

Laparoscopy-first Hartmann strategy for generalized diverticular peritonitis: a national multicenter overlap-weighted cohort study

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Abstract

Background

Primary anastomosis improves long-term stoma outcomes compared with Hartmann's procedure, but Hartmann remains attractive in generalized peritonitis because avoiding an emergency anastomosis may make a nonrestorative resection more readily achievable by minimally invasive surgery. A laparoscopy-first Hartmann strategy could therefore preserve the technical simplicity of a nonrestorative procedure while offering the potential early postoperative benefits of laparoscopy and, by potentially reducing postoperative adhesions, facilitating subsequent reversal. Whether this strategy can narrow the long-term disadvantage in stoma outcomes associated with Hartmann's procedure remains uncertain. We compared postoperative outcomes and stoma reversal between a laparoscopy-first Hartmann strategy and protected resection-anastomosis in generalized diverticular peritonitis.

Methods

Retrospective multicenter cohort study of patients undergoing emergency surgery for Hinchey III–IV diverticular peritonitis. A laparoscopy-first Hartmann strategy, retaining conversions, was compared with protected resection-anastomosis performed laparoscopically or openly. Perioperative outcomes were compared using propensity-score overlap weighting. Stoma reversal was assessed using weighted Aalen–Johansen estimates, with death before reversal treated as a competing event.

Results

The cohort included 340 patients from 36 centers: 136 underwent a laparoscopy-first Hartmann strategy and 204 protected resection-anastomosis. Half of Hartmann procedures required conversion to laparotomy. After overlap weighting, baseline characteristics were balanced. Weighted 90-day morbidity was 52.5% after Hartmann and 54.5% after protected resection-anastomosis, and major complication risks were 27.6% and 27.2%, respectively. Weighted 90-day mortality was 5.7% and 1.7%, respectively (absolute difference, – 4.1 percentage points; 95% CI, – 8.5 to 0.4). At 12 months, the cumulative incidence of stoma reversal was 71.7% after Hartmann and 91.5% after protected resection-anastomosis, corresponding to an absolute difference of 19.8 percentage points (95% CI, 10.3–29.4). Results were consistent in sensitivity analyses restricted to centers using both strategies and to procedures initiated laparoscopically in both groups.

Conclusions

A laparoscopy-first Hartmann strategy was not associated with better early postoperative outcomes and remained associated with a substantially lower 12-month cumulative incidence of stoma reversal than protected resection-anastomosis. When reconstruction is technically feasible in appropriately selected patients, these findings support protected resection-anastomosis as the preferred restorative strategy.

Trial registration

Background

Acute perforated sigmoid diverticulitis with generalized peritonitis (Hinchey III-IV) is a surgical emergency requiring rapid source control while balancing postoperative morbidity and the risk of a permanent stoma (1). Historically, Hartmann's procedure was the standard of care but was associated with substantial morbidity and low reversal rates (2,3). Following randomized trials and meta-analyses, national and international guidelines have shifted the paradigm toward sigmoid resection with primary anastomosis when feasible, as it provides similar short-term outcomes but higher rates of restoration of bowel continuity than Hartmann's procedure (4–10). Regarding omission of a diverting stoma, guidelines remain cautious, generally restricting unprotected anastomosis to selected patients (11).

Over the same period, minimally invasive colorectal surgery has expanded into the emergency setting (12,13). While laparoscopic peritoneal lavage has fallen out of favor, laparoscopic sigmoid resection has emerged as a feasible option (14,15). Current data suggest that in experienced hands, emergency laparoscopic resection could reduce parietal morbidity and hospital stay compared with open surgery (16–19). However, the specific role of the laparoscopic Hartmann's procedure remains debated. Observational studies suggest that laparoscopic Hartmann's procedure is feasible, although evidence for short-term benefit over open Hartmann's procedure remains inconsistent.

A laparoscopy-first Hartmann strategy may be particularly attractive in generalized peritonitis because avoiding an emergency anastomosis may make the procedure technically more straightforward to complete minimally invasively than a restorative resection. It could therefore combine the technical simplicity of a nonrestorative procedure with the potential early postoperative benefits of laparoscopy. A minimally invasive first stage might reduce postoperative adhesions and facilitate subsequent reversal, thereby potentially mitigating the long-term disadvantage in stoma outcomes associated with Hartmann's procedure (19,20).

It remains unclear whether these theoretical advantages translate into better early postoperative outcomes and a higher likelihood of subsequent stoma reversal. We therefore compared a laparoscopy-first Hartmann strategy retaining conversions with protected resection-anastomosis performed according to the operative approach selected by the surgical team. The aim was to compare short-term postoperative outcomes and the 12-month cumulative incidence of stoma reversal between these two operative strategies.

