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SCIENTIFIC REVIEW

Conventional Versus Minimally Invasive Hartmann Takedown: A Meta-analysis of the Literature

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Abstract Although end colostomy closure following Hartmann's procedure is a major surgery that is traditionally performed by conventional celiotomy, over the last decade there has been a growing interest toward the application of different minimally invasive techniques. We aimed at evaluating the relative outcomes of conventional surgery versus minimally invasive surgery by meta-analyzing the available data from the medical literature. The PubMed/MEDLINE, Cochrane Library and EMBASE electronic databases were searched through August 2018. Inclusion criteria considered eligible all comparative studies evaluating open versus minimally invasive procedures. Conventional laparoscopy, robotic and single-port laparoscopy were considered as minimally invasive techniques. Overall morbidity, rate of anastomotic failure, rate of wound complications and mortality were evaluated as primary outcomes. Perioperative details and surgical outcomes were also assessed. The data of a total of 13,740 patients from 26 studies were eventually included in the analysis. There were no significant differences on baseline characteristics such as age, BMI and proportion of high-risk patients between the two groups of patients. As compared to the conventional technique, minimally invasive surgery proved significantly superior in terms of postoperative morbidity, length of hospital stay and rate of incisional hernia. The current literature suggests that minimally invasive surgery should be considered in performing Hartmann's reversal, if technically viable. However, due to the low level of the available evidence it is impossible to draw definitive conclusions.

Introduction

Hartmann reversal (HR) is a major procedure carrying a substantive rate of postoperative morbidity. [1–3] Despite HR is still generally undertaken by open surgery, [4–10] along the last years there has been a growing interest in the application of minimally invasive surgery (MIS). Several authors have reported the feasibility of laparoscopic HR (LHR) and a number of advantages over its open counterpart (OHR), especially with regard to postoperative morbidity, length of hospital stay and return to daily activities. [3, 9] Despite this, it is still difficult to establish the actual impact of LHR versus OHR in general clinical practice, [11, 12] as much of the available data are derived from single-institution, selected case series. [8, 9] Moreover, most studies are flawed by relatively low caseload so that it is arduous to define objective differences between minimally invasive and conventional approach. [9, 12] Accordingly, the aim of our analysis is to investigate the potential merits of LHR of OHR by aggregating and meta-analyzing all the existing evidence from the literature.

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Materials and methods

The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) [13] and MOOSE (Meta-analysis Of Observational Studies in Epidemiology) [14] guidelines were employed to identify studies comparing LHR versus OHR. Two authors (CDB, DC) performed an independent literature search up to August 2018. The *PubMed/Medline, EMBASE* and *Cochrane Library* electronic databases were queried with a combination of the following search words: "Hartmann," "Hartmann's," "colostomy," "reversal," "takedown" and "closure." All article typologies were considered eligible with the exception of conference proceedings, case reports and small series with less than ten patients. Our search criteria were also restricted to English language. Independently, the two authors screened titles and abstracts of the retrieved records. Full-text versions of the papers deemed suitable for inclusion were appraised, and relative references were screened to identify additional, eligible articles. Differences in opinion were discussed with the input of a third author (FG).

Primary outcome variables of interest included overall morbidity (defined as the development of at least one complication), rate of anastomotic failure (defined as clinically or radiologically diagnosed leak of the anastomosis), incidence of surgical site infection (SSI) and postoperative mortality. Suitable studies were thus evaluated and pooled in the meta-analysis if the following criteria were met:

- Inclusion of adult patients undergoing end colostomy reversal
- A minimally invasive procedure (standard laparoscopic, single-port laparoscopic, or robotic) and a conventional open comparator intervention
- Detailed data on at least one of the primary outcomes of interest

According to a pre-established protocol, from each eligible study the retrieved data were the following: study characteristics, details about patients' baseline characteristics (including age, Body Mass Index (BMI) and American Society of Anesthesiologists (ASA) physical status classification) and operative data. As for postoperative courses, data on the primary outcomes of interest were retrieved firstly, where available, secondary outcomes were thus appraised. Details about postoperative morbidity were searched to find the relative incidences of postoperative cardiopulmonary complications, hemorrhage, wound dehiscence and the percentage of patients requiring reoperation during the postoperative course. The length of hospital stay following surgery was also appraised and compared between LHR and OHR. Long-term outcomes were also assessed with regard to the incidence of incisional hernia.

Relevant data were retrieved from each included study according to an *intention to treat* principle of analysis. When multiple studies by the same authors provided duplicate data with overlap among patients groups, the most recent or the most detailed data were analyzed.

To assess methodological quality, the Cochrane handbook for systematic reviews of interventions guidelines were followed. [15]

Statistical analysis

Data are presented in descriptive statistics. Statistical analysis was performed with the Statistical Package for the Social Sciences v 20.00 (SPSS Inc, Chicago, IL, US). Meta-analysis of the included studies was carried out with RevMan 5.3 (Cochrane Collaboration, Oxford, England) with a random-effects model. According to the method popularized by *Hozo* et al. [16], medians with ranges were converted into means with standard deviation, where needed. Estimated effect measures were calculated for event-related outcomes as odds ratio (ORs). Mean differences (MDs) were calculated with the inverse variance method in the case of continuous variables, while statistical heterogeneity was evaluated by inspecting I^2 statistics. ORs and MDs were calculated and reported with 95% confidence interval (CI). The Z test for overall effect and its two-sided p value were thus assessed. Statistical significance was set at the 0.05 probability level.

