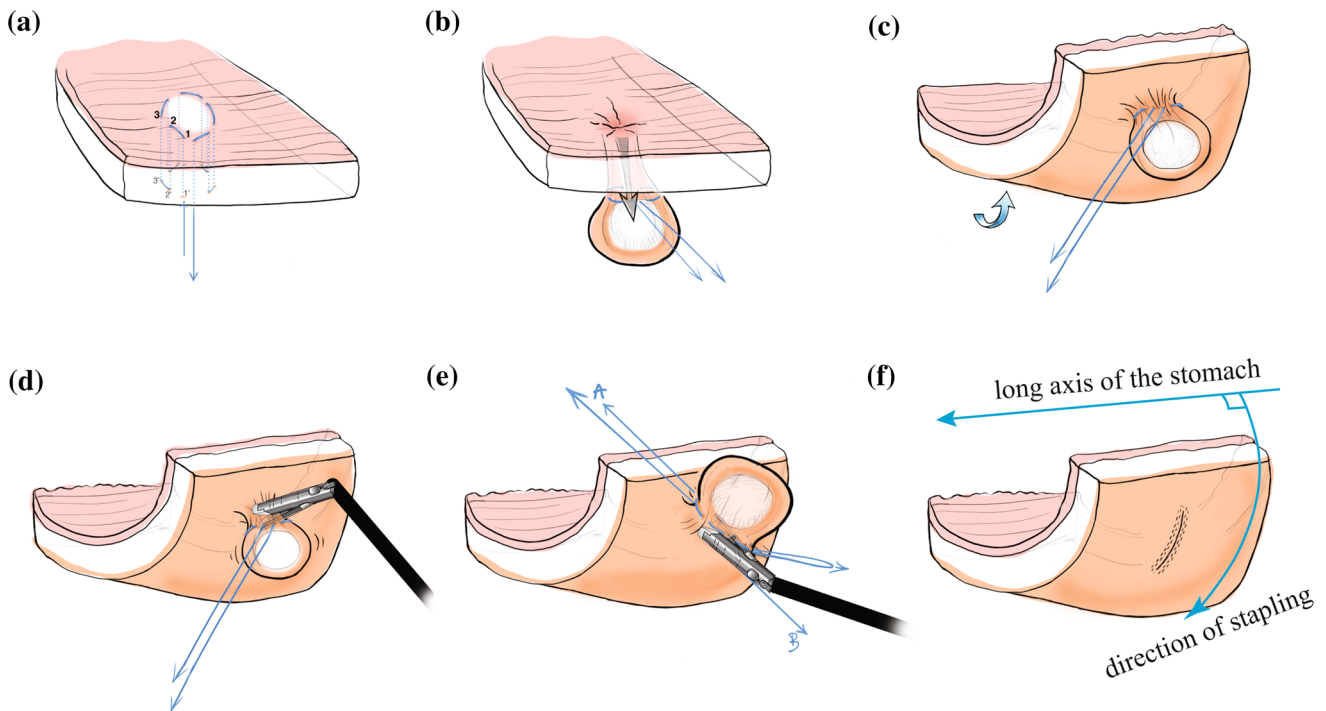


Fig. 3 Purse-string suture method. **A** After a purse-string suture has encompassed the lesion, **B** fastening of the suture results in the outpouching of the lesion. **C** The posterior wall of the stomach is rotated anteriorly to expose the pouch, and **D** the stapler is applied

below the purse-string suture. **E** Alternatively, the suture could be retracted bidirectionally. **F** The suture can guide the orientation of the stapler and make it perpendicular to the long axis of the stomach

stapler (Covidien, Boulder, Colorado) loaded with 45-mm cartridges was introduced just below the purse-string suture. Resection of the tumor was performed in order for the staple line to run parallel to the small gastric vessels in the lesser and greater curvature of the stomach, which is perpendicular to the long axis of the stomach. The resected specimen was removed through one of the port sites, after the skin incision was enlarged, and was opened for measurement of the target lesion and resection lines. The stomach was re-inflated, and the staple line was assessed for completeness and orientation using endoscopy and laparoscopy (see video clip 1).