Methods

Study design and reporting

Data were obtained from a retrospective multicenter database including all adults operated on for sigmoid diverticulitis between January 2010 and September 2021 across 43 French centers. This

analysis is part of a study registered at ClinicalTrials.gov (NCT06200857) (21). Individual informed consent was waived because of the retrospective study design. Reporting followed the STROBE statement (22).

Patients

Patients were included if they underwent emergency surgery for Hinchey III-IV sigmoid diverticular peritonitis and were treated either with a laparoscopy-first Hartmann strategy or protected resection-anastomosis, regardless of operative approach. Hinchey stage was determined from operative reports, with stage III defined as generalized purulent peritonitis and stage IV as generalized fecal peritonitis (1). Non-urgent surgery, Hinchey stages < III, and other surgical strategies were excluded.

Hartmann's procedure was classified according to the initial operative strategy, with conversions to laparotomy retained in the laparoscopy-first Hartmann group. Protected resection-anastomosis included procedures initiated laparoscopically or through laparotomy. Operative coding was required to be concordant with the corresponding procedure indicator. All eligible centers were retained, including centers using only one of the two strategies.

Endpoints

The primary outcome was the 12-month cumulative incidence of recorded stoma reversal, with death before reversal treated as a competing event. Time was measured from the index operation, and reversal was counted only when its recorded date preceded death and the last known follow-up. The primary effect measure was the absolute difference in 12-month cumulative incidence between the two strategies.

Secondary outcomes included intraoperative morbidity, conversion among procedures initiated laparoscopically, 90-day mortality, 90-day postoperative morbidity according to the Clavien–Dindo classification, major complications defined as Clavien–Dindo > II, and postoperative length of stay. Stoma reversal was also estimated at 90, 180, and 730 days. Recurrent diverticulitis and incisional hernia were described without formal between-group comparisons.

Statistical analysis

Missing baseline covariates were handled using multiple imputation by chained equations with 20 imputed datasets, incorporating treatment, center, prespecified covariates, and outcome information (23–25). Within each imputation, propensity scores were estimated by logistic regression using prespecified covariates related to treatment selection or stoma recovery: age, sex, body mass index, ASA class, neurologic, cardiovascular and pulmonary comorbidities, diabetes, smoking, immunosuppression, anticoagulant and antiplatelet therapy, previous midline laparotomy, previous diverticulitis, surgery on the day of admission, Hinchey IV disease, bowel obstruction, fistula, and calendar year. Center was not

included in the primary propensity model because treatment strategy was structurally or near-structurally determined by center in several hospitals. Overlap weights, proportional to each patient's estimated probability of receiving the alternative strategy, were then applied, targeting the average treatment effect in the overlap population (ATO) (26). Covariate balance was assessed using standardized mean differences for continuous and binary covariates, with the unweighted pooled standard deviation within each imputation; variance ratios, Kolmogorov–Smirnov statistics, propensity-score and weight distributions, and effective sample sizes provided additional diagnostics (27).

Early postoperative outcomes were compared using overlap-weighted risks and absolute risk differences. Ninety-day mortality was estimated as one minus the overlap-weighted Kaplan-Meier survival probability at day 90, censoring patients last known alive before day 90. Stoma reversal was analyzed using weighted Aalen-Johansen estimators, with death before reversal treated as a competing event (28). The primary measure was the absolute difference in cumulative incidence at 12 months. Center-level bootstrap samples reestimated propensity scores and weights; within-imputation bootstrap variances and between-imputation variance were combined using Rubin's rules (23,24). A weighted Fine-Gray model with center-clustered robust variance provided a secondary relative summary, with proportionality assessed using weighted residuals (28,29).

Two sensitivity analyses were performed. The first was restricted to centers using both strategies, with center included in the propensity model. The second was restricted to procedures initiated laparoscopically in both groups, retaining conversions within the initially selected strategy. Covariates were reimputed and propensity scores and overlap weights reestimated within each restricted cohort.

An exploratory post hoc analysis compared stoma reversal after laparoscopically completed versus converted Hartmann procedures using unweighted Aalen–Johansen estimates, with death as a competing event and center-level bootstrap uncertainty.

Analyses used R version 4.6.1; all tests were two-sided. Full statistical methods are provided in Additional file 1.

Devstral Small 2 (24B; Mistral AI), run locally on an offline hospital computer, was used to assist in writing the statistical analysis code. All generated code was reviewed and tested by the authors, who take full responsibility for the analyses and results.