Results

Studies selection and perioperative data

The initial electronic search yielded 2917 titles. Titles and abstracts were evaluated, and duplicate records were excluded. Full texts with relative bibliographies were thus appraised, and a total of 26 studies were eventually deemed suitable for inclusion and data extraction. [2, 11, 17–40] The selection process is given in Fig. 1, while Table 1 describes the general characteristics of the included studies.

There were no randomized trials, and all studies were comparative, retrospective analyses. All studies had *unknown risk* of selection and performance bias, although most studies did compare contemporary groups with similar baseline characteristics. Most of the included studies were at *high risk* of detection bias. The most apparent methodological limit was the lack of detailed description of outcomes assessment. The vast majority of the included studies were at *low risk* of reporting bias.

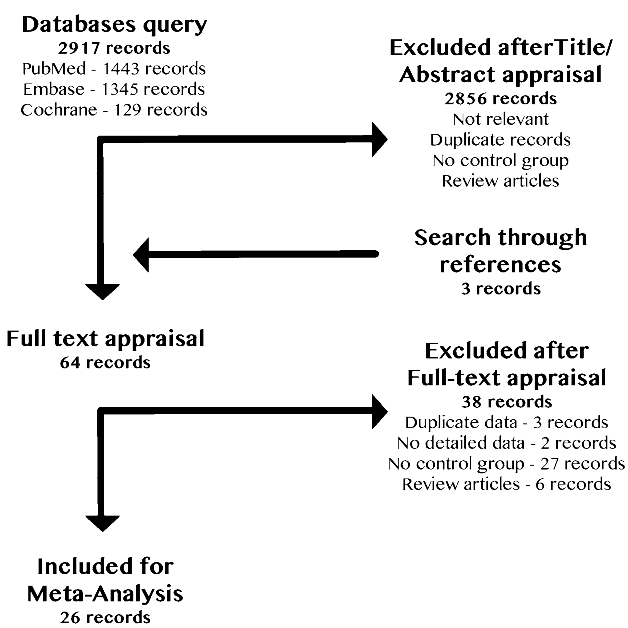

Fig. 1 Search strategy

Finally, a total of 13,740 patients from 26 studies were eventually included in the analysis. Of these, 51 percent were male (7054 out of 13,729 patients with detailed data). Some 3170 patients (23 percent) received a minimally invasive intervention, whereas 10,570 patients (77 percent) received HR by conventional surgery. Among the studies included, 24 studies compared OHR to the conventional laparoscopic procedure, while two studies compared OHR to single-port LHR (SP-LHR).

With reference to the primary surgery, i.e., Hartmann procedure (HP), most of the included studies did not provide detailed data about surgical approach. [2, 11, 17–19, 23, 26–31, 34, 36–40]. In seven studies, all HPs were performed by open surgery, [21, 22, 24, 32, 33, 35] while two articles did include both patients who had received open surgery and patients who had received surgery by laparoscopy. [20, 25] In particular, in the study by *Clermonts* et al., 3 out of the 25 patients (12 percent) in the LHR group had received laparoscopic HP, whereas all patients in the OHR group had undergone HP by open surgery. [20] In the study by *Kwak* et al., there were six laparoscopic HPs in the LHR group (35 percent) and four laparoscopic HPs in the OHR group (33 percent).

Mean age ranged between 50.7 and 63.4 years for LHR and between 50.2 and 63.7 years for OHR (data from 22 studies, 13,279 patients). Overall, there was no difference between the two groups of patients (MD = −0.43, $p = 0.59$). Details on BMI were available for 1132 patients from 14 studies. Mean BMI varied between 24 and 29.7 for LHR, while it ranged between 24.4 and 30.8 in the OHR group. This difference was not significant (OR = −0.17, $p = 0.76$). Twelve studies provided circumstantial data on the preoperative ASA score of 737 patients. Overall, the rate of ASA III-IV patients was 33 percent (244 patients), with no statistical difference between the relative incidences in the LHR (29 percent) and OHR (36 percent) group (OR = 0.96, $p = 0.84$).

Conversion rates varied substantially among the included studies (0–50 percent). The overall proportion of minimally invasive procedures converted to OHR was 17 percent (data from 19 studies, 623 patients). Mean operative time varied between 104 and 291 min for LHR and between 141 and 277 for OHR. At meta-analysis, there was a MD of −24.24 ($p = 0.0007$). Overall, minimally invasive surgery showed significantly lower blood loss than conventional surgery (MD = −104.81, $p < 0.00001$). The rate of ileostomy creation was reported by 10 studies, including a total of 623 patients. At the time of HR, a protective stoma was fashioned in 14 percent of patients. A lower proportion of patients had protective stoma in the LHR as compared to the OHR group (7 vs. 20 percent, OR = 0.23, $p < 0.0001$). Perioperative details are given in Table 2.

Outcomes evaluation

The pooled data on both primary and secondary variables of interest showed mild heterogeneity (I^2 = 0–36 percent), with the exception of postoperative hospital stay (I^2 = 87 percent).

All included studies reported detailed data about postoperative complications. In four studies, postoperative morbidity was reported according to the Clavien–Dindo classification system [20, 24, 25, 35], whereas in three studies postoperative morbidity was only divided into minor and major complications. [28, 33, 40] The remaining studies did not use any classification model to indicate postoperative complications. Overall, postoperative morbidity was 26.8 percent (3688 out of a total of 13,740 patients). There was a statistically significant difference between the two groups, with 18.5 percent (588 out of 3170 patients) and 29.3 percent of patients (3100 out of 10,570) suffering a complication in the LHR and OHR group, respectively (OR = 0.43, $p < 0.00001$, I^2 = 36 percent, Fig. 2).