In the four other pigs, the transgastric suture was performed in a continuous horizontal mattress configuration starting from the side of the greater curvature toward the side of the lesser curvature. In this configuration, the staple line was orientated perpendicularly to the long axis of the stomach (Fig. 4). Sutures were passed in order to cross over the lesion inside of the gastric lumen and in such a way that, once completed, the fastening of the suture could make the lesion outpouching. Once the suture was made, each end of the suture was held by the operator and the assistant, and the Endo-GIA[®] linear stapler was used below the suture line. Remaining steps were identical to those described for the purse-string suture procedures (Fig. 5; see video clip 2).

In the last pig, we created a situation that would mimic a clinical case where additional resection due to gastric cancer involves in a small portion of the distal margin. The imaginary margin for additional resection was marked around the previous staple line using endoscopic coagulation of 2×2 cm, and the lesion was re-excised by means of a horizontal mattress type of suture and using our stapling method to evaluate the feasibility of repeated resections.

Two methods were compared in terms of operative time, average distance between target resection margins and resection lines calculated from measurements in eight directions, and the number of staplers used.

A Mann–Whitney *U* test was performed using PASW statistics 18 (IBM Corporation, Sommers, NY, USA) for statistical analysis.

Results

Despite the relatively large diameter of the prototype suture passer, penetration of the gastric wall was easy when the stomach was sufficiently inflated and stay sutures were pulled for tension purposes. Even when the tip of the suture passer device could not be correctly visualized using the laparoscopic view, the endoscopic guidance of the location of the tip allowed for an accurate puncture (Fig. 2D). No

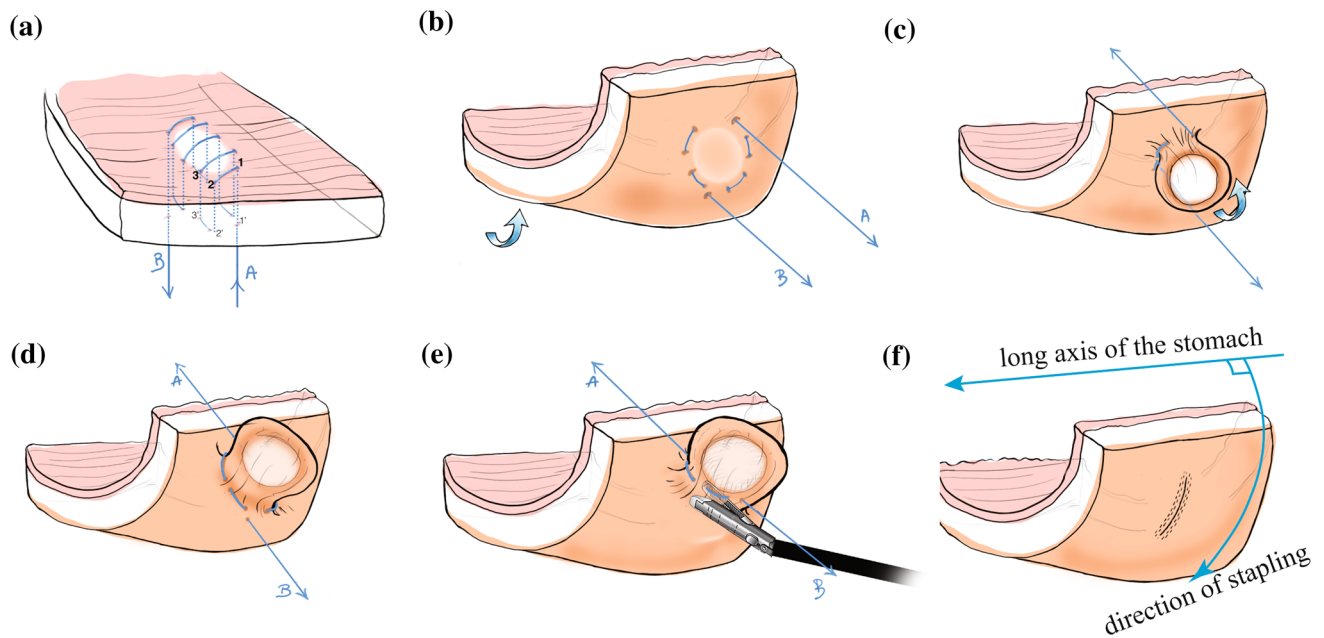


Fig. 4 Horizontal mattress suture method. **A** The suture is placed according to the direction of the staple line. **B–D** Fastening of the suture and anterior rotation of the posterior wall of the stomach

contributes to preparing the stapling. **E, F** Application of the stapler below the suture aims to resect the lesion, leaving a staple line, which is perpendicular to the long axis of the stomach