Results

Study population and covariate balance

The final cohort included 340 patients from 36 centers: 136 underwent a laparoscopy-first Hartmann strategy and 204 protected resection-anastomosis (Fig. 1). Twelve centers used only one strategy. Before weighting, the largest absolute standardized mean difference across imputations was 0.380. After weighting, prespecified propensity-score covariates were exactly balanced in weighted means, as

expected with logistic overlap weights (26). Mean effective sample sizes were 125.3 for Hartmann and 172.6 for protected resection-anastomosis. Detailed diagnostics are provided in Additional file 1 (Supplementary Figures S3–S4 and Supplementary Tables S2–S3).

Preoperative characteristics

Before weighting, Hartmann patients were older (median, 63.0 vs 57.5 years) and more frequently had Hinchey IV peritonitis (36.8% vs 21.6%). Previous diverticulitis (22.8% vs 32.8%) and smoking history (25.6% vs 34.1%) were less frequent in the Hartmann group, whereas ASA class and major comorbidities were broadly similar. In the overlap-weighted population, 28.6% had Hinchey IV peritonitis; 17.6% were ASA class III and 3.6% ASA class IV (Table 1).

Table 1
Preoperative characteristics and imbalance before overlap weighting

Characteristic	Observed cohort		
	Lap. Hartmann N = 136 ¹	Protected RA N = 204 ¹	Max SMD before OW
Age, years	63.0 [51.0, 76.0]	57.5 [49.0, 67.0]	0.380
Male sex	52.9%	60.3%	0.149
Body mass index, kg/m ²	25.6 [22.3, 28.4]	25.4 [22.8, 28.7]	0.149
ASA class			0.219
1	24.2%	30.7%	
2	50.0%	52.8%	
3	21.2%	14.1%	
4	4.5%	2.5%	
Neurologic comorbidity	16.9%	13.2%	0.103
Cardiovascular comorbidity	36.4%	35.9%	0.031
Pulmonary comorbidity	18.5%	14.1%	0.146
Diabetes	7.6%	7.0%	0.054
Smoking history	25.6%	34.1%	0.253
Immunosuppression	18.2%	9.1%	0.284
Anticoagulant therapy	10.1%	7.5%	0.150
Antiplatelet therapy	13.4%	9.1%	0.183
Previous midline laparotomy	11.5%	7.7%	0.173
Previous diverticulitis	22.8%	32.8%	0.282
Operation on admission day	99.2%	94.9%	0.273
Hinchey IV peritonitis	36.8%	21.6%	0.339
Bowel obstruction	5.2%	5.9%	0.032
Fistula	1.5%	5.4%	0.217
¹ Median [Q1, Q3]; %			
Values are median [Q1, Q3] or percentages. N values are observed unweighted patient counts; observed summaries use available cases. Missing data are reported in Additional file 1 (Supplementary Table S1). Continuous and binary covariates were standardized using the unweighted pooled standard deviation within each imputed dataset; pre-weighting SMDs are the			

Characteristic	Observed cohort		
	Lap. Hartmann N = 136 ¹	Protected RA N = 204 ¹	Max SMD before OW
maximum absolute values across the 20 imputed datasets. Overlap weighting achieved exact weighted mean balance for all terms included in the propensity-score model. Weighted characteristics and detailed balance and distributional diagnostics are reported in Additional file 1 (Supplementary Table S2 and Supplementary Figure S3).			

Intraoperative characteristics

Overlap-weighted intraoperative characteristics are summarized in Table 2. Splenic flexure mobilization (14.7% vs 71.9%) and high ligation of the inferior mesenteric artery (5.6% vs 19.6%) were less frequent with the Hartmann strategy, and median operative time was shorter (138 [97–169] vs 194 [140–240] minutes). Intraoperative transfusion was uncommon in both groups.

Table 2
Weighted intraoperative characteristics

Intraoperative characteristic	Lap. Hartmann N = 136 ¹	Protected RA N = 204 ¹
Initial laparoscopic approach	100.0%	25.6%
Initial open approach	0.0%	74.4%
Splenic flexure mobilization	14.7%	71.9%
High inferior mesenteric artery ligation	5.6%	19.6%
Abdominal drainage	92.8%	81.3%
Operative time, min	138.0 [97.0, 169.0]	194.0 [140.0, 240.0]
Intraoperative transfusion	1.7%	1.3%
Conversion among initial laparoscopic approaches, n/N (%)	68/136 (50.0%)	30/59 (50.8%)
¹ %; Median [Q1, Q3]		
N values in column headings are observed unweighted counts; all percentages and quantiles in the body are computed from the equally weighted stack of 20 imputed datasets. The conversion row alone gives observed unweighted n/N (%) among patients with an initial laparoscopic approach.		