With regard to wound infection, data on 13,327 patients from 22 studies were available. The overall incidence of wound infection was 12.8 percent (1709 patients), 7.8 and 14.3 percent being the relative rates for LHR and OHR, respectively. This difference was statistically significant (OR = 0.49, $p < 0.00001$, I^2 = 0 percent, Fig. 3).

The rate of anastomotic failure was 4.2 percent (554 out of 13,270 patients, 20 studies). It varied significantly

Table 1 Main characteristics of the included studies

Author	Origin	Year	Interval of recruitment	Comparison	Patients	LHR	OHR	Indication to HP
Achkasov et al. [17]	Russia	2010	2008–2010	LHR versus OHR	71	36	35	All
Brathwaite et al. [18]	USA	2015	2007–2010	LHR versus OHR	81	19	62	All
Chouillard et al. [19]	France	2009	2002–2007	LHR versus OHR	88	44	44	All
Clermonts et al. [20]	Netherlands	2015	2009–2014	SP-LHR versus OHR	41	25	16	All
Costantino et al. [21]	USA	1994	1991–1993	LHR versus OHR	11	3	8	All
De Angelis et al. [22]	France	2013	2000–2010	LHR versus OHR	46	28	18	Complicated diverticular disease
Faure et al. [23]	France	2007	2000–2004	LHR versus OHR	34	14	20	All
Haughn et al. [2]	USA	2008	1998–2004	LHR versus OHR	122	61	61	All
Horesh et al. [24]	Israel	2018	2004–2015	LHR versus OHR	260	76	184	All
Kwak et al. [25]	South Korea	2017	2007–2014	LHR versus OHR	29	17	12	All
Lin et al. [26]	USA	2013	2004–2011	LHR versus OHR	95	17	78	All
Maitra et al. [27]	UK	2013	2003–2011	LHR versus OHR	95	45	50	All
Mazeh et al. [28]	Israel	2008	1998–2006	LHR versus OHR	82	41	41	All
Melkonian et al. [29]	Chile	2017	1997–2011	LHR versus OHR	74	49	25	All
Ng et al. [30]	Hong Kong	2013	2000–2012	LHR versus OHR	82	47	35	All
Okolica et al. [31]	USA	2011	1997–2007	LHR versus OHR	204	24	180	All
Onder et al. [32]	USA	2016	2005–2014	LHR versus OHR	36	18	18	Complicated diverticular disease
Pei et al. [11]	USA	2017	2005–2014	LHR versus OHR	11,762	2423	9339	All
Rosen et al. [33]	USA	2006	1997–2004	LHR versus OHR	44	22	22	All
Schmelzer et al. [34]	USA	2007	2000–2006	LHR versus OHR	113	17	96	All
Studer et al. [35]	Switzerland	2014	2006–2011	LHR versus OHR	53	28	25	All
Svenningsen et al. [36]	Denmark	2010	2005–2008	LHR versus OHR	43	21	22	All
Vermeulen et al. [37]	Netherlands	2010	1995–2009	SP-LHR versus OHR	48	16	32	Complicated diverticular disease
Walklett et al. [38]	UK	2014	2007–2012	LHR versus OHR	49	12	37	All
Yang et al. [39]	Australia	2014	2001–2012	LHR versus OHR	107	43	64	All
Zimmerman et al. [40]	Germany	2014	1999–2011	LHR versus OHR	70	24	46	All
				Total	13.740	3.170	10.570	

LHR laparoscopic Hartmann reversal, *OHR* open Hartmann reversal, *SP-LHR* single-port laparoscopic Hartmann reversal

between the two groups favoring LHR over OHR (2.6 vs. 4.6 percent, OR = 0.58, $p < 0.0001$, $I^2 = 0$ percent).

By analyzing the 13 studies that provided circumstantial data, 3.2 percent of patients had cardiopulmonary complications in the postoperative course (404 out of 12,660 patients). There was a statistically significant difference between LHR and OHR (1.9 vs. 3.5 percent, OR = 0.45, $p = 0.002$, $I^2 = 11$ percent).

Data on postoperative hemorrhage were available from 10 studies including 12,529 patients. Overall, 521 patients (4.2 percent) had evidence of postoperative bleeding, 3.1 and 4.4 being the relative incidence for HRL and OHR, respectively (OR = 0.73, $p = 0.009$, $I^2 = 0$ percent).

Six studies provided data about the incidence of wound dehiscence. There were 223 cases of wound dehiscence among 12,119 patients (1.8 percent). The difference between LHR (18 out of 2565 patients, 0.7 percent) and

Table 2 Perioperative data

	LHR	OHR	*p* value
Procedures (%)	23	77	–
Mean OT (min)	104–291	141–277	< 0.0007
Mean EBL (ml)	64.7–254	124–594	< 0.00001
Conversion rate (%)	17%	–	–
Ileostomy rate (%)	7	20	< 0.0001

LHR laparoscopic Hartmann reversal, *OHR* open Hartmann reversal, *EBL* estimated blood loss, *OT* operation time

OHR (205 out of 9554 patients, 2.1 percent) elicited statistical significance (OR = 0.34, $p < 0.00001$, $I^2 = 0$ percent).

A total of 680 patients underwent reoperation (5.3 percent). The two groups differed without significance (4.3 vs. 5.6 percent, OR = 0.74, $p = 0.07$, $I^2 = 3$ percent).