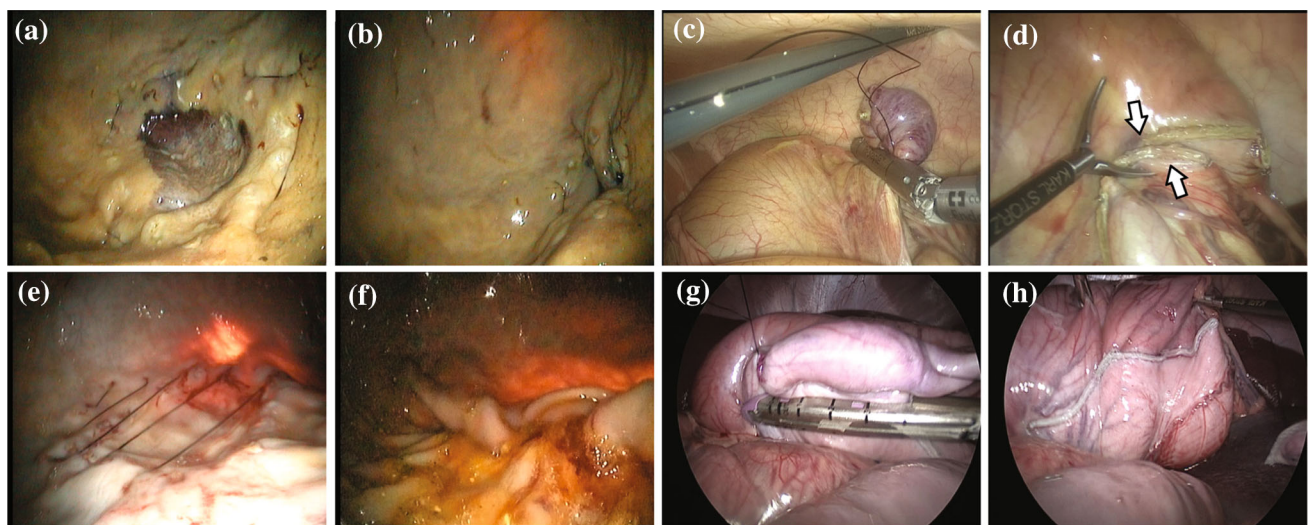


Fig. 5 Operative views of PS method (**A–D**) and HM method (**E–H**). **B–F** When the sutures were fastened, the lesions were outpouched (**B, F**). **D** PS methods resulted in the overlapping of the staple line in one

case (*arrows*). **D, H** The orientation of the staple line was parallel to that of blood vessels in the gastric wall, which runs perpendicular to the long axis of the stomach. *PS* purse string, *HM* horizontal mattress

significant bleeding or leakage could be identified at the penetration sites during the procedures.

In both methods, when the suture was pulled and fastened, the margins of the lesion were inverted while the lesion itself was outpouching toward the abdominal cavity (Fig. 5).

Operating results are summarized in Table 1. Duration for transgastric suture and stapling was 20 min 38 s \pm 5 min 26 s, and every case took 30 min or less. All

lesions were resected encompassing all target markings. In the HM technique, the margins tended to be closer to the intended marked area.

Time for stapling was statistically significantly shorter in the horizontal mattress type of method ($p = 0.028$). In case No. 1 of the purse-string method, fastening suture ends resulted in some wrinkles of the gastric wall. It took some minutes to smoothen the wrinkles of the gastric wall by releasing and fastening the suture. It also resulted in the