Among procedures initiated laparoscopically, conversion occurred in 68 of 136 Hartmann procedures (50.0%) and 30 of 59 protected resection-anastomoses (50.8%).

Postoperative outcomes

Overlap-weighted postoperative outcomes are summarized in Table 3. Ninety-day morbidity was 52.5% after Hartmann and 54.5% after protected resection-anastomosis (risk difference, 2.0 percentage points; 95% CI, – 13.4 to 17.5). Major complication risks were 27.6% and 27.2%, respectively (risk difference, -0.4 percentage points; 95% CI, -13.9 to 13.1). Anastomotic leakage occurred in 17 of 202 protected resection-anastomosis patients (8.4%; weighted risk, 8.3%). Vital status through 90 days was available for 314 patients. Overlap-weighted mortality was 5.7% after Hartmann and 1.7% after protected resection-anastomosis (risk difference, -4.1 percentage points; 95% CI, -8.5 to 0.4).

Table 3
Observed and overlap-weighted early postoperative outcomes

Outcome	Lap. Hartmann, n/N; OW risk	Protected RA, n/N; OW risk	OW risk difference, percentage points (95% CI)
90-day mortality	9/123; 5.7%	3/191; 1.7%	-4.1 (– 8.5 to 0.4)
Any 90-day morbidity	74/136; 52.5%	111/203; 54.5%	2.0 (– 13.4 to 17.5)
Clavien–Dindo grade > II	40/136; 27.6%	58/203; 27.2%	-0.4 (– 13.9 to 13.1)
Deep abscess	10/133; 7.8%	17/202; 8.7%	0.9 (– 5.6 to 7.5)
Postoperative drainage procedure	1/136; 1.0%	3/201; 1.3%	0.3 (– 2.3 to 2.9)
Hemorrhagic complication	8/133; 4.3%	8/202; 4.2%	-0.1 (– 4.9 to 4.8)
Postoperative transfusion	10/130; 5.8%	9/200; 4.7%	-1.1 (– 6.8 to 4.6)
Reoperation	16/134; 11.9%	36/204; 16.5%	4.6 (– 8.7 to 17.9)
Intensive care admission	26/134; 17.0%	20/201; 11.0%	-6.0 (– 14.2 to 2.2)
Anastomotic leak	-	17/202; 8.3%	-
Readmission	21/123; 16.6%	47/191; 22.4%	
Data are observed events/patients with known status followed by the mean overlap-weighted (OW) risk across 20 imputed datasets. For 90-day mortality, the OW estimate was obtained from the weighted Kaplan–Meier estimator. Risk differences are protected RA minus Hartmann and are expressed in percentage points (pp). Confidence intervals were obtained by center-level bootstrap with propensity-score reestimation and Rubin pooling. Anastomotic leak was assessed only after protected resection-anastomosis.			

Cumulative incidence of stoma reversal

Seven patients had no usable follow-up and were excluded only from time-to-event analyses: 5 after Hartmann and 2 after protected resection-anastomosis. Median potential follow-up, estimated using the reverse Kaplan–Meier method, was 751 and 446 days, respectively. At 12 months, the overlap-weighted

cumulative incidence of stoma reversal was 71.7% (95% CI, 62.0%–81.4%) after Hartmann and 91.5% (95% CI, 85.8%–97.2%) after protected resection-anastomosis, an absolute difference of 19.8 percentage points (95% CI, 10.3–29.4) (Fig. 2). At 730 days, cumulative incidences were 77.9% and 94.7%, respectively, although few patients remained under observation. Estimates at all prespecified times are reported in Additional file 1 (Supplementary Table S4).

The secondary weighted Fine–Gray model yielded an sHR of 2.26 (95% CI, 1.68–3.03) for protected resection-anastomosis versus Hartmann. Because the proportional subdistribution hazards assumption was not supported, this estimate was considered an exploratory average relative summary rather than a constant relative effect over follow-up.

Sensitivity analyses gave similar results. The 12-month absolute difference was 22.9 percentage points (95% CI, 10.4–35.4) among 294 patients from centers using both strategies and 16.1 percentage points (95% CI, 3.9–28.2) among 195 patients whose procedures were initiated laparoscopically (Additional file 1: Supplementary Tables S6–S8 and Supplementary Figure S5).

In an exploratory post hoc analysis of the 136 Hartmann procedures, 68 were completed laparoscopically and 68 were converted; 131 patients were analyzable. The 12-month cumulative incidence of stoma reversal was 65.3% after laparoscopic completion and 66.3% after conversion (absolute difference, 1.0 percentage point; 95% CI, – 18.6 to 20.6) (Additional file 1: Supplementary Table S9 and Supplementary Figure S6).