Nineteen studies provided specific data on mortality. The vast majority of studies did not provide a specific definition of postoperative mortality. On the contrary, five of the included studies have reported mortality as the number of deaths within 1 month [22, 23, 39], 3 months [24] or 6 months [2] following surgery. On total, there were 100 deaths among 13,076 patients, defining an overall mortality rate of 0.8 percent. The relative rates of mortality did not differ between the two groups (OR = 1.22, $p = 0.38$, $I^2 = 0$ percent).

The length of hospital stay ranged 4–12.3 and 8.1–19.1 following LHR and OHR, respectively. Patients receiving surgery laparoscopically experienced significantly shorter postoperative hospitalization than patients undergoing conventional surgery (MD = −3.72, $p < 0.00001$, $I^2 = 87$ percent Fig. 4).

Nine papers including 575 patients contributed to the pooled analysis of abdominal wall-related long-term complications. On this point, there was certain heterogeneity among studies ($I^2 = 29\%$). The overall rate of incisional hernia was 12.7 percent, and LHR showed a significantly lower incidence than OHR (7.6 vs. 17 percent, OR = 0.33, $p = 0.009$, $I^2 = 29$ percent). Table 3 summarizes main outcome variables.

Discussion

The last two decades have seen a dramatic penetration of the minimally invasive method in colorectal surgical practice, essentially due to increased experience in its application and availability of new technologies. [41] Despite this, restoring colonic continuity after an end colostomy has been performed is considered a technically

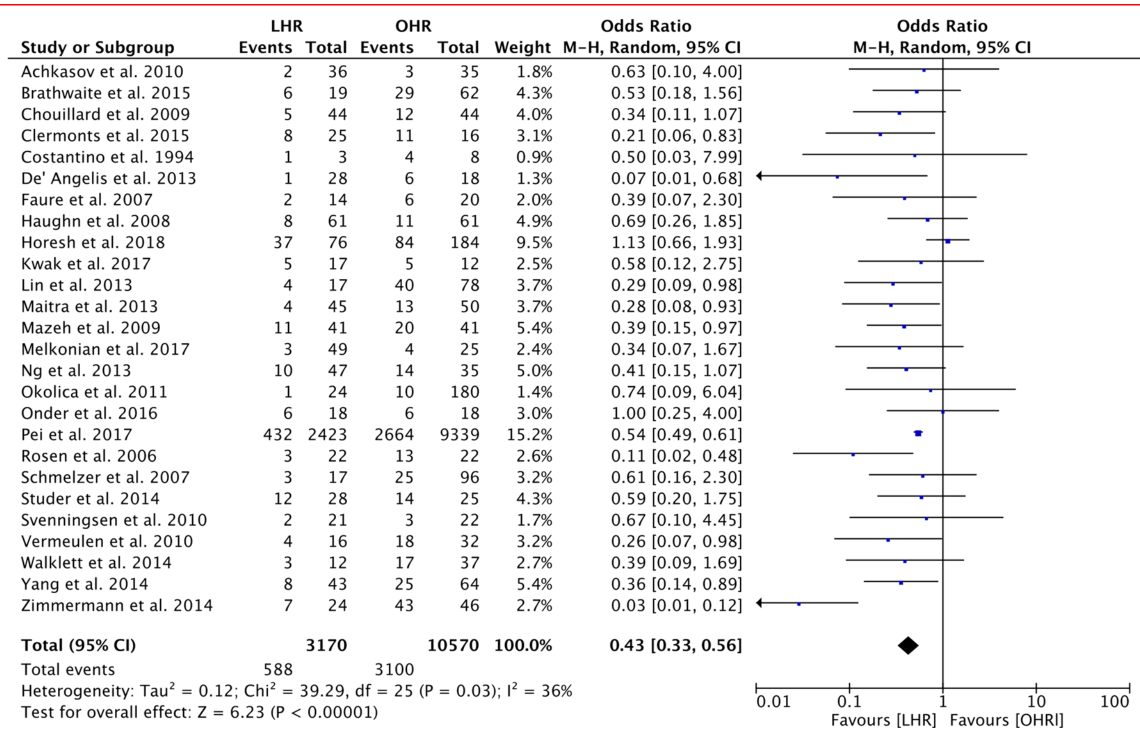

Fig. 2 Overall morbidity

Study or Subgroup	LHR Events	LHR Total	OHR Events	OHR Total	Weight	Odds Ratio M–H, Random, 95% CI
Brathwaite et al. 2015	3	19	13	62	1.1%	0.71 [0.18, 2.80]
Chouillard et al. 2009	4	44	6	44	1.2%	0.63 [0.17, 2.42]
Clermonts et al. 2015	5	25	12	16	1.0%	0.08 [0.02, 0.37]
Costantino et al. 1994	0	3	1	8	0.2%	0.71 [0.02, 22.34]
De' Angelis et al. 2013	0	28	6	18	0.2%	0.03 [0.00, 0.65]
Faure et al. 2007	1	14	0	20	0.2%	4.56 [0.17, 120.28]
Haughn et al. 2008	2	61	4	61	0.7%	0.48 [0.09, 2.74]
Horesh et al. 2018	12	76	41	184	4.3%	0.65 [0.32, 1.33]
Kwak et al. 2017	2	17	0	12	0.2%	4.03 [0.18, 91.91]
Maitra et al. 2013	2	45	1	50	0.4%	2.28 [0.20, 26.02]
Mazeh et al. 2009	6	41	8	41	1.6%	0.71 [0.22, 2.26]
Melkonian et al. 2017	1	49	1	25	0.3%	0.50 [0.03, 8.34]
Ng et al. 2013	6	47	8	35	1.6%	0.49 [0.15, 1.58]
Onder et al. 2016	2	18	4	18	0.6%	0.44 [0.07, 2.76]
Pei et al. 2017	177	2423	1313	9339	80.9%	0.48 [0.41, 0.57]
Rosen et al. 2006	3	22	6	22	0.9%	0.42 [0.09, 1.96]
Schmelzer et al. 2007	2	17	16	96	0.9%	0.67 [0.14, 3.20]
Studer et al. 2014	4	28	8	25	1.2%	0.35 [0.09, 1.37]
Vermeulen et al. 2010	1	16	5	32	0.4%	0.36 [0.04, 3.37]
Walklett et al. 2014	2	12	9	37	0.8%	0.62 [0.11, 3.38]
Yang et al. 2014	2	43	1	64	0.4%	3.07 [0.27, 34.99]
Zimmermann et al. 2014	2	24	7	46	0.8%	0.51 [0.10, 2.65]
Total (95% CI)		**3072**		**10255**	**100.0%**	**0.49 [0.43, 0.57]**
Total events	239		1470			