Table 1 Data with a comparison between PS and HM methods

Case no.	Time for transgastric suture	Time for stapling	Size of marking	Size of resected specimen (mucosal side)	Size of resected specimen (serosal side)	Distance between resection margin and marking ^a [min, max]	Number of 45-mm staplers
<i>Pursestring</i>							
1	17 min	13 min	5.6 × 3.9	7.0 × 4.4	6.3 × 4.2	0.38 ± 0.41 [0, 1.2]	3
2	15 min	12 min	3.6 × 2.8	8.6 × 6.4	7.1 × 5.7	1.99 ± 1.24 [0.9, 3.2]	5
3	11 min	9 min	2.8 × 2.8	6.1 × 4.7	5.2 × 4.0	1.28 ± 0.46 [0.8, 2.0]	4
4	9 min	6 min [†]	3.5 × 3.0	6.5 × 5.8	6.3 × 4.0	1.55 ± 0.92 [0.8, 3.8]	3
Average	13 min 0 s ± 3 min 39 s	10 min 0 s ± 3 min 10 s	3.9 × 1.2	7.1 × 5.2	6.2 × 4.5	1.3 ± 1.0	3.8 ± 1.0
<i>Horizontal mattress</i>							
5	12 min	6 min	4.6 × 4.4	6.9 × 6.2	5.8 × 4.7	1.0 ± 0.42 [0.3, 1.6]	3
6	16 min	5 min	6.5 × 4.0	7.6 × 5.6	6.5 × 4.5	0.46 ± 0.36 [0, 1.0]	3
7	9 min	5 min 30 s	4.7 × 3.3	7.1 × 6.3	6.1 × 3.9	1.23 ± 0.71 [0.3, 2.3]	3
8	14 min	5 min 30 s	6.2 × 5.0	8.1 × 5.9	6.6 × 4.1	0.63 ± 0.51 [0, 1.5]	4
Average ^c	12 min 45 s ± 2 min 59 s	5 min 30 s ± 24 s	5.5 × 4.2	7.4 × 6.0	6.3 × 4.3	0.8 ± 0.6	3.3 ± 0.5
<i>p</i> value ^b	0.885	0.028	0.080	0.386	1.000	0.248	0.405

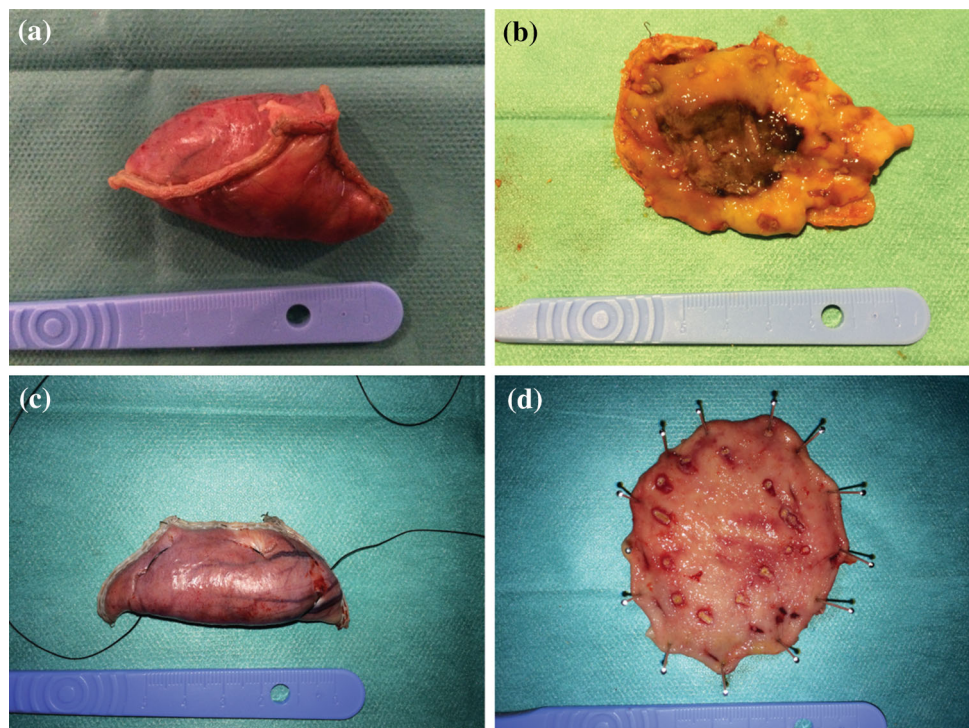
Average values are outlined with standard deviation. Size and distance are presented in cm

^a Average distance in eight directions

^b Bidirectional traction was used unlike in other cases using purse-string methods

^c Mann–Whitney *U* test

Fig. 6 Representative photographs of resected specimens by PS method (A, B) and HM method (C, D). A The shape of the specimen shows a *round-shaped* configuration by overlappings of the staple line in one case using the PS method, C while the shape of the specimen is linear in the HM method. PS purse string, HM horizontal mattress



overlapping of staple lines in the remaining stomach and the specimen (Figs. 5D, 6A). In subsequent cases, more staplers were used to prevent overlapping.