Discussion

Randomized trials have supported primary anastomosis as the preferred reconstructive strategy over Hartmann's procedure in appropriately selected patients with perforated diverticulitis and generalized peritonitis. Across the Oberkofler, DIVERTI, and LADIES trials, short-term morbidity and mortality were broadly similar between strategies, whereas restoration of bowel continuity was more frequent after primary anastomosis (8–10). Nevertheless, contemporary practice remains highly selective: in the prospective international Goodbye Hartmann study, Hartmann's procedure remained commonly used for left-sided colonic emergencies and was preferentially performed in older and higher-risk patients (30). However, these trials were not designed to determine whether a laparoscopy-first Hartmann strategy could narrow this long-term disadvantage. The rationale for a laparoscopy-first Hartmann strategy is particularly relevant in generalized peritonitis, where avoiding an emergency anastomosis may make a nonrestorative resection more readily achievable by minimally invasive surgery than a restorative procedure. If laparoscopy could confer its potential early postoperative benefits while also reducing postoperative adhesions, a laparoscopy-first Hartmann strategy might preserve the technical simplicity of Hartmann's procedure while narrowing its long-term disadvantage in stoma reversal (31). The present study therefore compared a laparoscopy-first Hartmann strategy, retaining conversions, with protected resection-anastomosis performed according to the operative approach selected by the surgical team,

focusing on both early postoperative outcomes and the 12-month cumulative incidence of stoma reversal.

The main finding of this overlap-weighted analysis is that, in the measured-overlap population, early postoperative outcome estimates were similar between strategies, whereas the 12-month cumulative incidence of stoma reversal was substantially lower after a laparoscopy-first Hartmann strategy than after protected resection-anastomosis. Overlap-weighted 90-day morbidity was 52.5% versus 54.5%, and major complication risks were 27.6% versus 27.2%, respectively. At 12 months, the cumulative incidence of stoma reversal was 71.7% after Hartmann versus 91.5% after protected resection-anastomosis, corresponding to an absolute difference of 19.8 percentage points (95% CI, 10.3–29.4). Estimates remained in the same direction in sensitivity analyses restricted to centers using both strategies (22.9 percentage points; 95% CI, 10.4–35.4) and to procedures initiated laparoscopically in both groups (16.1 percentage points; 95% CI, 3.9–28.2). The secondary Fine-Gray analysis was directionally concordant with the primary analysis (sHR, 2.26; 95% CI, 1.68–3.03), but its proportionality assumption was not supported; absolute Aalen–Johansen estimates therefore remain primary.

Protected resection-anastomosis was selected as the reference restorative strategy because it reflects a widely accepted option for hemodynamically stable, appropriately selected patients with generalized diverticular peritonitis. Current guidelines allow primary anastomosis with or without diversion, but remain cautious regarding omission of a protective stoma, particularly in higher-risk patients (5–7). In the present study, anastomotic leakage occurred in 17 of 202 patients undergoing protected resection-anastomosis (8.4%; overlap-weighted risk, 8.3%). A diverting stoma is intended to mitigate the clinical consequences of an anastomotic leak, but carries its own morbidity and requires a subsequent reversal procedure, itself associated with substantial complication rates (32,33). Importantly, the available randomized trials comparing Hartmann’s procedure with primary anastomosis do not establish whether diversion is routinely necessary: DIVERTI used primary anastomosis with diversion, whereas LADIES allowed primary anastomosis with or without diversion (8–10). The ongoing DIVERTI2 trial specifically addresses this question by randomizing patients with Hinchey III-IV peritonitis undergoing primary anastomosis to a protective stoma or no stoma (11). Accordingly, our findings should not be interpreted as evidence for systematic diversion, but rather as supporting protected resection-anastomosis as a pragmatic restorative strategy associated with a substantially higher 12-month cumulative incidence of stoma reversal than a laparoscopy-first Hartmann strategy.

The present findings extend the limited and heterogeneous observational literature on minimally invasive emergency surgery for perforated diverticulitis. Vennix et al. reported lower morbidity and shorter hospital stay after emergency laparoscopic sigmoidectomy and, among patients undergoing Hartmann’s procedure, a higher 12-month probability of stoma reversal after a laparoscopic than an open approach; however, their analysis primarily addressed surgical access across mixed reconstructive strategies and did not directly compare a laparoscopy-first Hartmann strategy with primary anastomosis (17). Cassini et al. showed the feasibility of a selected fully laparoscopic two-stage strategy without a

contemporaneous reconstructive comparator (19). Here, the laparoscopy-first Hartmann strategy was associated with a 19.8-percentage-point lower 12-month cumulative incidence of reversal.