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 17.87$, df = 21 (P = 0.66); $I^2 = 0\%$
Test for overall effect: Z = 9.38 (P < 0.00001)

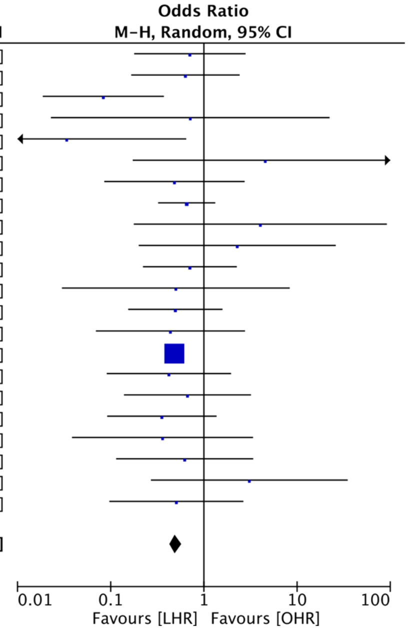

Fig. 3 Wound infection

Study or Subgroup	LHR Mean	LHR SD	LHR Total	OHR Mean	OHR SD	OHR Total	Weight	Mean Difference IV, Random, 95% CI
Achkasov et al. 2010	9.1	2.7	36	12.9	3.4	35	8.1%	−3.80 [−5.23, −2.37]
Clermonts et al. 2015	4	6.3	25	16	16.3	16	2.0%	−12.00 [−20.36, −3.64]
De' Angelis et al. 2013	6.7	1.9	28	11.2	5.3	18	6.8%	−4.50 [−7.05, −1.95]
Faure et al. 2007	10.25	4	14	16.75	8.25	20	4.8%	−6.50 [−10.68, −2.32]
Haughn et al. 2008	4.1	0.6	61	8.5	8.8	61	7.2%	−4.40 [−6.61, −2.19]
Horesh et al. 2018	10.92	14.3	76	11.81	7	184	5.7%	−0.89 [−4.26, 2.48]
Kwak et al. 2017	12.35	4.5	17	19.15	8.9	12	3.6%	−6.80 [−12.27, −1.33]
Maitra et al. 2013	6.78	0.8	45	14.93	4.41	50	8.3%	−8.15 [−9.39, −6.91]
Mazeh et al. 2009	6.5	3.25	41	8.1	4.5	41	7.8%	−1.60 [−3.30, 0.10]
Ng et al. 2013	12	3.7	47	14	7.25	35	6.7%	−2.00 [−4.62, 0.62]
Onder et al. 2016	5.4	3.1	18	8.3	4.8	18	6.7%	−2.90 [−5.54, −0.26]
Pei et al. 2017	5.75	6.24	2423	7.63	8.01	9339	8.9%	−1.88 [−2.18, −1.58]
Studer et al. 2014	11.3	8.5	28	15.4	11.9	25	3.5%	−4.10 [−9.73, 1.53]
Vermeulen et al. 2010	8	5	16	9	15	32	3.4%	−1.00 [−6.75, 4.75]
Walklett et al. 2014	7.5	3.47	12	8.52	2.5	37	7.3%	−1.02 [−3.14, 1.10]
Yang et al. 2014	6.7	2.6	43	10.8	6.4	64	7.8%	−4.10 [−5.85, −2.35]
Zimmermann et al. 2014	9.75	1.75	24	15	38.75	46	1.2%	−5.25 [−16.47, 5.97]
Total (95% CI)			**2954**			**10033**	**100.0%**	**−3.72 [−5.07, −2.37]**

Heterogeneity: $Tau^2 = 5.32$; $Chi^2 = 122.35$, df = 16 (P < 0.00001); $I^2 = 87\%$
Test for overall effect: Z = 5.39 (P < 0.00001)

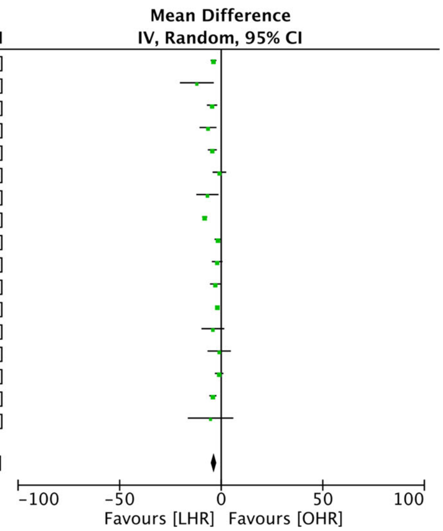

Fig. 4 Length of hospital stay

demanding operation for which the implementation of MIS has been more cautious to proceed. [6, 8, 10]

In fact, as compared to other colorectal procedures, HR is generally preceded by an open procedure, often performed in the setting of generalized peritonitis. [8, 12] As a consequence, the presence of severe adherences may render a laparoscopic approach difficult. [8] Nevertheless, the diffusion of LHR is increasing steadily over the recent years [8, 11] and a number of analyses worldwide have reported encouraging results. [8, 10, 11] Still, the available data are relatively scarce, being derived mainly from low-evidence studies. [11] Actually, it is difficult to draw general conclusions, as crude data on outcomes measures vary significantly among studies. [8, 42]

Accordingly, we aimed to pool the available evidence within the medical literature to define, in a general and comprehensive manner, the actual role of MIS in performing HR, as compared to the conventional celiotomy procedure.