In contrast, application of the stapler was much easier, and time for stapling was shorter in the continuous horizontal mattress type of method. Fastening of the two ends

of the suture did not result in wrinkles which could interfere with stapling, but it rather provided a good linear configuration, which could facilitate the stapling perpendicularly to the long axis of the stomach.

Control endoscopy and laparoscopy were performed to check for leaks at the end of the procedure. There were no major breaks or air leaks in the staple lines nor evidence of stenosis in the remaining stomach for either suturing method.

In case No. 8, we re-resected the part of the staple line, having hypothesized that a small part of the lateral margin was involved by cancer (Fig. 7). The 2.6×2.4 -cm-sized marked lesion was successfully removed with a horizontal mattress type of method in 20 min, with distances of 0.5–1.5 cm between the marking and the resection line.

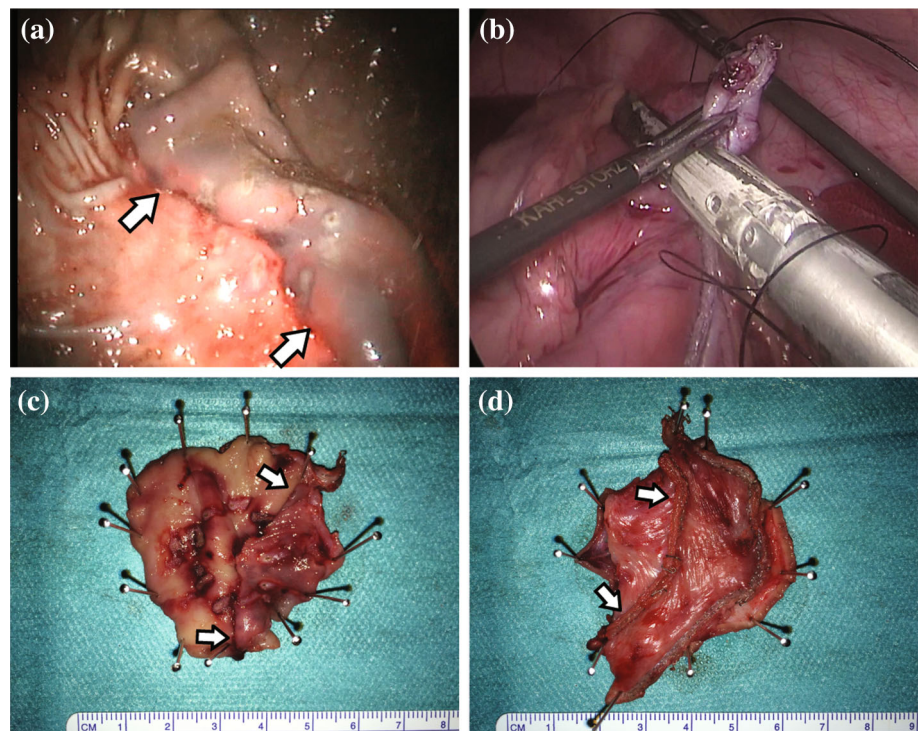
Discussion

Laparo-endoscopic hybrid surgery methods, which are also named laparoscopic endoscopic cooperative surgery (LECS) by Japanese groups, were first advocated for the resection of gastrointestinal stromal tumors (GISTs) to minimize the excision of normal gastric tissue and to facilitate the surgical approach to anatomically difficult lesions of the stomach [7, 9–11]. When compared to GIST resection, where the mucosa is intact, resection of gastric cancer should be performed more carefully to prevent spillage of gastric contents. In fact, spillage not only could be at the origin of potential bacterial contamination, but

could also increase the risk of cancer dissemination, as it has been shown that free cancer cells might be found in the gastric lumen, even in the presence of early gastric cancer [12, 13]. A few methods have been developed to minimize spillage, such as crown-shaped hanging sutures and resections with the lesion inverted in the gastric lumen (inverted LECS) [14], a combination of laparoscopic and endoscopic approaches to neoplasia with non-exposure technique (CLEAN-NET) [15] and non-exposed endoscopic wall-inversion surgery (NEWS) [16–18].