Conversion deserves particular attention because approximately half of the procedures initiated laparoscopically were converted in both groups. This rate is consistent with Vennix et al. ($\approx 54\%$) but exceeds the 10% reported in the selected expert series of Cassini et al., possibly reflecting patient selection, operative difficulty, and expertise (17,19). Registry-based analyses such as Turley et al. cannot reliably distinguish planned open procedures from conversions after an initial laparoscopic attempt (16). In our primary analyses, conversions therefore remained assigned to the initially selected strategy. This preserved the comparison of operative strategies as undertaken. When both groups were restricted to procedures initiated laparoscopically, the 12-month difference in stoma-reversal incidence remained similar to the primary estimate (16.1 vs 19.8 percentage points). The primary finding was therefore not explained solely by the inclusion of planned open procedures in the protected resection-anastomosis group. Because the high conversion rate might have contributed to the poorer stoma outcome after Hartmann, a post hoc analysis compared converted procedures with those completed laparoscopically. Stoma-reversal incidence was not lower after conversion, although the estimate was imprecise. Previous Hartmann cohorts have shown that reversal is associated with survival, age, ASA class, comorbidity, functional status, and patient willingness (34,35). Final operative access is therefore only one of several potential determinants. However, this analysis does not establish that conversion is harmless. Conversion is influenced by operative findings and surgeon judgment, and its reasons were not fully recorded.

Whether these theoretical advantages translate into better early outcomes in generalized peritonitis remains uncertain. In our study, the laparoscopy-first Hartmann strategy showed no clear short-term advantage over protected resection-anastomosis: 90-day morbidity and major complication estimates were similar, while the mortality estimate favored protected resection-anastomosis but was imprecise. This is consistent with Turley et al., who found no reduction in morbidity or mortality with laparoscopic versus open Hartmann's procedure after propensity matching (16). More recently, Lahtinen et al. reported fewer wound complications and shorter hospital stay with laparoscopy in a propensity score-matched cohort of emergency colon resections, although the cohort included heterogeneous indications and the lower overall complication burden was observed when conversion was avoided (36). More broadly, evidence for emergency laparoscopy in complicated diverticulitis remains heterogeneous, with potential benefits reported mainly in selected observational cohorts and less consistent findings in emergency or randomized data (37–39). Although the randomized Sigma trial demonstrated perioperative benefits of laparoscopy in elective diverticular surgery, these findings cannot be assumed to extend to generalized peritonitis, where technical complexity and patient selection may attenuate any advantage (40).

This study has several strengths, including a large multicenter cohort focused specifically on generalized Hinchey III-IV diverticular peritonitis, explicit analysis of treatment strategies as initially undertaken, multiple imputation of missing baseline covariates, overlap weighting, and competing-risk estimation of

stoma reversal. However, several limitations warrant caution. First, the retrospective observational design precludes causal interpretation, and overlap weighting addresses only measured patient-level confounding. Center was not included in the primary propensity model because treatment choice was structurally or near-structurally determined by center in several hospitals; therefore, residual confounding related to institutional practice, surgeon expertise, and unmeasured clinical or intraoperative factors remains possible. The dual-strategy-center sensitivity analysis yielded a similar estimate but targeted a narrower population. Second, the compared strategies were asymmetric with respect to operative access, although the sensitivity analysis restricted to procedures initiated laparoscopically yielded results in the same direction. Reasons for conversion were unavailable. Third, stoma reversal represents different restorative procedures after Hartmann and protected resection-anastomosis, and detailed information on reversal technique and subsequent diversion was not available. Follow-up duration also differed between strategies; competing-risk methods appropriately accounted for death before reversal but cannot eliminate bias from informative loss to follow-up. Data on late postoperative complications were not available, precluding comparison of longer-term morbidity between strategies. Quality-of-life data were also unavailable.

Conclusions

In this overlap-weighted multicenter cohort, a laparoscopy-first Hartmann strategy was associated with early postoperative outcomes of similar magnitude but a substantially lower 12-month cumulative incidence of stoma reversal than protected resection-anastomosis. When reconstruction is technically feasible in appropriately selected patients, these findings support protected resection-anastomosis as the preferred restorative strategy, while Hartmann's procedure remains an important option when primary anastomosis is considered unsuitable.

Abbreviations

AFC

French Surgical Association

ASA

American Society of Anesthesiologists

ATO

average treatment effect in the overlap population

CI

confidence interval

ESS

effective sample size

OW

overlap weighting

RA

resection-anastomosis

sHR

subdistribution hazard ratio

STROBE

Strengthening the Reporting of Observational Studies in Epidemiology.