Table 3 Main outcomes of the included studies

	LHR	OHR	Tot.	*p* value
Overall morbidity	18.5	29.3	26.8	< 0.00001
Cardiopulmonary	1.9	3.5	3.2	0.002
Bleeding	3.1	4.4	4.2	0.009
Anastomotic failure	2.6	4.6	4.2	0.0001
Wound infection	7.8	14.3	12.8	< 0.00001
Wound dehiscence	0.7	2.1	1.8	< 0.00001
Reoperation	4.3	5.6	5.3	0.07
Hernia	7.6	17	12.7	0.009

Values are presented as percentages. *LHR* laparoscopic Hartmann reversal, *OHR* open Hartmann reversal

Previous authors investigated the same argument by reviewing the available data from the literature. [3, 42, 43]

In 2010, *van de Wall* et al. published the results of their review of the literature on minimally invasive HR. [42] Globally, the authors pooled the outcomes of more than 6000 patients who underwent LHR. As for evaluating LHR versus OHR, they finally found only five comparative studies, mostly reporting on limited, initial experiences. More recently *Celentano and colleagues* performed a well-conducted meta-analysis including a total of 826 patients, whereby 47 percent undergoing LHR and 53 percent undergoing OHR. [43] Overall, the LHR and OHR groups of patients were comparable in terms of demographic baseline characteristics. With regard to surgical outcomes, the two groups proved similar on overall mortality, operative time, anastomotic failure and rate of reoperation. On the contrary, they differed in favor of MIS on estimated blood loss, overall morbidity, wound infection, postoperative ileus and length of hospital stay.

Probably due to the significant increase in the application of minimally invasive surgery in performing HR worldwide, a far more substantive number of patients have been eventually included in the present analysis, which aggregates the data of nearly 14 thousand patients. Moreover, as for minimally invasive techniques, studies comparing OHR to conventional LHR *or* single-port LHR (SP-LHR) were considered in the present analysis. The merits of avoiding midline laparotomy and its potentially detrimental consequences are well known. [2, 41] With HR in particular, most of postoperative complications and most of those requiring subsequent surgery are abdominal wall-related complications, especially in terms of wound infection and incisional hernia. [2] Accordingly, the choice of including both LHR and SP-LHR was made to aggregate all existing evidence on minimally invasive surgery.

Globally, our present review reveals a marked increase in the application of minimally invasive techniques in performing HR along the last decade. [5, 11, 12] In general, it is arduous to ascertain the actual percentage of HR procedures worldwide that are completed in a minimally invasive manner, given than the vast majority of data is provided by selected case series, with data reported according to a *per treatment* principle. [8] The largest evidence is that published by *Pei and colleagues,* who recently investigated the available data on HR from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP). [11] Between 2005 and 2014, on a total of more than 11.700 procedures identified, nearly 20 percent were done laparoscopically. Interestingly, the proportion of laparoscopic procedures increased dramatically over time, from about zero in 2005 to more than 25% in 2014. [11] Nevertheless, the authors did not provide reliable information about conversion, as patients whose LHR was converted to an OHR procedure were excluded from the analysis. As for the proportion of minimally invasive turned into conventional surgeries, previous analyses on LHR have reported rates up to more than 60%. [8, 9, 33] Particularly, in the reviews by *Siddiqui* et al. and *Celentano* et al., the conversion rate ranged between zero and 50 percent, while it was 7–22 percent in the review by *van de Wall* et al. [3, 42, 43] The overall percentage of conversion in the present analysis was as high as 17 percent, with significant variation among studies (range 0–50 percent). This difference is likely to reflect the recent advancements in the application of minimally invasive techniques and the increasing experience of a growing number of centers through the recent years. [8]

HR is accompanied by a considerable incidence of postoperative complications, which is reported as up to 50%. [3, 11, 12, 42] Patients receiving minimally invasive surgery almost invariably have lower overall morbidity as compared to those undergoing an open procedure. [2, 11, 12, 25, 42] Nevertheless, in most reports patients treated laparoscopically had more favorable baseline characteristics than patients operated conventionally, since the former were tendentially younger, [28, 34, 35, 37, 42] had lower proportion of oncological indication, [28, 33, 39, 42] and less comorbidities. [28, 35, 39] In discordance with previous investigations and with the general opinion that MIS patients are superselected, [12] there were no statistical differences in patient baseline demographics in the present analysis. Of note, patients in the LHR did not differ significantly from those in the OHR group on age, BMI and ASA score.

As for postoperative outcomes, a number of main points have to be outlined as novelties as compared to the available data. Firstly, the present study confirms a significant superiority of LHR over OHR on overall morbidity on a large amount of procedures, with specific advantages also in terms of cardiopulmonary complications, postoperative bleeding and incisional hernia. Secondly, unlike previous meta-analyses, our review did notice significant difference between minimally invasive surgery and conventional surgery in terms of anastomotic failure in favor of LHR. Lastly, it is interesting to note the relative rates of SSI/wound problems, which are the most frequent complication after HR, especially in the case of obese patients: [10, 11, 42] in contradiction with previous analyses [3, 42] in the present study the relative incidence of wound-related complications favored LHR over OHR with significance.