Even though all of these techniques have been successfully used with accurate resection margins, they require relatively long operative times and highly trained flexible endoscopists. It is also required to use an endoscopic carbon dioxide insufflator for all these techniques, which is not universally available, since a planned stomach perforation is required in the inverted LECS technique, and inadvertent perforations might occur during seromuscular cuttings when using CLEAN-NET and NEWS technique. Repeated time-consuming submucosal injections are also required to reduce the risks of perforation [18]. In the technique we propose here, endoscopic carbon dioxide insufflation is not mandatory. Air leaks were not noticeable through penetration sites during our procedure despite a relatively thick diameter of prototype suture passers, which might originate from a contraction of the muscular layer. We expect that the refinement of the instrument into a narrower design will further decrease the likelihood of spillage. Theoretically, our method is not a “completely

Fig. 7 An additional resection was performed using a horizontal mattress suture method hypothesizing that a small part of the lateral resection margin was involved by cancer. **A** An imaginary remaining lesion of about 2×1 cm was marked by means of endoscopic coagulation. **B** Laparoscopic view of stapling **C** mucosal side and **D** serosal side of the resected specimen. Arrows previous staple line



non-exposed” method and might have minimal risk of cancer cell contamination. However, considering that no peritoneal metastasis occurred at long-term follow-up after endoluminal resections complicated by perforations [19], and considering that intracorporeal anastomosis after laparoscopic gastrectomy makes large defects in the remaining stomach, the small puncture holes required for our technique will probably not be more clinically relevant in terms of cancer cells contamination. Nevertheless, as great caution is recommended when dealing with cancer cells spillage, we would like to emphasize the potential benefits of intense irrigation and suction around the tumor site to reduce the risk of spreading.

We believe that our endoscopic procedure presents difficulties similar to those encountered with biopsy of the gastric lesion and do not require as much skills as required for inverted LECS or NEWS. Endoscopic procedures in our experiments were performed by a surgeon without any clinical experience with endoscopic techniques. Additionally, no specifically designed endoscopic cutting knives are required to perform the proposed technique.

Since our technique does not involve a fine dissection of submucosal or subserosal layers using complex endoscopic or laparoscopic approaches, it could greatly reduce operative times when compared to other methods. The average duration of the NEWS technique was 112 min in the *ex vivo* study and 153 min in the *in vivo* study using porcine stomachs [16]. The estimated time for inverted LECS technique, CLEAN-NET, and NEWS technique in humans is estimated at 3–4, 2–4, and 3–5 h, respectively [7]. In our *in vivo* experiments, time for transgastric suturing and stapling took less than 30 min in all cases. Although it may take longer in humans, one could expect the total operation time to be 1–2 h, taking into account the time required for additional steps including port placement, partial omentectomy, precoagulation of perigastric vessels around the resection area, sentinel node basin dissection, and retrieval of the specimen. All of these aspects including shorter operative times, the fact that a special endoscopic facility and highly trained endoscopists are not required, may contribute to reducing operative costs and to shortening the learning curve for full-thickness resection. Once the accurate demarcation of the cancer is determined by experienced endoscopist preoperatively or in the beginning of the operation, the procedure itself could be performed by physicians with relatively less experience with flexible endoscopy. In addition, resection with staplers rather than with electrocautery may be beneficial to evaluate tumor margins, because electrocautery can alter tissues and make its evaluation very difficult, and especially so in intraoperative frozen sections.

We tested our technique by selecting a difficult location to position the simulated lesion, namely the posterior wall

of the upper third of the stomach. Although other LECS techniques can be applied to remove lesions located posteriorly, with the majority of them it is generally more challenging to obtain full operative view, because a fully insufflated stomach is difficult to be rotated up to expose the posterior wall of the upper stomach. Compared to those techniques requiring full exposure, with our method it is not necessary to expose the whole serosal area of the lesion. To safely insert the suture passer, a limited exposure is sufficient. The instrument can palpate the serosa side by pushing and sliding movements, and the endoscopist can confirm the optimal puncture site by the “indentation” (Fig. 2D). Additionally, the gastric walls could be approximated in a linear configuration for an easy stapler application in desired directions using the horizontal mattress type of suture. Repair by either hand-sewing in NEWS or stapling in CLEAN-NET mandates a time-consuming procedure to obtain an ideal repair line, which runs perpendicular to the long axis of the stomach. In case No. 1, purse-string sutures seemed to have flaws as they tend to make wrinkles and cause overlapping of the staple line when the end of the suture is fastened. Even though the overlapping of the staple line is frequently experienced without any problem when resecting submucosal tumors with the intention of resecting in a direction perpendicular to the long axis of the stomach, more staplers were used in cases No. 2 and No. 3 to prevent the overlapping of staple lines. However, a bidirectional traction in case No. 4 resulted in similar ease and in a similar small number of staplers as in the horizontal mattress type of suture (Fig. 3D, E).