Declarations

Ethics approval and consent to participate

This retrospective study was registered at ClinicalTrials.gov (NCT06200857). Individual informed consent was waived because of the retrospective design. Local ethics committees approved the anonymized database and the use of the data.

Consent for publication

Not applicable.

Availability of data and materials

The data are governed by the French Surgical Association and are not publicly available because they contain confidential patient information. They may be available from the corresponding author on reasonable request and with the required institutional permissions.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

TH, MK, AA, CS, and AM conceived and designed the study. TH, AA, CS, and AM collected the data. TH and AM performed the statistical analysis. All authors interpreted the results, drafted or critically revised the manuscript, approved the submitted version, and accept responsibility for the work.

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Figures

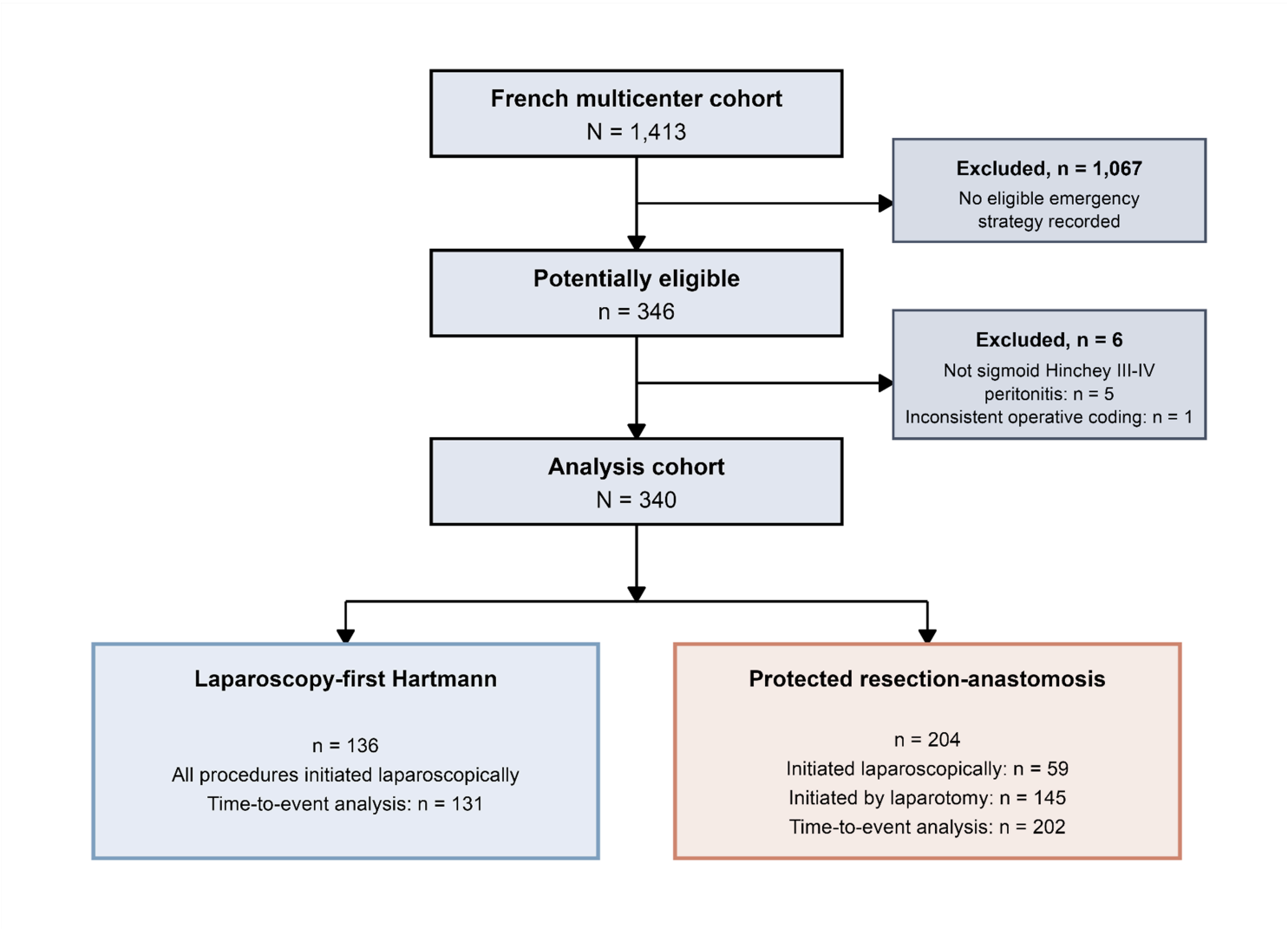


Figure 1

Patient selection and weighted analysis cohort. Emergency cases with an eligible and internally consistent operative strategy were retained from every eligible center. Initial operative approach and numbers entering the time-to-event analysis are shown within each strategy; seven patients without usable follow-up were excluded from time-to-event analyses only. Overlap weights retained all 340 patients.