With reference to these main findings, the inclusion and analysis of a large amount of data from a single national database may pose some concerns about quality and generalizability of the aggregated outcomes. Accordingly, the primary outcomes of interest have been also calculated excluding the large study by *Pei* et al. Overall, the directions of the effect sizes remained consistent for all of the outcomes with the exception of the rate of mortality, for which the OR went from 1.22 to 0.56, although still statistically nonsignificant ($p = 0.48$). On the contrary, the specific incidence of overall morbidity and SSI remained unchanged, favoring significantly LHR over OHR (OR from 0.45 to 0.42, $p < 0.00001$; and from 0.47 to 0.53, $p = 0.0002$). Interestingly, as for the relative rate of anastomotic leak, the specific OR went from 0.58 to 0.53 and lost statistical significance (from $p = 0.0001$ to $p = 0.06$).

Several limitations have to be acknowledged for the present study. First, the low methodological level of some of the included studies is likely to have affected the general results. This is fundamentally related to the absence of randomization and the likelihood of a number of detection biases within the primary studies. Particularly, diagnostic modalities for postoperative complications were not univocal. Secondly, we must consider that a major part of data concerning MIS refers to the results of the initial experience of single surgical teams in performing LHR. Inevitably, this has led to some differences in comparing LHR to the conventional procedure of OHR. Third, as already said the rate of protective stoma creation in the OHR was significantly higher than in the LHR. In the absence of detailed data upon this issue within the primary reports, this difference may suggest the presence of more complex cases in the OHR group of patients.

Moreover, some crucial factors while evaluating the surgical outcomes of HR, like the height of the anastomosis, the surgical approach approach at the time of stoma creation, the need for proctectomy and the presence of a protective stoma or prior chemoradiation therapy were not assessed for all studies due to the lack of detailed data.

Lastly, it has to be acknowledged the potential impact of the clinical heterogeneity of the included studies on the general results of the analysis. However, except for postoperative hospitalization, the I^2 statistics on primary and secondary outcomes showed mild heterogeneity (I^2 = 0–36 percent), indicating that the proportion of total variability in effect estimates attributable to between-study variation was null to low.

According to the available data from the literature, it seems that—when technically feasible—the application of minimally invasive techniques offers significant advantages in terms of faster recovery, shortened hospital stay, overall and surgical morbidity, while it does not impair the expected rate of general mortality. Nevertheless, probably the most important result of this systematic review is the current absence of high-level evidences on the topic. This relative scarcity of data precludes the possibility of reaching definitive conclusions on whether minimally invasive HR is superior to the conventional open procedure and poses the need for specific, randomized analyses.

Author's contribution All authors have contributed to the work in terms of conception and design, acquisition of data, analysis and interpretation of data. Francesco Guerra wrote the paper.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interests.

References

1. Hallam S, Mothe BS, Tirumulaju R (2018) Hartmann's procedure, reversal and rate of stoma-free survival. Ann R Coll Surg Engl 100:301–307
2. Haughn C, Ju B, Uchal M et al (2008) Complication rates after Hartmann's reversal: open versus laparoscopic approach. Dis Colon Rectum 51:1232–1236
3. Siddiqui MR, Sajid MS, Baig MK (2010) Open versus laparoscopic approach for reversal of Hartmann's procedure: a systematic review. Colorectal Dis 12:733–741
4. Horesh N, Lessing Y, Rudnicki Y et al (2017) Considerations for Hartmann's reversal and Hartmann's reversal outcomes-a multicenter study. Int J Colorectal Dis 32:1577–1582
5. Arkenbosch J, Miyagaki H, Kumara HM et al (2015) Efficacy of laparoscopic-assisted approach for reversal of Hartmann's procedure: results from the American college of surgeons national surgical quality improvement program (ACS-NSQIP) database. Surg Endosc 29:2109–2114
6. Garber A, Hyman N, Osler T (2014) Complications of Hartmann takedown in a decade of preferred primary anastomosis. Am J Surg 207:60–64
7. Royo-Aznar A, Moro-Valdezate D, Martín-Arévalo J et al (2018) Reversal of Hartmann's procedure: a single-centre experience of 533 consecutive cases. Colorectal Dis 20:631–638
8. Richards CH, Roxburgh CS, Scottish Surgical Research Group (SSRG) (2015) Surgical outcome in patients undergoing reversal of Hartmann's procedures: a multicentre study. Colorectal Dis 17:242–249
9. Sherman KL, Wexner SD (2017) Considerations in stoma reversal. Clin Colon Rectal Surg 30:172–177