Full-thickness sutures prevent sliding between the mucosa and the seromuscular layer and ensure a complete resection. They also make the lesion outpouching toward the abdominal cavity, which is not easily achievable using multiple serosal sutures outside of the stomach. Full-thickness sutures can be designed in different ways, such as multiple interrupted horizontal mattress sutures. Eventually, full-thickness methods should be accompanied with adjacent sentinel node basin dissection, which seems to be a preferred technique rather than individual sentinel node picking method. Some studies have demonstrated that within the same “sentinel node basin” were found true-positive nodes, even in case with false-negative sentinel node biopsies [20, 21]. We expect that our method can be also useful for full-thickness resections with sentinel node basin dissection, because the shape of resection area is not always round shaped in these situations [22].

Another advantage of this new technique is the applicability for re-resection in the previous resection site. Seromuscular cuttings with submucosal injection or endoscopic cutting around previous resection lines is quite challenging in other methods, but we experienced that

repeated re-resection around the staple line was feasible in case No. 8 (Fig. 7).

In conclusion, the laparo-endoscopic hybrid partial gastrectomy technique using a laparoscopic bendable transgastric suture passer was feasible in large animals. It can be a fast and easy option for partial full-thickness resection of gastric cancer using only simple endoscopic devices and is especially beneficial for lesions located at the posterior wall of the upper stomach.