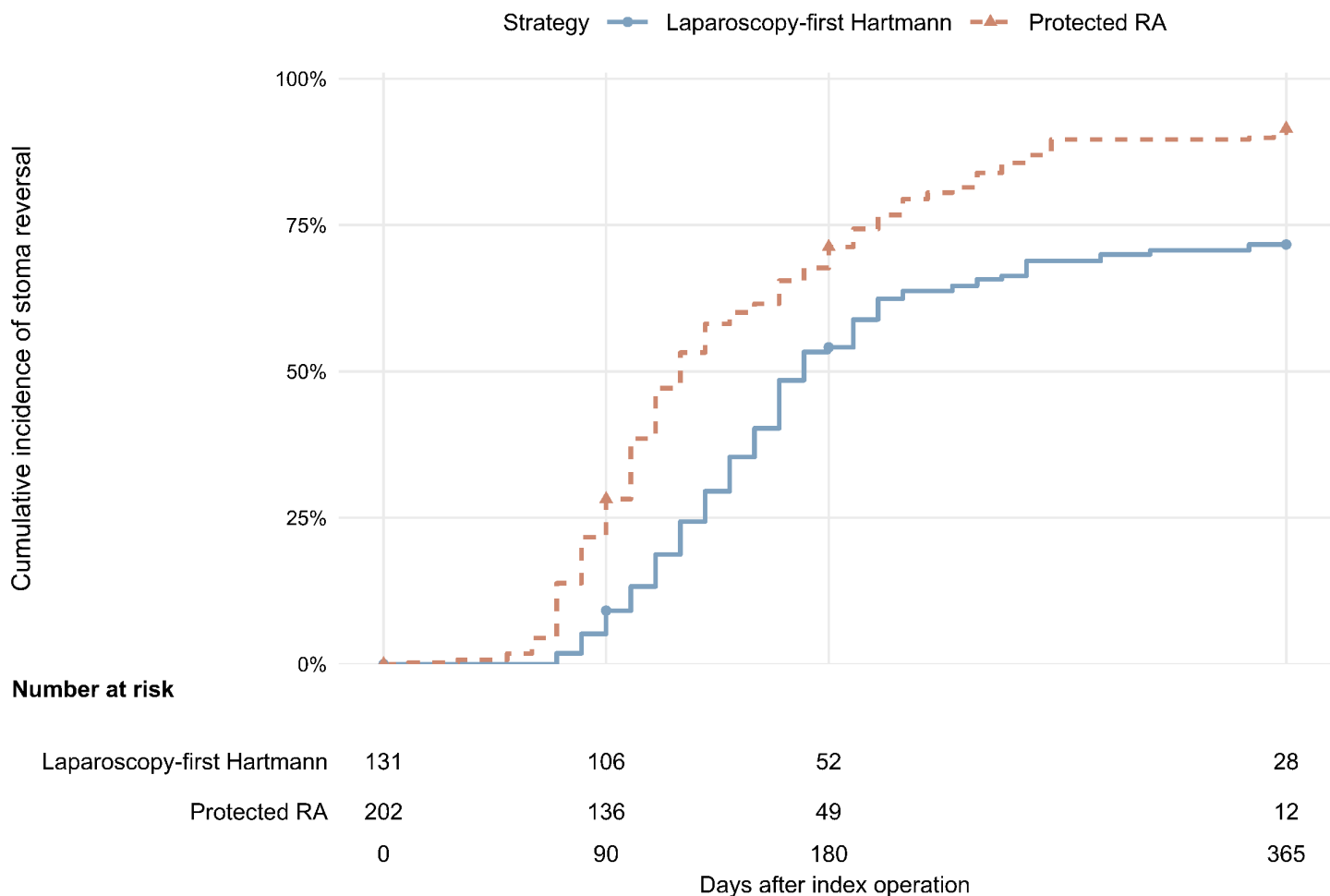


Figure 2

Stoma reversal with death as a competing event. Overlap-weighted Aalen–Johansen cumulative incidence curves of stoma reversal, with death before reversal treated as a competing event. Numbers remaining event-free and under observation are displayed below. The time axis is limited to the prespecified 365-day primary horizon. The cumulative incidence of death before reversal is shown separately in Additional file 1 (Supplementary Figure S7).

Supplementary Files

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