10. Brathwaite S, Latchana N, Esemuede I et al (2017) Risk factors for surgical site infection in open and laparoscopic Hartmann closure: a multivariate analysis. Surg Laparosc Endosc Percutan Tech 27:51–53
11. Pei KY, Davis KA, Zhang Y (2018) Assessing trends in laparoscopic colostomy reversal and evaluating outcomes when compared to open procedures. Surg Endosc 32:695–701
12. Cellini C, Deeb AP, Sharma A et al (2013) Association between operative approach and complications in patients undergoing Hartmann's reversal. Br J Surg 100:1094–1099
13. Liberati A, Altman DG, Tetzlaff J et al (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. Ann Intern Med 151(W65–94):18
14. Stroup DF, Berlin JA, Morton SC et al (2000) Meta-analysis of observational studies in epidemiology. JAMA 283:2008–2012
15. Higgins JPT,Green S (2011) Cochrane handbook for systematic reviews of interventions version 5.1.0. The cochrane collaboration www.cochrane-handbook.org
16. Hozo SP, Djulbegovic B, Hozo I (2005) Estimating the mean and variance from the median, range, and the size of a sample. BMC Med Res Methodol 5:13
17. Achkasov S, Vorobiev G, Zhuchenko A et al (2010) Laparoscopic-assisted reversal of Hartmann's procedure. Acta Chir Iugosl 57:59–65
18. Brathwaite S, Kuhrt M, YU L et al (2015) Retrospective evaluation of laparoscopic versus open Hartmann's reversal: a single-institution experience. Surg Laparosc Endosc Percutan Tech 25:e156–e158
19. Chouillard E, Pierard T, Campbell R et al (2009) Laparoscopically assisted Hartman's reversal is an efficacious and efficient procedure: a case control study. Minerva Chir 64:1–8
20. Clermonts SH, de Ruijter WM, van Loon YT et al (2016) Reversal of Hartmann's procedure utilizing single-port laparoscopy: an attractive alternative to laparotomy. Surg Endosc 30:1894–1901
21. Costantino GN, Mukalian GG (1994) Laparoscopic reversal of Hartmann procedure. J Laparoendosc Surg 4:429–433
22. De'angelis N, Brunetti F, Memeo R et al (2013) Comparison between open and laparoscopic reversal of Hartmann's procedure for diverticulitis. World J Gastrointest Surg 5:245–251
23. Faure JP, Doucet C, Essique D et al (2007) Comparison of conventional and laparoscopic Hartmann's procedure reversal. Surg Laparosc Endosc Percutan Tech 17:495–499
24. Horesh N, Lessing Y, Rudnicki Y (2018) Comparison between laparoscopic and open Hartmann's reversal: results of a decade-long multicenter retrospective study. Surg Endosc 32:4780–4787. https://doi.org/10.1007/s00464-018-6227-8
25. Kwak HD, Kim J, Kang DW et al (2018) Hartmann's reversal: a comparative study between laparoscopic and open approaches. ANZ J Surg 88:450–454
26. Lin FL, Boutros M, Da Silva GM et al (2013) Hartmann reversal: obesity adversely impacts outcome. Dis Colon Rectum 56:83–90
27. Maitra RK, Pinkney TD, Mohiuddin MK et al (2013) Should laparoscopic reversal of Hartmann's procedure be the first line approach in all patients? Int J Surg 11:971–976
28. Mazeh H, Greenstein AJ, Swedish K et al (2009) Laparoscopic and open reversal of Hartmann's procedure–a comparative retrospective analysis. Surg Endosc 23:496–502
29. Melkonian E, Heine C, Contreras D et al (2017) Reversal of the Hartmann's procedure: a comparative study of laparoscopic versus open surgery. J Minim Access Surg 13:47–50
30. Ng DC, Guarino S, Yau SL et al (2013) Laparoscopic reversal of Hartmann's procedure: safety and feasibility. Gastroenterol Rep 1(2):149–152
31. Okolica D, Bishawi M, Karas JR et al (2012) Factors influencing postoperative adverse events after Hartmann's reversal. Colorectal Dis 14:369–373
32. Onder A, Gorgun E, Costedio M et al (2016) Comparison of short-term outcomes after laparoscopic versus open Hartmann reversal: a case-matched study. Surg Laparosc Endosc Percutan Tech 26:e75–e79
33. Rosen MJ, Cobb WS, Kercher KW et al (2006) Laparoscopic versus open colostomy reversal: a comparative analysis. J Gastrointest Surg 10(6):895–900
34. Schmelzer TM, Mostafa G, Norton HJ (2007) Reversal of Hartmann's procedure: a high-risk operation? Surgery 142:598–607
35. Studer P, Schnüriger B, Umer M et al (2014) Laparoscopic versus open end colostomy closure: a single-center experience. Am Surg 80:361–365
36. Svenningsen PO, Bulut O, Jess P (2010) Laparoscopic reversal of Hartmann's procedure. Dan Med Bull 57:A4149
37. Vermeulen J, Leijtens JW, Mannaerts GH (2010) Reversal of Hartmann's procedure after perforated diverticulitis through the stomal side without additional incisions: the SIR procedure. Dig Surg 27:391–396
38. Walklett CL, Yeomans NP (2014) A retrospective case note review of laparoscopic versus open reversal of Hartmann's procedure. Ann R Coll Surg Engl 96:539–542
39. Yang PF, Morgan MJ (2014) Laparoscopic versus open reversal of Hartmann's procedure: a retrospective review. ANZ J Surg 84:965–969
40. Zimmermann M, Hoffmann M, Laubert T et al (2014) Laparoscopic versus open reversal of a Hartmann procedure: a single-center study. World J Surg 38:2145–2152. https://doi.org/10.1007/s00268-014-2507-1
41. Bonjer HJ, Deijen CL, Abis GA et al (2015) COLOR II Study Group. A randomized trial of laparoscopic versus open surgery for rectal cancer. N Engl J Med 372:1324–1332
42. van de Wall BJ, Draaisma WA, Schouten ES et al (2010) Conventional and laparoscopic reversal of the Hartmann procedure: a review of literature. J Gastrointest Surg 14:743–752
43. Celentano V, Giglio MC, Bucci L (2015) Laparoscopic versus open Hartmann's reversal:a systematic review and meta-analysis. Int J Colorectal Dis 30:1603–1615