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References

- Hamashima C, Ogoshi K, Okamoto M, Shabana M, Kishimoto T, Fukao A (2013) A community-based, case-control study evaluating mortality reduction from gastric cancer by endoscopic screening in Japan. *PLoS ONE* 8(11):e79088. doi:10.1371/journal.pone.0079088
- Kim YG, Kong SH, Oh SY, Lee KG, Suh YS, Yang JY, Choi J, Kim SG, Kim JS, Kim WH, Lee HJ, Yang HK (2014) Effects of screening on gastric cancer management: comparative analysis of the results in 2006 and in 2011. *J Gastric Cancer* 14(2):129–134. doi:10.5230/jgc.2014.14.2.129
- Gotoda T, Kusano C, Moriyasu F (2014) Future perspective of gastric cancer endotherapy. *Ann Transl Med* 2(3):25. doi:10.3978/j.issn.2305-5839.2014.03.03
- Kong SH, Yoo MW, Kim JW, Lee HJ, Kim WH, Lee KU, Yang HK (2011) Validation of limited lymphadenectomy for lower-third gastric cancer based on depth of tumour invasion. *Br J Surg* 98(1):65–72. doi:10.1002/bjs.7266
- Schlag C, Wilhelm D, von Delius S, Feussner H, Meining A (2013) EndoResect study: endoscopic full-thickness resection of gastric subepithelial tumors. *Endoscopy* 45(1):4–11. doi:10.1055/s-0032-1325760
- Asakuma M, Cahill RA, Lee SW, Nomura E, Tanigawa N (2010) NOTES: the question for minimal resection and sentinel node in early gastric cancer. *World J Gastrointest Surg* 2(6):203–206. doi:10.4240/wjgs.v2.i6.203
- Hiki N, Nunobe S, Matsuda T, Hirasawa T, Yamamoto Y, Yamaguchi T (2014) Laparoscopic endoscopic cooperative surgery (LECS). *Dig Endosc*. doi:10.1111/den.12404
- Fujimura T, Fushida S, Tsukada T, Kinoshita J, Oyama K, Miyashita T, Takamura H, Kinami S, Ohta T (2014) A new stage of sentinel node navigation surgery in early gastric cancer. *Gastric Cancer*. doi:10.1007/s10120-014-0446-z
- Hiki N, Yamamoto Y, Fukunaga T, Yamaguchi T, Nunobe S, Tokunaga M, Miki A, Ohyama S, Seto Y (2008) Laparoscopic and endoscopic cooperative surgery for gastrointestinal stromal tumor dissection. *Surg Endosc* 22(7):1729–1735. doi:10.1007/s00464-007-9696-8
- Abe N, Takeuchi H, Yanagida O, Masaki T, Mori T, Sugiyama M, Atomi Y (2009) Endoscopic full-thickness resection with laparoscopic assistance as hybrid NOTES for gastric submucosal tumor. *Surg Endosc* 23(8):1908–1913. doi:10.1007/s00464-008-0317-y
- Kong SH, Yang HK (2013) Surgical treatment of gastric gastrointestinal stromal tumor. *J Gastric Cancer* 13(1):3–18. doi:10.5230/jgc.2013.13.1.3
- Narula VK, Hazey JW, Renton DB, Reavis KM, Paul CM, Hinshaw KE, Needleman BJ, Mikami DJ, Ellison EC, Melvin WS (2008) Transgastric instrumentation and bacterial contamination of the peritoneal cavity. *Surg Endosc* 22(3):605–611. doi:10.1007/s00464-007-9661-6
- Han TS, Kong SH, Lee HJ, Ahn HS, Hur K, Yu J, Kim WH, Yang HK (2011) Dissemination of free cancer cells from the gastric lumen and from perigastric lymphovascular pedicles during radical gastric cancer surgery. *Ann Surg Oncol* 18(10):2818–2825. doi:10.1245/s10434-011-1620-8
- Nunobe S, Hiki N, Gotoda T, Murao T, Haruma K, Matsumoto H, Hirai T, Tanimura S, Sano T, Yamaguchi T (2012) Successful application of laparoscopic and endoscopic cooperative surgery (LECS) for a lateral-spreading mucosal gastric cancer. *Gastric Cancer* 15(3):338–342. doi:10.1007/s10120-012-0146-5
- Inoue H, Ikeda H, Hosoya T, Yoshida A, Onimaru M, Suzuki M, Kudo SE (2012) Endoscopic mucosal resection, endoscopic submucosal dissection, and beyond: full-layer resection for gastric cancer with nonexposure technique (CLEAN-NET). *Surg Oncol Clin N Am* 21(1):129–140. doi:10.1016/j.soc.2011.09.012
- Mitsui T, Goto O, Shimizu N, Hatao F, Wada I, Niimi K, Asada-Hirayama I, Fujishiro M, Koike K, Seto Y (2013) Novel technique for full-thickness resection of gastric malignancy: feasibility of nonexposed endoscopic wall-inversion surgery (news) in porcine models. *Surg Laparosc Endosc Percutan Tech* 23(6):e217–e221. doi:10.1097/SLE.0b013e31828e3f94
- Goto O, Takeuchi H, Kawakubo H, Matsuda S, Kato F, Sasaki M, Fujimoto A, Ochiai Y, Horii J, Uraoka T, Kitagawa Y, Yahagi N (2014) Feasibility of non-exposed endoscopic wall-inversion surgery with sentinel node basin dissection as a new surgical method for early gastric cancer: a porcine survival study. *Gastric Cancer*. doi:10.1007/s10120-014-0358-y
- Mitsui T, Niimi K, Yamashita H, Goto O, Aikou S, Hatao F, Wada I, Shimizu N, Fujishiro M, Koike K, Seto Y (2014) Non-exposed endoscopic wall-inversion surgery as a novel partial gastrectomy technique. *Gastric Cancer* 17(3):594–599. doi:10.1007/s10120-013-0291-5
- Ikehara H, Gotoda T, Ono H, Oda I, Saito D (2007) Gastric perforation during endoscopic resection for gastric carcinoma and the risk of peritoneal dissemination. *Br J Surg* 94(8):992–995. doi:10.1002/bjs.5636
- Miwa K, Kinami S, Taniguchi K, Fushida S, Fujimura T, Nonomura A (2003) Mapping sentinel nodes in patients with early-stage gastric carcinoma. *Br J Surg* 90(2):178–182. doi:10.1002/bjs.4031
- Kitagawa Y, Takeuchi H, Takagi Y, Natsugoe S, Terashima M, Murakami N, Fujimura T, Tsujimoto H, Hayashi H, Yoshimizu N, Takagane A, Mohri Y, Nabeshima K, Uenosono Y, Kinami S, Sakamoto J, Morita S, Aikou T, Miwa K, Kitajima M (2013) Sentinel node mapping for gastric cancer: a prospective multicenter trial in Japan. *J Clin Oncol* 31(29):3704–3710. doi:10.1200/JCO.2013.50.3789
- Lee JH, Lee MS, Kim HH, Park DJ, Lee KH, Hwang JY, Lee HJ, Yang HK, Lee KU (2011) Feasibility of laparoscopic partial gastrectomy with sentinel node basin dissection in a porcine model. *Surg Endosc* 25(4):1070–1075. doi:10.1007/s00464-010-1318-1